KETUA PENGARAH KERJA RAYA

DIRECTOR-GENERAL OF PUBLIC WORKS

Rujukan: JKR.KPKR:121.010/05 Jld. 27 (5)

Tarikh : 2 Mac 2022

Semua Pengarah Kanan/ Pengarah Cawangan Ibu Pejabat JKR

Semua Pengarah Kerja Raya Negeri

Semua Pengarah Kerja Raya Wilayah Persekutuan

Semua Pengarah Pembinaan

Pengarah JKR KESEDAR

Pengarah JKR KETENGAH

Semua Jurutera Daerah

SURAT ARAHAN KPKR BIL. 5 /2022

PINDAAN KEPADA SPESIFIKASI PIAWAI UNTUK KERJA BANGUNAN 2020

(*STANDARD SPECIFICATION FOR BUILDING WORKS 2020*)

1.0 TUJUAN

1.1 Surat Arahan ini bertujuan untuk memaklumkan mengenai pindaan kepada dokumen Spesifikasi Piawai Untuk Kerja Bangunan 2020 (*Standard Specification for Building Works 2020*).

Jabatan Kerja Raya Malaysia
Public Works Department Malaysia
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CERTIFIED TO ISO 9001:2015 CERT. NO.: QMS 03597
CERTIFIED TO ISO 14001:2015 CERT. NO.: EMS 00227
CERTIFIED TO ISO 45001:2018 CERT. NO.: OHS 00604
CERTIFIED TO ISO 50001:2018 CERT. NO.: EnMS 00111

1.2 Surat Arahan ini dikeluarkan adalah khusus untuk membuat pindaan kepada seksyen-seksyen di bawah sahaja:

1.2.1. ***Section B : Excavation & Earthworks***
1.2.2. ***Section C : Foundation & Works Below Lowest Floor Level***
1.2.3. ***Section D : Concreting***
1.2.4. ***Section V : Ground Improvement***
1.2.5. ***Section X : Internal Cold Water & Sanitary Plumbing System***

2.0 LATAR BELAKANG

2.1 Dokumen Spesifikasi Piawai Untuk Kerja Bangunan 2020 (*Standard Specification for Building Works 2020*) telah dikeluarkan pada 11 Disember 2020. Walau bagaimanapun, terdapat pindaan yang perlu dibuat khususnya pada seksyen yang dinyatakan pada para 1.2.

2.2 Pindaan ini telah dibentangkan dan diluluskan dalam Mesyuarat Pengurusan Tertinggi (MPT) JKR Malaysia Bil. 9/2021 pada 24 Disember 2021. Pindaan ini perlu dibuat bagi mengambil kira keperluan semasa industri dan kaedah pembinaan terkini.

3.0 KAEDAH PELAKSANAAN

3.1 Pindaan bagi seksyen berkaitan hendaklah dijadikan sebagai addendum (Pindaan No.1) dan dimasukkan bersama-sama dengan dokumen Spesifikasi Piawai Untuk Kerja Bangunan 2020 (*Standard Specification for Building Works 2020*).

3.2 Pindaan Spesifikasi Piawai Untuk Kerja Bangunan 2020 (*Standard Specification For Building Works 2020*) ini boleh diakses melalui laman web JKR di pautan http://jpedia.jkr.gov.my/index.php/Spesifikasi_Piawai_Untuk_Kerja-Kerja_Bangunan_2020

4.0 KUAT KUASA

4.1 Surat Arahan ini hendaklah dibaca bersekali dengan Surat Arahan KPKR Bil. 28/2020 bertarikh 11 Disember 2020.

4.2 Surat Arahan ini berkuat kuasa pada tarikh ianya ditandatangani dan akan disemak sekiranya terdapat arahan dasar terkini atau perkembangan baharu yang memerlukannya dikaji semula dan dikemas kini.

Sekian, terima kasih.

"WAWASAN KEMAKMURAN BERSAMA 2030"

"BERKHIDMAT UNTUK NEGARA"

(DATUK Ir. HAJI MOHAMAD ZULKEFLY BIN SULAIMAN)

s.k.

- Timbalan Ketua Pengarah Kerja Raya (Sektor Infra)
- Timbalan Ketua Pengarah Kerja Raya (Sektor Pakar)
- Timbalan Ketua Pengarah Kerja Raya (Sektor Bangunan)
- Pengarah Cawangan Dasar dan Pengurusan Korporat

TABLE OF CONTENTS

SECTION B: EXCAVATION AND EARTHWORKS		PAGE
1.	General	B/1
2.	Soil Investigation Report	B/1
3.	Site Clearing, Grubbing and Stripping Topsoil	B/1
4.	Timber	B/2
5.	Demolition of Existing Structures	B/3
6.	Relocation of Existing Utilities and Services	B/3
7.	Excavation Works	B/3
8.	Filling Works	B/9
9.	Protection and Maintenance for Erosion Control	B/14

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1. General

1.1. This work shall consist of all the required excavation and earthworks within the limits of the Works. It shall include the removal and proper utilization and hauling, or disposal of all excavated materials, and constructing, shaping and finishing of all earthworks over the entire extent of the Works, in conformity with the Drawings and these Specifications.

1.2. The excavation and earthworks shall be executed in such a manner and order as approved by the S.O.. The Contractor shall be responsible for compliance with by-laws and regulations relating to earthworks.

1.3. Excavation in rock and/or hard material shall respectively be measured and paid for as extra over to excavation and earthworks in accordance with the Provisional B.Q.. The Contractor shall give reasonable notice to the S.O. to examine, classify the excavation and to take measurement prior to breaking up.

1.4. For contract based on Specifications and Drawings, unless otherwise provided in the Contract, for the purpose of pricing the excavation and earthworks, the whole excavation shall be assumed to be without rock and/or hard material as defined hereunder.

1.5. For contract based on Quantities, the pricing shall be in accordance with the B.Q. and deem to include all validation and quality control testing required by this specification.

1.6. Computation of volume of rock excavation for payment shall be based on nett volume excavated as shown on the Drawings.

1.7. The Contractor shall comply with all statutory requirements and regulations such as payment of royalties and environmental protection for removal of unsuitable material and borrow materials.

2. Soil Investigation Report

A soil investigation report shall be made available (if any) at the S.O.'s office for the Contractor information. The Contractor shall study the soil investigation report in detail and make his own interpretation of the information provided and make due allowance for the effect of site conditions on his construction operations. No responsibility is assumed by the S.O. for any opinion given in the soil investigation report.

3. Site Clearing, Grubbing and Stripping Topsoil

This work shall consist of clearing, grubbing and stripping topsoil in the areas within the limits of Works designated hereunder and/or shown on the Drawings and/or directed by the S.O., and of clearing only in other areas designated hereunder and/or shown on the Drawings and/or directed by the S.O., all as specified herein and as required by the S.O.. The work shall also include the demolition and disposal of structures in the said areas, except where otherwise provided for in the Contract, as specified herein and as required by the S.O..

3.1. Site clearing

3.1.1. Clearing shall consist of cutting and/or taking down, removal and disposal of everything above ground level, including objects such as walls, fences, drains and other obstructions, except such trees, vegetation, structures or parts of structures and other things which are designated in the Contract

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to remain, to be protect as satisfied under SECTION R: LANDSCAPING AND TURFING. The material to be cleared shall include but not necessarily be limited to trees, stumps (parts above ground), logs, brushwood, undergrowth, long grasses, crops, loose vegetable matter and structures (except those structures whose removal or clearance is otherwise provided for in the Contract). Clearing shall also include levelling of obsolete dikes, terraces, ditches, et cetera, unless otherwise directed by the S.O..

3.1.2. All holes and cavities in the ground surface after clearing, grubbing and stripping topsoil shall be filled with materials similar to the adjacent ground, and such fill shall be compacted to a dry density as specified by sub-section 8.4.3., with the agreement of the S.O.. This work shall be considered incidental to the work of clearing, grubbing and striping topsoil, and shall not be measured for payment.

3.2. Grubbing

Grubbing shall consist of removal and disposal of surface vegetation, bases of stumps, roots, underground parts of structures, and other obstructions to a depth of at least 500mm below ground level, with the agreement of the S.O..

3.3. Stripping topsoil

3.3.1. Stripping topsoil shall consist of the removal of topsoil to an average depth of at least 100mm below ground level, and its stockpiling for use in the Works, and/or its disposal, as directed by the S.O..

3.3.2. Topsoil to be stockpiled for the Works shall be sufficiently fertile to promote and support the growth of vegetation, and shall be taken from such areas where clearing, grubbing and stripping topsoil is required as approved or directed by the S.O.. Before stockpiling, topsoil shall be separated from objectionable materials such as combustible material including all timber (except timber to be salvaged or used), all brushwood, stumps, roots, vegetation from clearing, grubbing and stripping topsoil (including the demolition of structures), with the agreement of the S.O.. The Contractor shall arrange for stockpile sites either within or outside the site, at his own expense, and with the agreement of the S.O. or as required by the relevant laws and regulations.

3.4. Disposal

All materials resulting from site clearing, grubbing and stripping topsoil shall be removed and disposed of as approved by the S.O. in accordance with *Environmental Quality Act 1974 (Act 127)* and *Solid Waste and Public Cleansing Management Act 2007 (Act 672)*.

4. Timber

4.1. The ownership of timber is vested in the Government. Saleable timber shall be trimmed and stacked in accordance with the requirements of the appropriate Government agency, in accessible places within the site as approved or directed by the S.O..

4.2. The Contractor shall have the right to use unsaleable timber (or saleable timber when permission is granted in writing by the appropriate Government agency or

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authority) for his own purposes in connection with the Contract, always provided that he shall comply with the requirements of the S.O..

5. Demolition of Existing Structures

5.1. Major structures are those which cannot practicably be cleared by bulldozer and/or hydraulic excavator, whose demolition requires pneumatic tools, explosives and/or other specialized equipment. A brief description of each major structure (if any) and depth to which extent it shall be demolished is given in the B.Q..

5.2. All fences, buildings, structures, and encumbrances of any character within the limits of the limits of the Works, except those to be removed by others or designated to remain, shall be demolished and removed by the Contractor.

5.3. Materials designated in the Contract or directed by the S.O. to be salvaged, shall be carefully removed and stored, and shall be the property of the Government.

6. Relocation of Existing Utilities and Services

6.1. The Contractor's attention is specially drawn to his responsibilities under the Clause headed 'Damage to Property' of the Condition of Contract.

6.2. Before commencing on any excavation, the Contractor or his representative shall accompany the S.O. on a site inspection to identify the presence of underground cables, water or other service pipes at or in the vicinity of such excavation. Thereafter, the Contractor shall carry out the excavation work in a manner and sequence as approved by the S.O..

6.3. If during excavation, the Contractor's workmen uncover any cables, water or other service pipes, work shall be stopped immediately and shall not be again started until the matter has been reported to the S.O. who will notify the appropriate local authority, and subsequently issue whatever directions he deemed appropriate.

7. Excavation Works

7.1. General Requirements

7.1.1. The work shall include the excavation of all types of material, backfilling, compaction, forming embankments and slopes, et cetera, as is necessary for the completion of the works up to the formation levels, in accordance with the lines, grades, dimensions, shapes and typical cross-sections shown on the Drawings and to the approval of the S.O..

7.1.2. The Contractor shall provide where necessary temporary water courses, ditches, drains, pumping or other means of maintaining the earthworks free from water. Such provision shall include carrying out the work of forming the cuttings and embankments in such a manner that their surfaces have at all times a sufficient gradient to enable them to shed water and prevent water ponding.

7.1.3. In pumping water out from excavation and in the lowering of water table the Contractor shall pay due regard to the stability and settlement of all structures.

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7.1.4. Adequate means for trapping silt shall be provided on all temporary drainage systems. Similar arrangements shall be made for all earthworks including excavation whether for pile trenches, foundations or cuttings.

7.1.5. Should the surface of completed areas be damaged by erosion or by any other causes, the Contractor shall at his own cost make good such areas to the approval of the S.O..

7.1.6. The Contractor shall exercise care in preventing wastage of suitable material needed for embankment or fill construction.

7.2. Definitions

7.2.1. Formation level

Formation level means the final earthwork level after cutting or filling.

7.2.2. Common excavation

Common excavation shall mean excavation in any materials which are not rock or hard materials as defined in sub-section 7.2.5. and sub-section 7.2.6..

7.2.3. Unsuitable materials

7.2.3.1. Unsuitable materials shall include:

(i) Running silt, peat, logs, stumps, roots, grass and other vegetable matter, perishable or toxic material, slurry or mud; or

(ii) Organic clay and organic silt; or

(iii) Any material

a) Which is susceptible to spontaneous combustion; or

b) Which is clay having a liquid limit exceeding 80% and/or a plasticity index exceeding 55%; or

c) Which has a loss of weight greater than 2.5% on ignition.

7.2.3.2. Materials that are soft or unstable merely because they are too wet or too dry for effective compaction shall not be classified as unsuitable, unless otherwise classified by the S.O..

7.2.4. Suitable materials

7.2.4.1. Suitable materials shall mean those materials other than the unsuitable materials defined in sub-section 7.2.3..

7.2.4.2. General fill shall generally comprise of suitable materials made up of either cohesive soil or cohesion less soil or mixture of both. The classification of cohesive and cohesion less soil shall be based on Soil Classification System set out in the latest *MS 1056: Method of Test for Soil for Civil Engineering Purpose*.

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7.2.4.3. Special fill shall comprise of material, which would otherwise be classified as general fill, but which contains durable well-graded natural sand and gravel or crushed rock, other than argillaceous rock (e.g. mudstone, shale), or durable clean crushed demolition rubble of similar particle size and free from any contaminants.

7.2.5. Hard Mass

7.2.5.1. This shall mean any cemented sediments, rock mass and highly fractured rock mass which can be excavated using an excavator with minimum weight of 41.4 tonnes and nett horsepower rating of 321 brake horsepower with production rate not exceeding 50m^3/hour. All machineries shall be in good condition and operated by skilled personnel approved by S.O.

7.2.5.2. Hard mass shall exclude individual masses less than 0.5m^3.

7.2.6. Rock mass

7.2.6.1. Rock mass shall mean masses found in ledges or masses which can be excavated using the following machinery with production rate not exceeding 20m^3/hour:

(i) Track-type tractor (dozer)

Machinery with minimum weight of 37 tonnes and nett horsepower rating of 303 brake horsepower or more. The tractor unit is to be in good condition and operated by skilled personnel in the use of ripping equipment; and

(ii) Ripping unit

The ripper to be attached to the above-mentioned tractor shall have a minimum penetration force of 120kN. The ripper shall have a single shank in good working condition with sharpened cutting point.

7.2.6.2. Boulders or detached pieces shall only be regarded as rock if they individually exceed 0.5m^3. For boulders or detached pieces individually measuring less than 0.5m3, it shall be considered as common excavation. For determination of the volume of individual boulder, diameters of the boulder in three (3) orthogonal directions shall be taken. The average of the three (3) diameters shall be used to calculate the volume of boulder. Records of measurements and photographs shall be taken and kept supporting the calculation of the volume of boulder.

7.2.7. Confirmation of Common Excavation/Hard Mass or Rock Mass Excavation

7.2.7.1. Confirmation of common excavation/hard mass excavation or rock mass excavation shall be carried out with direct method and indirect method as specified below. Both criteria shall be fulfilled in order for the material to be classified as hard mass or rock mass. Confirmation test shall be carried out again when in S.O.'s opinion the materials are different from those excavated from the trial excavation before.

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(i) Direct Method by Trial Excavation

Trial excavation shall be carried out using the machineries as specified in sub-sections 7.2.5. and 7.2.6. to confirm that the excavated material is categorized under hard mass or rock mass excavation based on its hourly production rate. The trial excavation shall be carried out on a flat platform (as much as possible) in order to develop the rated horsepower at maximum efficiency. All machineries shall be run in good condition and operated by skilled personnel approved by the S.O.

In the event where the Contractor unable to provide the machineries as stated in sub-sections 7.2.5. and 7.2.6., the Contractor may propose similar machine that can be used at site for the purpose of trial excavation for the S.O. approval. The equivalent production rate of the machine can be calculated by referring to Table B1 & B2.

The ripper unit shall be used in excavation of hard mass and rock mass only and shall not be used in common excavation.

(ii) Indirect Method

Point load test shall be carried out on excavated material for this purpose by using portable point load tester apparatus. Minimum ten (10) Rock samples from the excavated material resulted from the direct method by trial excavation (as described in (i)) shall be tested and the results interpretation are shown in **Table B3**. Sample to be tested shall have size not less than 30mm and not more than 85mm with the preferred dimension about 50mm according to ASTM D5731.

The provision of point load test equipment at site for the above-mentioned testing shall be at Contractor's own cost and time. The point load test apparatus shall be calibrated and a valid calibration certificate shall made available to the S.O. upon request

7.3. Dimensional Tolerances

Slopes in cutting shall be trimmed mechanically to neat and even surfaces which shall have gradients not steeper than that shown on the Drawings. Widths of excavations shall not exceed the dimensions shown on the Drawings by more than 300mm with encumbrance free to complete the Work, unless otherwise approved by the S.O..

7.4. Separation and Stockpiling of Suitable Material

Where excavation reveals a combination of suitable and unsuitable materials, the Contractor shall, wherever the S.O. considers it practicable, carry out the excavation in such a manner that the suitable materials are excavated separately for use in the Works without contamination by the unsuitable materials.

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7.5. Removal of Excavated Material from Site

7.5.1. Trial pit shall be carried out prior to removal of material to be excavated to confirm water table and depth of excavation.

7.5.2. No excavated material shall be removed from the Site except on the direction or with the approval of the S.O.. Should the Contractor be permitted to remove suitable materials from the Site to suit his operational procedure, then he shall make good any consequent deficit of fill material arising there from, at his own expense. Unless designated dump sites have been shown on the Drawings, the Contractor shall dispose of surplus suitable material at his own dump areas outside the Site as approved by the S.O..

7.6. Removal of Unsuitable Material

7.6.1. Trial pit/ hand auger/JKR Probe shall be carried out prior to removal of material to be excavated to confirm water table and depth of excavation.

7.6.2. Unsuitable material shall be excavated to such depth and over such area as shown on the Drawings and/or directed by the S.O. and be transported and disposed of in an approved manner. Unless approval of the S.O. to dump and spread the unsuitable material within the Site is obtained, the Contractor shall be responsible for providing his own dump site for such unsuitable material. Voids created due to removal of unsuitable material shall be backfilled with suitable material compacted to a dry density as specified in sub-section 8.4.3. or that specified for the respective part earthworks or as directed by the S.O..

7.7. Replacement of Excavated Material under Standing Water

Where it is decided by the S.O. that replacement of excavated material shall be done under standing water, voids created due to removal of excavated material shall be backfilled with hard clean crushed rock, natural gravel or sand having grading within the respective limits specified in **Table B4**.

7.8. Sides of Excavation

The Contractor shall ensure that at all times, the sides of the excavation are maintained in a safe and stable condition and shall be responsible for the adequate provision of all shoring and strutting including sheet piling required for this purpose. All temporary works shall comply with the requirements of *BS 5975 Code of Practice for Temporary Works Procedures and The Permissible Stress Design of Falsework*.

7.9. Widening Cuts

7.9.1. The S.O. may instruct the Contractor or the Contractor himself may elect to obtain material for the Works by widening cuts. In the latter case, the Contractor shall first request permission in writing from the S.O..

7.9.2. Widening of cuts shall not be permitted beyond the limits of the road reserve.

7.9.3. Any additional costs and time incurred that resulted from widening cuts shall be borne by the Contractor.

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7.10. Excavation of Rock

7.10.1. Rock excavation shall be carried out by methods appropriate to site requirements as approved by the S.O..

7.10.2. Where the excavation is too hard to be performed by digging, dozing, scraping, ripping, splitting, breaking, jack picking or other such methods, the Contractor may make a written request to the S.O. for permission to blast. Such permission will be granted only if the S.O. is satisfied that all reasonable measures have been tried to carry out the excavation by methods other than blasting.

7.10.3. Where explosives are used, the Contractor shall provide a method statement and shall comply fully with requirements of these Specifications, or any direction, order, requirement or instruction given by the PDRM or any other authority competent to do so under any written law. The Contractor shall comply to the safety and hazard requirements as specify in Occupational Safety and Health Act (OSHA) and any misconduct and the use of excessive explosive shall be the responsibility of the Contractor.

7.10.4. All material from rock excavations shall be used as far as is practicable in the Works.

7.10.5. Where the rock is of satisfactory quality, the Contractor may elect to crush and screen it to produce aggregates required for concrete, road base, sub-base, or other purposes with the prior approval of the S.O.. Excavated rock needed for earthwork construction which the Contractor elects so to use for producing aggregate materials shall be replaced at the Contractor's own expense by borrow materials of satisfactory quality from alternative locations approved by the S.O..

7.10.6. Otherwise, excavated rock shall be used in the construction of embankment and fill, to the fullest practical extent, in either of the two (2) following ways:

7.10.6.1. Excavated rock shall be broken down to a maximum particle size of 300mm and used as rock fill as described in sub-section 8.6..

7.10.6.2. Excavated rock shall be broken down to a maximum particle size of 150mm, blended with suitable earth fill material in a proportion not exceeding 1 rock to 1 earth, and used as common fill.

7.10.7. The Contractor may only waste excavated rock with the approval of the S.O.. Excavated rock needed for earthwork construction which the Contractor elects to waste shall be replaced at the Contractor's own expense by borrow materials of satisfactory quality from alternative locations approved by the S.O..

7.11. Storage and Handling of Explosives

The storage and handling of explosive shall be adhered to all Authorities' requirement. The prevention of any unauthorised issue or improper use of any explosive brought on the Works shall be the responsibility of the Contractor and only experienced and qualified personnel shall be employed to handle explosives for the purpose of the Works.

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7.12. Blasting

7.12.1. Explosives shall be used in the quantities and manner recommended by the manufacturers and blasting specialist. Blasting shall be restricted to such periods as the S.O. may prescribe and to comply with all authority's requirement. If, in the opinion of the S.O., blasting would be dangerous to persons or properties or to any finished work, or is being carried on in a reckless manner, he may prohibit it, and order the rock to be excavated by other means. Such authorisation shall not in any way relieve the Contractor of his liabilities under the Conditions of Contract.

7.12.2. All necessary precautions shall be taken to avoid overbreak As the excavation approaches its final lines face, blasting with pre-splitting technique shall be carried out to reduce blast damage and create reasonably even finished surface.

7.13. Safety Measures

7.13.1. When blasting is carried out close to properties or roads, safety rules complying to all authorities' requirements shall be strictly adhered to. Where necessary or as directed by the S.O., heavy mesh blasting mats or any other controlled materials shall be used to ensure that no damage is caused to persons or properties on or off Site. Special care shall be taken on highly weathered rock mass and sensitive ground. Plaster shooting will not be permitted within 400m of any building or structure. The Contractor shall keep records of the nearby existing properties and provide sufficient monitoring instrumentation before any blasting commence. Any damage caused by blasting shall be borne by the Contractor.

7.13.2. If traffic on any road or railway has to be interrupted for blasting operations, the Contractor shall obtain approval of his schedule for such interruption from the appropriate authorities and shall prove to the S.O. that he has obtained it, prior to the interruption.

7.13.3. When blasting is carried out with close proximity to sensitive structures and environmental sensitive areas, thresholds and criteria of vibration, air blast, dust, fly rock and other blasting impact shall be established for monitoring purpose.

7.14. Insecure Material

The cut slopes shall be cleared of all rock fragments which move when pried with a crowbar. The Contractor shall excavate any insecure material to an approved depth and build up the resulting spaces with Grade 15P/20 concrete or masonry using rock similar to the adjoining natural rock so as to ensure a solid face.

8. Filling Works

8.1. Material

8.1.1. Fill materials to form formation level shall be of suitable material obtained from excavation in cuttings. Where the quantity of such materials is inadequate, the Contractor shall obtain suitable materials from the designated borrow pits or from his own borrow pits which have been approved by the S.O..

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8.1.2. The fill material shall be free from roots, grass, other vegetable material, clay lump or material of particles size larger than 150mm.

8.1.3. Unless otherwise directed by the S.O., the following tests shall be carried out for every 1,500m^3 of fill material to be placed at Site:

(i) Atterberg limits

(ii) Gradation analysis

(iii) M.S 1056 Compaction Test (4.5 kg rammer method)

8.1.4. Sand shall not be used as fill materials at outer edges of the embankment.

8.2. Borrow Pits

8.2.1. The Contractor shall be responsible for locating borrow pits. Designated borrow pits shown on the Drawings only indicate to the Contractor potential areas for borrow. Whether the Contractor obtains materials from the designated or his own borrow pit, it shall be his responsibility to ascertain the suitability of the pit with respect to the quantity and quality of the materials, which shall be subjected to the approval of the S.O..

8.2.2. The Contractor shall keep the borrow pits free from water ponding and the excavation neat and tidy. The contractor shall make sure the sidewall of the borrow pits is stable, protect the slope surface by turfing and shall carry out other necessary erosion and environmental protection measures following the agreed method statement or as instructed by the S.O..

8.3. Placement of Fill Materials

8.3.1. All fill materials shall be deposited in layers and brought up at a uniform rate so that all parts of the Site reach the designed level at the same time. The loose depth for each layer of fill shall be determined from the trial compaction. Each layer shall extend over the full width of the fill area and shall be compacted in accordance with the requirements of sub-section 8.4.. Each compacted layer shall be maintained at all times with a sufficiently even surface of longitudinal and cross slope in order to maintain the stability and drain away the surface water.

8.3.2. Where embankment is to be constructed on ground with a cross slope flatter than 1 (vertical) to 10 (horizontal) but steeper than 1 (vertical) to 30 (horizontal), the foundation material, except where this is rock, shall be scarified to a depth of 100mm, blended with embankment fill material and compacted as described in sub-section 8.4..

8.3.3. Where embankment is to be constructed against existing embankment or on ground with a cross-slope steeper than 1 (vertical) to 10 (horizontal), the foundation shall be excavated in all materials (including hard rock) to form benches with horizontal and vertical faces from which construction of the embankment shall proceed. The benches shall be contiguous beneath the full width of the embankment and shall be of a suitable width to accommodate construction equipment such as motor-graders, trucks, rollers, et cetera. Scarifying of the horizontal and vertical faces of the benches shall not normally be required, and the material excavated in forming the benches may normally be used as fill in the embankment as approved by the S.O..

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8.4. Compaction

8.4.1. General

8.4.1.1. All materials used in embankments and as fill elsewhere shall be compacted as soon as practicable after being placed and spread. Compaction shall be undertaken to the requirements of this section by plant approved by the S.O.. All compaction requirements shall be controlled by means of field density measurement.

8.4.1.2. For compaction of embankment slope, the Contractor may either extend each compacted layer beyond the design slope surface by at least 600mm then trim back to the required slope angle, or he may employ an agreed tow type roller to compact the sloping surface.

8.4.2. Compaction trials

8.4.2.1. The latest *MS 1056* Compaction Test (4.5kg rammer method) shall be used in determining the moisture versus density relation of soil.

8.4.2.2. The Contractor shall submit to the S.O. for his agreement the proposed method of compaction for each main type of material to be used in the embankment. This shall include the type of compaction plant for each type of material and the number of passes in relation to the loose depth of material to achieve desired compaction. The maximum loose thickness for fill shall generally be limited to 400mm unless trial compaction shows compliance with larger loose thickness and with the approval from the S.O.. The Contractor shall carry out field compaction trials, supplemented by any necessary laboratory investigations, as required by the S.O.. This shall be done by using the procedures proposed by the Contractor for earthworks and shall demonstrate to the S.O. that all the specified requirements regarding compaction can be achieved. Compaction trials with the main types of material likely to be encountered shall be completed before the works with the corresponding materials will be allowed to commence. Each trial area shall be not smaller than 8m x 15m.

8.4.2.3. For earthwork compaction of less than 100m^3, trial compaction can be waived with approval from the S.O., but field density testing as per sub-section 8.4.4. is remained necessary as and when instructed by the S.O..

8.4.3. Degree of compaction

The whole of the fill area shall be compacted in layers until no visible track line and to not less than 90% (for cohesive material) or 95% (for cohesion less material) of the maximum dry density (MDD) determined in the latest *MS 1056* Compaction Test (4.5kg-rammer method), unless otherwise as shown on the Drawings.

8.4.4. Field density testing

Field density tests on each layer of compacted earth fill shall be carried out using the sand replacement method in accordance with the latest *MS*

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1056 or by using other means of testing of comparable accuracy approved by the S.O..

8.4.5. Moisture control

8.4.5.1. Each layer of earth fill shall be processed as necessary to bring its moisture content to a uniform level throughout the material, suitable for compaction. The optimum moisture content (OMC) as determined by the latest *MS 1056* Compaction Test (4.5kg rammer method) shall be used as a guide in determining the proper range of moisture content, preferably on the wet side, at which each soil type shall be compacted. Water shall be added in fine spray for consistent moisture absorption in the fill, or the material aerated and dried to adjust the soil to the proper range of moisture content to obtain the required density. Dry sand or cement or mixture of sand and cement can be added for the same purpose upon approval by the S.O.. A satisfactory method and sufficient equipment as approved by the S.O. shall be used for the furnishing and handling of water.

8.4.5.2. If the natural water content of suitable material is too high for the proper compaction to be carried out, the Contractor can either bring down the moisture content by aeration or drying or alternatively replace it with suitable materials of compactable moisture range at his own cost.

8.4.6. Air voids

To reduce potential of collapse compression of unsaturated cohesive fill due to wetting, the moisture content range at fill placement shall be controlled to achieve a compacted fill with allowable air void content not exceeding 5%.

8.5. Frequency of Control Tests

8.5.1. For fill/ imported material, control test shall include a series of test as per Sub-section 8.1.3.

8.5.2. For compacted material, control test shall consist of one field density test which evenly allocated to each compacted layer of the entire compacted fill.

8.5.3. The frequency of control tests shall be in accordance with **Table B5**.

8.5.4. The control tests shall be evenly allocated to each compacted layer of the entire compacted fill.

8.5.5. If certain test methods are used for the reasons of speed and economy, calibration between such tests and the master test method as per latest *MS 1056* shall be carried out at the interval of every 100 tests subject to the S.O. agreement. The calibration is material specific and shall be performed for each material type. The non-master test method with variation of more than ± 5% shall be rejected.

8.6. Rock Fill Embankment

8.6.1. Rock used in rock fill embankments shall be of maximum particle size of 300mm so that it can be deposited in horizontal layers, each not exceeding 500mm in compacted depth and extending over the full width of the

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embankment except for any specified external cover to slopes or new formation level. The materials shall be spread and levelled by a crawler tractor weighing not less than 15 tonnes. Each layer shall consist of reasonably well graded rock and all large voids with averaging dimension of exceeding 150mm shall be filled with broken fragments before the next layer is placed. The top surface and side slopes of embankments so formed shall be thoroughly blinded with approved fine graded material to seal the surface.

8.6.2. There shall be a transition layer between rock fill and earth fill or the top 300mm of subgrade of at least 300mm compacted thickness. This shall consist of uniformly graded crushed rock between 6mm and 150mm as approved by the S.O..

8.6.3. Each layer of rock used as rock fill in embankments shall be systematically compacted by at least 12 passes of a vibrating roller with a static load per 25mm width of roll of at least 45kg or a grid roller with load per 25mm width of roll of at least 200kg or other approved plant.

8.7. Filling on Soft Ground

8.7.1. Foundation treatment

8.7.1.1. Where soft ground under embankment is to be treated as shown on the Drawings or as directed by the S.O., the foundation soil shall be improved as specified in SECTION V: GROUND IMPROVEMENT.

8.7.1.2. The first layer of fill materials shall be deposited over the full width of the embankment and berms in thicknesses not more than 500mm or as approved by the S.O. to sufficiently support earthwork machineries.

8.7.1.3. If fill materials are required to be placed under standing water, hard clean crushed rock, natural gravel or sand having grading within the respective limits specified in **Table B4** shall be used to backfill the embankment not less than 300mm above the standing water to receive compacted suitable fill thereafter.

8.7.2. Surcharge and staged construction

Where indicated in the Contract or directed by the S.O., the embankment shall be built to different heights in stages with or without surcharge and with allowance for consolidation time periods in between stages, all in accordance with the Contract. Where surcharge is specified, the work shall be carried as specified in SECTION V: GROUND IMPROVEMENT WORKS. The Contractor shall be responsible for the provision of surcharge material and the removal and disposal of excess material on completion of consolidation or when directed by the S.O..

8.7.3. Geotechnical instrumentations

8.7.3.1. Geotechnical instruments shall be provided and installed by the Contractor in the positions as shown on the Drawings or as directed by the S.O. for the purpose of measuring intended reading at specified location(s) during and after the construction period. The details of geotechnical instruments shall be as shown on the Drawings and the Contractor shall be responsible

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for supplying, installing and maintaining the functionality of the geotechnical instruments as the work proceeds.

8.7.3.2. Geotechnical instrumentation works shall also comply to SECTION V: GROUND IMPROVEMENT WORKS.

8.7.4. Monitoring records

8.7.4.1. All monitoring works and records taken shall comply to SECTION V: GROUND IMPROVEMENT WORKS.

8.7.4.2. Joint recording of geotechnical instruments reading shall be conducted as specified. The monitoring records shall be submitted to the S.O. on an approved printed form to be supplied by the Contractor. Softcopy of monitoring records shall be submitted together with the hard copy records.

8.7.4.3. For the measurement of the volume that has settled below the original level of the foundation of the embankment, the measured settlement of each settlement gauge shall be used for volume computation following the method shown on the Drawings.

9. Protection and Maintenance for Erosion Control

9.1. The Contractor shall be fully responsible to repair/ remedy any slope erosion, slip or tension cracks (if any and due to whatever causes) at his own cost if the requirements are not fully complied with. The method and procedure of remedy/ stabilization plus necessary stability analysis shall be prepared and endorsed by Professional Engineer with full design verification and justifications.

9.2. Where turfing is required for earthworks protection, it shall be planted immediately after cutting or filling as specified under SECTION R: LANDSCAPING AND TURFING.

9.3. Where hydroseeding is required for earthworks protection, it shall be carried out immediately after cutting or filling as specified under SECTION W: HYDROSEEDING.

9.3.1. All grass shall be regularly watered until the vegetation is satisfactorily established to the requirements of these Specifications. Any dead grass shall be replaced at the Contractor's own expense.

9.4. Creepers

9.4.1. Where creepers are introduced on gunited slopes, rocks or unsuitable materials, species shall be of Malaysian origin such as *ficus pumila*, *centrusemo pubscens*, or to the agreement of the S.O..

9.4.2. The Contractor shall submit to the S.O. for his consideration and approval, at least four (4) weeks in advance of the proposed work, full details of his proposed method of planting the creepers. The information submitted shall include, but not limited to, a full description of the following aspects of the work:

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9.4.2.1. The preparation of the areas to be planted with creepers, including the amount of topsoil if appropriate to be used and its method of application;

9.4.2.2. The details and results of investigations to determine which types of creepers are compatible with the soil in the areas to be planted;

9.4.2.3. The types of creepers to be used, and the function, root and growth characteristics of each type;

9.4.2.4. The composition of fertilizer to be used at the time of planting the creepers and its rate of application;

9.4.2.5. The composition of fertilizer to be used after planting, the times of application and the rate of application;

9.4.2.6. The amounts of lime or other chemicals (if any) to be applied to improve the soil before, during and/or after planting;

9.4.2.7. the cultivation and after care of the areas, including rates and frequencies of watering, fertilizing and general maintenance for at least one (1) year after planting;

9.4.2.8. the time after planting required for establishing permanent, dense growth of creepers, which will require minimal maintenance;

9.4.2.9. Guarantees the success of the creepers planting work.

9.4.3. All creepers shall be regularly watered until the vegetation is satisfactorily established to the requirements of these Specifications. Any dead creepers shall be replaced at the Contractor's own expense.

9.5. Temporary Slope Protection

9.5.1. Should the Contractor be unable to turf/hydroseed the exposed slopes within one (1) weeks after cutting/filling works temporary protection measures such as covering with tarpaulin sheet or artificial cover to control erosion shall be taken.

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Table B1. Equivalent Production Rate of Hard Mass Based On Types of Excavators

Excavator Series	Weight (tonnes)	Engine Horsepower (HP)	Factor compared with 41.4 tonnes (Excavator Series 400)	Equivalent Production Rate for Hard Mass (m^3/hr)
150	15.4	99	0.33	16.5
200	21.2	170	0.58	29.0
250	27	188	0.63	31.5
300	31	242	0.67	33.5
350	36	271	0.75	37.5
400	41.4	321	1.0	50.0

Table B2. Equivalent Production Rate of Rock Mass Based On types of Track-Types Tractors With Ripping Equipment (bulldozer ripper)

Dozer	Flywheel power (kW)	Operating weight (tonne)	Factor compared with 37 tonnes (Bulldozer Ripper)	Equivalent Production Rate for Rock Mass (m^3/hr)
D6, D7	200-240	20-25	0.54	11.0
D8	303	37	1.0	20.0
D9	405	48	1.3	26.0

Note: If the contractor elects to use machinery larger than as specified above, it should be considered equivalent to the specified capacity for the purpose of approval.

Table B3. Category Of Excavation Based On Corrected Point Load Test Index $I_{s(50)}$

Type of excavation	Corrected point load test index $I_{s(50)}$ ≥ 2MPa
Common Excavation	Not applicable (no solid sample can be tested)
Hard Mass	< 80% of the samples
Rock Mass	≥ 80% of the samples

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Table B4. Grading Limits of Materials for Replacement of Excavated Material

B.S. Sieve Size	% Passing by Weight
Crushed Rock or Gravel	
63.0 mm	100
37.5 mm	85 – 100
20.0 mm	0 – 20
10.0 mm	0 – 5
Sand	
10.0 mm	100
5.0 mm	90 – 100
1.18 mm	45 – 80
300 µm	10 – 30
150 µm	2 - 10

Table B5. Frequency of Control Test for Earth Embankment

Type of Material	Frequency of Test
Fill/ Imported material	1 test per 1500m^3
Compacted material	1 test per 500m^2

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TABLE OF CONTENTS

SECTION C: FOUNDATION WORKS AND WORKS BELOW LOWEST FLOOR LEVEL		PAGE
1.	Description	C/1
2.	General Requirements	C/1
3.	Soil Investigation Works	C/2
4.	Shallow Foundations	C/2
5.	Deep Foundations	C/8
6.	Subterranean Termites Treatment	C/58
7.	Damp Proof Membrane (DPM)	C/59
8.	Damp Proof Course (DPC)	C/59
9.	Filling Under Floors, Aprons Etc.	C/59
10.	Hardcore	C/59

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1. Description

This work shall consist of the supply, installation/ construction and testing of foundation works in accordance with this Specification and the lines, levels, grades and cross-sections shown on the Drawings and as directed by the S.O..

2. General Requirements

2.1. Setting Out

Setting out shall be carried out using the data and reference points as shown on the Drawings. The foundation position shall be marked with suitable identifiable pegs or markers at least 300mm length driven into the ground and the location marked with contrasting material. If raking piles are to be installed then the setting out pins, pegs or markers is located in an offset position at piling platform level taking into account of depth to cut-off level and rake value of the pile. In addition, the alignment of pins, pegs or markers shall indicate the direction of the rake. Immediately before pile installation or casting of foundation, the foundation point shall be checked by the Contractor again.

2.2. Excavation

2.2.1. Foundations shall be excavated to the levels and dimensions as shown on the Drawings, with sides trimmed and bottoms levelled and stepped as required.

2.2.2. All excavations shall be carried down to the required level as shown on the Drawings unless otherwise, the depths of foundation are decided on the site by the S.O.. The Contractor shall, at his own cost and expense, make good any over excavation below the required depth with suitable granular material or concrete as approved by the S.O..

2.3. Method Statement for Construction Operations

2.3.1. Two (2) weeks before the commencement of foundation works, the Contractor shall submit to the S.O., a detailed method statement for the foundation works. The method statement shall contain the followings:

2.3.1.1. A detailed construction sequence;

2.3.1.2. Shop Drawings showing details of all special requirements for the construction activities such as hoisting of piles, reinforcement cages, cast in fixing, etc;

2.3.1.3. Design calculation of key temporary works endorsed by a Professional Engineer;

2.3.1.4. Materials, plant and labour requirement at each construction stage;

2.3.1.5. Rate of production output based on resources allocated;

2.3.1.6. Other information relevant to the foundation works.

2.3.2. If requested by the S.O., the Contractor shall submit additional information pertaining to the method of construction (including temporary works and the use of the construction plant), calculation of the stresses, strain and deflection that will arise in the permanent works of any part thereof during construction.

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2.3.3. The Contractor shall not deviate from the methods which have been approved by the S.O. Approval by the S.O on the Contractor's proposed methods of construction shall not, in any way, relieve the Contractor of any of his duties or responsibilities under the Contract.

2.4. Unexpected Ground Conditions

The Contractor shall give a written notice immediately to the S.O. of any circumstances which, in the Contractor's opinion, indicate ground conditions that may differ from those expected by the Engineer as shown in the Drawings. The Contractor shall submit to the S.O. a report which contains all information available to the Contractor that will materially assist the S.O. in verifying the conditions reported, and to modify the design, if necessary.

2.5. Adjacent Structures

2.5.1. The Contractor shall carry out a dilapidation survey of adjacent properties to establish the existing condition of the adjacent structures and facilities prior to commencement of foundation works. Dilapidation surveys shall be conducted by a registered building surveyor and the result of the survey shall be submitted to the S.O. for record.

2.5.2. The Contractor shall pay very careful attention to the construction constraints imposed by adjacent structures. The Contractor shall take adequate measures to ensure his foundation works do not disturb or damage existing adjacent structures and surrounding environment. The Contractor shall provide a proposal for monitoring adjacent structures and surrounding environment for any detrimental effects arising from execution of the foundation works, so that appropriate and timely preventive action can be taken to minimise damage. The Contractor's proposal and monitoring programme shall be certified by a Professional Engineer.

2.5.3. The Contractor shall be responsible and bear the cost incurred including claims for damages arising from his execution of the foundation works.

2.6. Existing Services

The Contractor shall give all required notices to the appropriate utility authorities before commencement of foundation works. The Contractor shall also locate existing services by piloting, protect existing services, rectify any damage or interference to them and provide temporary support while repairs are being carried out if so required.

3. Soil Investigation Works

A soil investigation report shall be made available (if any) at the S.O.'s office for the Contractor information. The Contractor shall study the soil investigation report in detail and make his own interpretation of the information provided and make due allowance for the effect of site condition on his construction operation. No responsibility is assumed by the S.O.'s for any opinion or conclusion given in the soil investigation report.

4. Shallow Foundations

4.1. Definition

Shallow foundation is a foundation constructed in depth of not exceeding 3.0m from formation level. The depth to width ratio of the foundation is D/B≤ 3. Unless otherwise specified, shallow foundations shall conform with *MS 1756*. On no

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account shall isolated foundations be founded on made up or filled ground unless detailed engineering analysis has been carried out.

4.2. Type of shallow foundation

4.2.1. Pad Foundation

Pad Foundation is spread or isolated foundation of rectangular or square reinforced concrete pad that supports localized single point loads such as structural columns.

4.2.2. Strip Foundation

Strip Foundation is continuous strip of reinforced concrete that supports continuous loads such as walls.

4.2.3. Raft Foundation

Raft Foundation is a combined strip or pad foundation that may cover the entire area under a structure supporting several columns and walls.

4.3. Materials

4.3.1. Concrete

The materials and workmanship for concrete shall be as specified under SECTION D: CONCRETING of this Specification.

4.3.2. Reinforcement

The steel reinforcement shall be as specified under SECTION D: CONCRETING of this Specification.

4.4. Confirmatory of Allowable Bearing Capacity of Soil

4.4.1. The Contractor shall conduct probe test to confirm the required allowable bearing capacity. For pad foundation, the probe test shall be conducted at every column position. Other types of shallow foundation probe test shall be conducted as stated in the Drawings. The Probe test shall be carried out according to *Standard Specification for Road Works "SECTION 17: SITE INVESTIGATION"*. The Contractor shall submit the results to the S.O. for approval.

4.4.2. In the case where the allowable bearing capacity required is more than or equals to 150 kN/m^2, the Contractor shall carry out the plate bearing test as stated in the Drawings.

4.5. Plate Bearing Test

4.5.1. General

4.5.1.1. To verify the allowable bearing capacity, the Contractor shall carry out plate bearing test as shown on the Drawings and/or as instructed by the S.O.. The recommended size of the test plate shall not be less than 500mm in diameter. Selection of bearing plate is such that it shall not warp or deform under the applied load.

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4.5.1.2. The design and construction of the load application system shall be satisfactory for the required test. These details shall be made available prior to the commencement of testing.

4.5.2. Preparation at Test Level

4.5.2.1. Notice of Excavation

The Contractor shall give at least 48 hours' prior notice of commencement of excavation of the specified location to be tested.

4.5.2.2. Method of Excavation

(i) Excavation to the test level shall commence as quickly as practicable to minimize the effects of stress relief, particularly when in cohesive soils. Temporary ground support shall be installed as and when necessary. Where the test is to be carried out below the groundwater level in permeable ground, the equipment for lowering the water level shall be installed and water level shall be lowered before the excavation reaches the water table in order to prevent ground disturbance.

(ii) All loose materials and any embedded fragments shall be removed so that the area for the plate is generally level and as undisturbed as possible. For uneven surface, place a layer of sand, nowhere exceeding 100mm in thickness to obtain a level soil surface. The depth of the test area should be the same as the foundation depth of the structure to be built on site.

4.5.2.3. Supervision

(i) The setting up of plate bearing test equipment shall be carried out under competent supervision and the equipment shall be checked to ensure that the setting-up is satisfactory before the commencement of load test.

(ii) All tests shall be carried out only under the direction of an experienced and competent supervisor conversant with the test equipment and test procedures. All personnel operating the test equipment shall have been trained in its use.

4.5.2.4. Notice of Test

The Contractor shall give at least 24 hours' prior notice of the commencement of the test. No load shall be applied to the test area before the confirmation of the specified test procedure.

4.5.3. Protection of Testing Equipment

4.5.3.1. Protection from Weather

Throughout the test period, all equipment for measuring load and movement, and beams shall be protected from adverse effects of sun, wind and precipitation.

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4.5.3.2. Prevention of Disturbance

Construction activities and persons who are not involved in the testing processes shall be kept at a sufficient distance from the test location to avoid disturbance due to any unavoidable activity and its effects.

4.5.4. Method of Loading

4.5.4.1. Test Load

(i) The test load shall be applied in one (1) of the following ways:

a) By means of a jack which obtains its reaction from the load heavier than the required load such as concrete blocks, water in tanks or others;

b) By means of a jack which obtains its reaction from tension piles or other suitable anchors.

(ii) In all cases, the reaction load or its supports shall be placed sufficiently far from the proposed test position to reduce the influence on the results to a tolerable level. Care shall be taken to ensure that the reaction load remains stable throughout the test without the possibility of load tilting or collapsing.

(iii) In addition to the reaction load, it shall be necessary to provide a loading frame, a bearing plate, a loading column and a hydraulic jack or other appropriate type of load measuring device. The loading column shall be of sufficient strength to prevent undue buckling under the maximum load. The total weight of the kentledge or reaction force provided shall be at least 1.2 times the maximum test load.

(iv) In all cases the Contractor shall ensure that when the hydraulic jack and load measuring device are mounted on the loading column, the entire system shall be stable up to the maximum load to be applied. If in the course of carrying out a test, any unforeseen occurrence should take place, further loading shall not be applied until a proper engineering assessment of the prevailing conditions has been made and steps taken to rectify any fault.

(v) Where an inadequacy in any part of the system might constitute a hazard, means shall be provided to enable the test to be controlled from a position clear of the kentledge stack or test frame.

(vi) The hydraulic jack, pump, hoses, pipes, couplings and other apparatus to be operated under hydraulic pressure shall be capable to withstand a pressure of 1.5 times the maximum pressure used in the test without leaking. Test certificate shall be submitted before carrying the test.

(vii) The maximum test load expressed as a reading on the gauge in use shall be displayed and all operators shall be made aware of this limit.

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(viii) When method (a) is used, care shall be taken to ensure that the centre of gravity of the kentledge is on the axis of the loading column. The longitudinal axis of the loading column and the centre of the bearing plate shall coincide, and the contact shall be such that any tendency for the plate to tilt is resisted.

(ix) When method (b) is used, all anchor piles shall be at a distance of at least three (3) times the bearing plate diameter from the centre of the plate.

(x) If the anchor piles are to be permanent working piles, their levels shall be observed during application of the test load to ensure no residual uplift occurs.

(xi) Alternatively, the Contractor may propose the use of other types, patented or otherwise, in which case the requirements as below shall be fully complied with.

4.5.4.2. Contractor's Load Test System

The Contractor may propose to use other different types from those specified. The proposal shall be submitted to the S.O. at least 90 days before the date of testing. The suitability or adequacy of any system shall be determined by the S.O.. In the event that the testing system proposed by the Contractor is acceptable, the Contractor shall obtain a Professional Engineer's endorsement on the load settlement results.

4.5.4.3. Deformation Measurement System

The deformation measurement components of the test apparatus shall be made to the required accuracy. Where a dial gauge or other measuring device is used on the plate, a reference beam may serve as the datum. At least four (4) dial gauges or other measuring devices are to be used for measuring the displacement. All settlement devices shall be readable to 0.01 mm. In addition, the levelling equipment shall be readable to 0.1 mm and placed at stable datum when specified. The levelling staff shall have a bubble attached to it so that the verticality of the staff can be checked.

4.5.5. Testing Procedure

4.5.5.1. General

Prior to the performance of any load test, the Contractor shall submit to the S.O. for his approval, Work Drawings showing the method and equipment he proposes to use in the performance of the load test and the measurement of settlements.

4.5.5.2. Maintained Load Test

(i) The Maintained Load Test shall be carried out as follows:

a) The Full Test Load (FTL) on a tested ground shall be three (3) times that of the Allowable Bearing Capacity specified on the Drawings.

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b) The test shall be carried out in three (3) cycles with first cycle test up to working load, second cycle test up to twice the Allowable Bearing Capacity and third cycle test up to full test load.

c) The load shall be applied in increments of 20% of the working load, until a maximum test load is reached. Each increment of load shall be applied as smoothly and as expeditiously as possible. Settlement readings and time observations shall be taken before and after each new load increment.

d) Settlement reading shall be taken for every 3 minutes. A time-settlement graph shall be plotted to indicate when the rate of settlement of 0.05mm per minute is reached. A further increment of load shall be applied when this rate of settlement is achieved, or until a minimum time of 15 minutes has elapsed, whichever is later. The process shall be repeated until the maximum test load is reached.

e) The maximum load at each cycle shall then be maintained for a minimum of 2 hours, and time-settlement readings shall be taken at regular intervals, as for the earlier load stages.

f) The test load shall then be decreased in four (4) equal stages, and time-settlement readings shall be as specified a foresaid, until the movement ceases. At least 15 minutes interval shall be allowed between the unloading decrements.

g) During testing, if the result from each dial gauge or other measuring devices differ by more than 20%, the Contractor shall release the load and recheck the arrangement of the load cell and redo the load test.

h) Settlement readings shall be made immediately after and before every load increment is applied or removed.

The procedure of plate bearing test shall be as specified in **Table C1**.

4.5.6. Submission of Results

4.5.6.1. Full test data, complete field test records and results from the readout unit shall be jointly signed by the S.O.'s representative and the Contractor's authorised agent and submit to the S.O. immediately upon completion of the load test. The submission shall also consist of the following information:

(i) Stage of loading

(ii) The depth of the test level from ground level

(iii) The plate sizes

(iv) Period for which the load was held

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(v) Final load and load increment

(vi) Maximum settlement

4.5.6.2. These are to be plotted as time-settlement graphs.

4.5.7. Interpretation of Test Results

The S.O.'s interpretation and conclusions on the test results shall be final. Unless otherwise specified, the plate bearing test shall be deemed to have failed if the total settlement at any stage of loading exceeds 25mm.

5. Deep Foundations

5.1. Definition

Deep foundation is defined as those where the depth is more than 3m below the formation level. The types of deep foundation covered under this specification are as follows, and not limited to:

(i) Precast reinforced concrete piles

(ii) Prestressed spun concrete piles

(iii) Steel H section piles

(iv) Steel pipe piles

(v) Bored cast in-situ piles

(vi) Micro piles

(vii) Caisson

5.1.1. Trial Pile

A trial pile is a pile installed for ultimate pile load test for which the pile is normally tested to 2.5 to 3.5 times working load, or until failure occurs so that the design parameters can be verified. The location of the trial pile shall be as per drawing or as directed by the S.O.. The trial pile shall not be used as a working pile.

5.1.2. Preliminary Pile

A preliminary pile is a pile installed before the commencement of the main piling works for the purpose of establishing the pile installation criteria for subsequent working piles and for confirming the adequacy of the design, dimensions and working load. This pile can be used as a working pile unless otherwise directed by the S.O..

5.1.3. Working Pile

A working pile is a pile which is installed as part of the permanent foundation work.

5.1.4. Working Load

The Working Load is the Design Load modified to allow for group effect, pile

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spacing or any other factors changing the efficiency of the total foundation from that of a single isolated pile and is at least equal to the dead plus imposed loads on the pile together with the down drag or uplift loads as appropriate.

5.1.5. Test Load

Test load is load applied to a selected pile to confirm that it is suitable for the load at the settlement specified. The Full Test Load (FTL) on a pile shall be twice the Working Load (WL) noted on the Drawings.

5.2. General Requirement

5.2.1. Position

For a pile cut off at or above ground level the maximum permitted deviation of the pile centre from the centre points shown on the Drawings shall not exceed 75mm in any direction. No pile edge shall be nearer than 150mm from the edge of any pile cap.

5.2.2. Verticality

The maximum permitted deviation of the finished pile from the vertical is 1 in 75 at any level.

5.2.3. Rake

The piling rig shall be set and maintained to attain the required rake. The maximum permitted deviation of the finished pile from the specified rake or the rake shown on the Drawings is 1 in 25.

5.2.4. Forcible Corrections

Forcible corrections to concrete piles shall not be permitted. Forcible corrections may be permitted to specific types of piles if approved by the S.O.. However, no forcible corrections shall be made to piles which have deviated beyond the permissible limits specified in sub-sections 5.2.1., 5.2.2., 5.2.3..

5.2.5. Piles Out of Alignment or Position

The Contractor shall, if instructed by the S.O., extract and reinstall any pile which has deviated out of position or alignment by more than the specified limit, or alternatively the substructure shall be modified and certified by a Professional Engineer with Practicing Certificate to the approval of the S.O.. The cost of such extraction and reinstallation or any extra cost in the design and construction of a modified foundation shall be borne by the Contractor if such extra works have been made necessary due to the error and/or negligence of the Contractor.

5.2.6. Welding

5.2.6.1. Unless otherwise specified or shown on the drawing, all welds shall be full penetration butt welds complying with the requirements of *BS EN 12334*.

5.2.6.2. Redriving of the piles shall only be allowed after the welded joints have sufficiently air cooled to 100°C or below.

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5.2.7. Welders' Qualification

5.2.7.1. All welding works shall be executed by qualified welders with valid certificate issued by approved Authorities such as CIAST.

5.2.7.2. Only welders who are qualified to *BS EN 287-1* or who have attained a similar standard shall be employed on the Works. Proof of welders' proficiency shall be made available on request by the S.O..

5.2.8. Preboring And Jetting of Piles

5.2.8.1. Piles shall not be prebored without the written approval of the S.O.. Preboring of piles may be allowed for the following reasons:

(i) To ease pile drivability by breaking through hard layers;

(ii) To reduce lateral soil displacement where this could cause damage to nearby structure;

(iii) To investigate and possibly deal with obstruction in the ground.

5.2.8.2. The piles shall be in contact with surrounding soil and the completed piles shall comply with the requirements of this Specification. Diameter of preboring shall be in accordance with sub-section 5.7.2.1. of this Specification. If boring is oversize, any gap between the tube and ground shall be filled with compacted sand prior to driving the pile.

5.2.8.3. In some soils, jetting may lift adjacent structure or cause undermining of nearby foundations. Pile shall not be jetted without the written approval of the S.O.. Prior to jetting any pile, the Contractor shall submit to the S.O. details of the equipment to be used and the proposed method to be adopted.

5.2.9. Damage to Piles

5.2.9.1. The Contractor shall execute the work in such a manner so as to minimise damage to piles.

5.2.9.2. All piles damaged during handling, transporting, pitching, and driving or at any other time shall be replaced by the Contractor at his own expense. All piles found damaged shall be taken out from site.

5.2.10. Safety Precautions

The Contractor shall take safety precautions throughout the piling operation in accordance with the requirements of the relevant laws and by-laws.

5.2.11. Records

The Contractor shall keep records of the installation of each pile and shall submit two (2) signed copies of these records to the S.O. not later than the next working day after the pile has been installed. The signed records shall form part of the records for the Works. Any unexpected driving or boring conditions shall be noted in the records.

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5.2.12. As-built Locations Plan

The Contractor shall submit an As-built pile location plan certified by a Licensed Surveyor to the S.O. within seven (7) working days of completion of the last pile. Partial as-built plan may be submitted throughout construction of the foundation for verification by the S.O..

5.3. Precast Reinforced Concrete Piles

5.3.1. Material

5.3.1.1. Reinforced Concrete

(i) The materials shall be as specified in **Table C2** or as in *MS 1314*.

(ii) The materials and workmanship for concrete shall be as specified under SECTION D: CONCRETING of this Specification.

5.3.1.2. Pile Shoes

(i) The type of pile shoes to be used shall be as shown on the Drawings and shall comply with *MS 1314*:

a) "Chilled-hardened" cast iron shoes as used for making grey iron castings to *BS EN 1561*, Grade 10; or

b) Mild steel to *BS EN 10025* or equivalent, Grade 50B; or

c) Cast steel to *BS EN 10293*, Grade A.

(ii) Mild steel straps cast into the shoes shall be as shown on the Drawings. Rock shoes where required shall consist of wrought iron shoes and mild steel straps cast into "Chilled-hardened" cast iron blocks, as shown on the Drawings.

(iii) The shoes shall be truly coaxial and firmly embedded on to end of the pile.

5.3.2. Supply and Delivery of Piles

The Contractor shall only use precast concrete piles supplied by approved manufacturers. The Contractor shall produce the mill certificate and Perakuan Pematuhan Standard (PPS) from CIDB to the S.O. for approval. No piles shall be allowed for transportation before achieving concrete strength of 30N/mm^2.

5.3.3. Handling and Storage

5.3.3.1. The method and sequence of lifting, handling, transporting and storing piles shall be such that piles are not damaged or having crack width greater than 0.1mm. Only the designed lifting and support points shall be used. During transport and storage, piles shall be placed on adequate supports located under the lifting points of the piles. Piles shall be stored and stacked on firm ground not liable to settlement under the weight of piles. The supports shall be vertically above one another. All piles within a stack shall be in groups of the same length. Packings of uniform

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thicknesses shall be provided between piles at the lifting points.

5.3.3.2. No pile shall be driven before the specified characteristic strength of appropriate grade of concrete has been achieved.

5.3.4. Installation of Precast Reinforced Concrete Piles

5.3.4.1. Pitching of Piles

Piles shall be pitched accurately in the positions as shown on the Drawings. At all stages during driving and until the pile has set or been installed to the required length, all exposed piles shall be adequately supported and restrained by means of leaders, trestles, temporary supports or other guide arrangements to maintain position and alignment and to prevent buckling and damage to the piles.

5.3.4.2. Driving of Piles

(i) Each pile shall be installed continuously until the specified set and/or depth has been reached, unless otherwise approved by the S.O.. The installation equipment used shall be of such type and capacity to the approval of the S.O.. A follower (long dolly) shall not be used unless approved by S.O., subject to the following requirements:

a) The first pile in each pile system and every tenth pile driven thereafter shall be driven full length, without a follower, to verify that adequate pile length is being attained to develop the desired pile capacity.

b) The follower and pile shall be held and maintained in equal and proper alignment during driving;

c) The follower shall be of such material and dimension to permit the piles to be driven to the length determined necessary from the driving of the full-length piles;

d) The final position and alignment of the first two (2) piles installed with follower in each substructure unit shall be verified to be in accordance with the location tolerances specified in sub-section 5.2.1. before additional piles are installed.

(ii) Follower shall not be used in driving of raked pile.

(iii) A detailed record of the driving resistance over the full length of each pile shall be kept. The log shall record the number of blows for every 0.3m of pile penetration. The Contractor shall inform the S.O. without delay if an unexpected change in driving characteristics is encountered. Where required by the S.O. set shall be taken at approved intervals during the driving to establish the behaviour of the piles.

(iv) A set shall be taken only in the presence of the S.O. unless otherwise approved. The Contractor shall provide all facilities to enable the S.O. to check driving resistances. The final set of a pile other than as friction pile, shall be recorded as the penetration in millimetres per 10 blows. The

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temporary compression of the pile shall be recorded if required.

(v) When a set is being measured, the following requirements shall be met:

a) The pile shall be in good condition, without damage or distortion;

b) The hammer blow shall be in line with the axis of the pile and the impact surface shall be flat and perpendicular to the hammer axis;

c) The hammer shall be in good condition, delivering the required energy per blow and operating correctly;

d) The rebound shall be measured and recorded accordingly.

(vi) When an acceptable resistance or set appears to have been reached, the driving of pile should be suspended for an interval sufficient to permit the soil to recover from the disturbance of pile driving, and then resumed to determine whether there is any increase or decrease in resistance.

(vii) In soils that dilate when disturbed e.g. silts and some shales, negative pore pressure can be set up temporarily and the driving resistance may fall as these pore pressure returns to normal. In clays disturbance can cause positive pore pressure to develop and the strength of the soil may increase as these dissipate. The necessary time interval before redriving may vary from one (1) hour to two (2) hours for non-cohesive soils or two (2) days or more for clays.

(viii) The resistance at the start of redriving is more likely to be representative of the true bearing value of the pile, and each redriving result should be taken into consideration when deciding the pile penetration length.

(ix) Piles shall be driven in an approved sequence to minimise the detrimental effects of heave and lateral displacement of the ground. When required, careful levelling from a datum unaffected by the piling shall be made on the pile heads already driven, before and after driving subsequent piles. Piles which have been displaced vertically by more than 3 mm as a result of driving adjacent piles shall be redriven to the required resistance.

5.3.4.3. Repair of Damaged Pile Heads

(i) If a pile is to be subjected to further driving, concrete in the damaged pile head shall be cut off square at sound concrete, and all loose particles shall be removed by wire brushing, followed by washing with water. Care shall be exercised to ensure that the reinforcement in the pile head is not in any way damaged. Any damaged reinforcement shall be made good to the satisfaction of the S.O.. The head shall be replaced with concrete of similar grade or higher.

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(ii) The new head shall be cast truly in line with the remainder of the pile and be properly cured and allowed to harden sufficiently to develop the strength necessary for further driving. If a pile has been driven to the required set or depth but the level of sound concrete of the pile is below cut-off level, the pile shall be made good to the cut-off level as described above so that the completed foundation will safely withstand the specified ultimate load.

5.3.4.4. Lengthening of Piles

(i) Where piles have to be lengthened, other than by means of welding of steel plates as detailed on the Drawings, the reinforcement shall be stripped of all surrounding concrete for a distance equal to forty (40) times the diameter of the main reinforcement measured from the pile head for spliced joints and 300mm for butt welded joints and all lateral reinforcement shall be removed.

(ii) The new concrete shall be of the same grade or higher as the original concrete on pile and shall be adequately compacted.

(iii) The lengthening bars shall butt on the exposed bars in true alignment and shall be butt welded as specified or shall be spliced with bars of the same diameter as the main pile bars, 60 diameters in length and lapping the main bars for a distance of 40 diameters above and below the joint and shall be securely bound with 1.63mm soft annealed iron wire.

(iv) New binders of similar size shall be provided and spaced at half the centres of the binders in the main body of the pile and shall be securely bound with 1.63mm soft annealed iron wire and the pile extended by concreting in properly constructed mounds to the length required.

(v) Care shall be taken to form the joint between the old and new concrete as specified hereinbefore. The old concrete shall be adequately roughened, and all loose particles shall be removed by wire brushing, followed by washing with clean water. The extension shall be truly in line at all stages of handling and driving with the remainder of the pile and be properly cured and allowed to harden sufficiently to develop the strength necessary for further driving.

5.3.4.5. Pile Joint

The bending strength test of pile joint shall be done for laterally loaded pile only to determine the bending capacity at each respective joint. The test shall be done as in sub-section 5.3.4.6. provided that the joint is positioned at the centre of the span. The bending capacity at the pile joint shall be greater than the bending capacity of the pile body by 10%. The result shall be submitted to S.O. for approval prior to driving of any pile.

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5.3.4.6. Pile Bending Strength Test

Pile bending strength test shall be performed in accordance with Appendix C/1 of this Specification.

5.3.4.7. Cutting and Preparation of Pile Heads

(i) Piles shall be driven in an approved sequence to minimise the detrimental effects of heave and lateral displacement of the ground. When required, careful levelling from a datum unaffected by the piling shall be made on the pile heads already driven, before and after driving subsequent piles. Piles which have been displaced vertically by more than 3 mm as a result of driving adjacent piles shall be redriven to the required resistance.

(ii) When a pile has been driven to the required set or depth, the head of the pile shall be cut off to the level specified or shown on the Drawings. This shall be done carefully to avoid shattering or otherwise damaging the rest of the pile. Any cracked or defective concrete shall be cut away and made good with new concrete properly bonded to the old. The length of reinforcing bars projecting above this level shall be as shown or specified on the Drawings. If the length of reinforcing bars left projecting is insufficient, then they shall be extended by either of the following methods:

a) Butt Welding

The extension bars shall butt on the projecting bars in true alignment and shall be butt welded in accordance with sub-section 5.6.3. of this Specification.

b) Splicing

The projecting bars shall be stripped of all surrounding concrete as necessary to allow splices of length 60 diameters with extension bars. The extension bars shall be securely bound to the projecting bars with 1.63mm soft annealed iron wire. The concrete of the pile shall be made good either before or together with the casting of the pile cap, all to the satisfaction of the S.O.. Care shall be taken to avoid cracking or otherwise damaging the rest of the pile. Any cracked or defective concrete shall be cut away and made good with new concrete properly bonded to the old.

5.4. Prestressed Spun Concrete Piles

5.4.1. Material

5.4.1.1. Concrete

(i) The materials shall be as specified in **Table C2** or as in *MS1314.*

(ii) The materials and workmanship for concrete shall be as specified under SECTION D: CONCRETING of this Specification.

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5.4.1.2. Reinforcement

(i) The prestressing tendons and the non-prestressing reinforcement of the piles including workmanship shall be as specified under SECTION D: CONCRETING of this Specification and as per manufacturer details and shall comply with *MS 1314*.

(ii) Prestressing steel shall comply with *JIS G3137* or *BS 4486* or *BS 5896* or *ASTM A416* or equivalent.

(iii) A Certificate of Conformance is required for every delivery of reinforcement.

5.4.1.3. End Plates

Details of end plates of each length of pile shall be as per manufacturer details and shall comply with MS 1314. Each end plate shall be machine-finished and provided with a chamfer to accommodate the welding when two (2) lengths of pile are jointed.

5.4.1.4. Pile Shoes

If specified, the type of pile shoes to be used shall be as per manufacturer details and shall comply with *MS 1314*.

5.4.2. Supply and Delivery of Piles

The contractor shall only use Prestressed Spun Concrete piles supplied by approved manufacturers. The Contractor shall produce the mill certificate and Perakuan Pematuhan Standard (PPS) from CIDB to the S.O. for approval. No piles shall be allowed for transportation before achieving concrete strength of 30N/mm2.

5.4.3. Handling and Storage

Handling, storing and transporting prestressed concrete pile shall be done in such a manner as to avoid excessive bending stresses, cracking, spalling or injurious result. Piles that are damaged during handling and transporting shall be replaced by Contractor at his own expenses. All damaged and rejected piles shall be removed from the site.

5.4.4. Installation of Prestressed Spun Concrete Piles

5.4.4.1. Pitching and Installation of Piles

Pitching and installation of piles shall be in accordance with sub-sections 5.3.4.1. and 5.3.4.2. Piles shall not be installed until the concrete has achieved the specified characteristic strength.

If repair of damaged pile head is required, refer sub-section 5.3.4.3.

5.4.4.2. Lengthening of Piles

Where lengthening of piles is required, the details of the joint shall be as shown on the Drawings and in accordance with sub-section 5.6.3.. When two (2) lengths of pile are jointed, the end plates

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shall bear over their complete areas. Shims for packing shall not be accepted. For laterally loaded pile, the pile joint shall be in accordance with sub-section 5.3.5.5..

5.4.4.3. Cutting and Preparation of Pile Heads

When a pile has been driven to the required set or depth, the head of the pile shall be cut off to the level specified or shown on the Drawings using a diamond cutter. Pile heads shall be constructed to details as per manufacturer details and shall comply with *MS 1314*.

5.5. Steel H-Section Piles

5.5.1. Material

All steel H- section piles including the cast steel shoe shall comply with the requirement of *BS EN 10025* and/ or *BS EN 10029*, *BS EN 10210*, *BS EN 10113*, *BS EN 10293*, *BS 7668* or *JIS A5526*. The profile and grade to be used are as specified or as shown on the Drawings. The Contractor shall provide mill certificate of the manufactured H-section pile as may be requested by S.O..

5.5.2. Manufacture and Storage of Steel H-Section Piles

5.5.2.1. Manufacturing Tolerances

(i) All piles shall be of the type and cross-sectional dimensions as designed. For standard rolled sections the dimensional tolerances and weight shall comply with the relevant established standard. Length tolerance of H-section steel bearing piles shall be ± 50mm in accordance with *BS EN 10034*.

(ii) The rolling or proprietary tolerances for H-section steel bearing piles shall be such that the actual weight of the section does not differ from the theoretical weight by more than ± 2.5%.

5.5.2.2. Straightness of Sections

(i) All piles shall be of the type and cross-sectional dimensions as designed. For standard rolled sections the dimensional tolerances and weight shall comply with the relevant established standard. Length tolerance of H-section steel bearing piles shall be ± 50mm in accordance with *BS EN 10034*.

(ii) For standard rolled sections the deviation from straightness shall be within the compliance provisions of BS EN 10034. When two (2) or more rolled sections are joined by butt-jointing, the deviation from straightness shall not exceed 1/600 of the overall length of the pile.

(iii) For proprietary sections made up from rolled sections and for tubular piles the deviation from straightness on any longitudinal face shall not exceed 1/600 of the length of the pile nor 5mm in any 3m length.

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(iv) Based on the results of pile driving resistance and/or load tests carried out on piles driven on the Site, the S.O. may, from time to time, instruct the lengths of piles to be modified.

5.5.2.3. Strengthening of Piles

Unless otherwise approved by the S.O., the strengthening of the toe of the pile in lieu of a shoe, or the strengthening of the head of a pile, shall be made from material of the same grade or strength class as the pile and to the details as shown on the Drawings.

5.5.2.4. Marking of Piles

Each pile shall be clearly marked with white undeletable marking at the flanged head showing its reference number and overall length. In addition, each pile shall be marked at intervals of 500mm along its length before being driven. The length of piles to be supplied shall be as shown on the Drawings subject to revision by the S.O..

5.5.2.5. Handling and Storage

(i) All piles shall be of the type and cross-sectional dimensions as designed. For standard rolled sections the dimensional tolerances and weight shall comply with the relevant established standard. Length tolerance of H-section steel bearing piles shall be ± 50mm in accordance with *BS EN 10034*.

(ii) All operations such as handling and transporting of piles shall be carried out in such a manner that damage to piles and their coatings is minimized. Piles that are damaged during handling and transporting shall be replaced by the Contractor at his own expense. All damaged and rejected piles shall be removed from the Site forthwith.

(iii) Piles within a stack shall be in groups of the same length and on approved supports.

5.5.3. Installation of Steel H-Section Piles

5.5.3.1. Pitching and Driving of Piles

Pitching and driving of piles shall be in accordance with sub-sections 5.3.4.1. and 5.3.4.2

5.5.3.2. Lengthening of Piles

(i) Where lengthening of piles is required, the piles shall be joined by butt welding. Butt welded joints shall be stiffened with plates fillet welded on all four (4) sides as detailed on the Drawings. All welding shall be continuous and complying with *BS 638, BS EN 1011-1* and *BS EN 1011-2* and *BS EN 1993* for arc welding and *BS EN ISO 4577* for resistance welding as appropriate. All welding procedures shall comply to *BS EN ISO 15607*, *BS EN ISO 15609-1, BS EN ISO 15613* and *BS EN ISO 15614-1*. The type and size of weld shall be as detailed on the Drawings. The Contractor shall make available full details of the welding procedure and

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electrodes with drawings and schedule as requested by S.O..

(ii) Weld tests shall be performed by radiographic or ultrasonic methods as specified. Provided that satisfactory results are being obtained, one (1) test of a length of 300mm shall be made for 10% or more of the number of welded splices.

5.5.3.3. Cutting and Preparation of Pile Heads

(i) When a pile has been driven to the required set or depth and before encasing in concrete, the piles shall be cut to within 20mm tolerance of the levels shown on the Drawings. Pile heads shall be constructed to the details as shown on the Drawings.

(ii) The remaining section which can be reused for lengthening of piles shall be stored and protected as directed by the S.O..

5.6. Steel Pipe Piles

5.6.1. Materials

All steel pipes shall comply with *BS EN 10296*, *BS EN 10297* and *BS EN 10305* with regard to sectional dimensions and the steel shall comply with the requirements of *BS EN 10113* or *BS EN 10025*. Mill certificates shall be provided to the S.O. prior to pile installation.

5.6.2. Manufacture and Storage of Steel Pipe Piles

5.6.2.1. Fabrication of Piles

(i) Pile lengths shall be set up so that the differences in dimensions are matched as evenly as possible. The length of piles to be supplied shall be as shown on the Drawings and subject to revision by the S.O..

(ii) Based on the results of pile driving resistance and/or load tests carried out on piles driven on the Site, the S.O. may, from time to time, order the lengths of piles to be modified.

(iii) For tubular piles where the load will be carried by the wall of the pile, and if the pile will be subjected to loads that induce reversal of stress during or after construction, the external diameter at any section as measured by using a steel tape on the circumference shall not differ from the theoretical diameter by more than ± 1%.

(iv) The ends of all tubular piles as manufactured shall be within a tolerance on ovality of ± 1% as measured by a ring gauge for a distance of 100mm at each end of the pile length.

(v) The root edges or root faces of lengths of piles that are to be shop butt-welded shall not differ by more than 25% of the thickness of pile walls not exceeding 12mm thick or by more than 3mm for piles where the wall is thicker than 12mm. When piles of unequal wall thickness are to be butt-welded, the thickness of the thinner material shall be the criterion.

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5.6.2.2. Matching of Pile Lengths

Longitudinal seam welds and spiral seam welds of lengths of pipe piles forming a completed pile shall, whenever possible, be evenly staggered. However, if in order to obtain a satisfactory match of the ends of piles or the specified straightness, where the longitudinal seams or spiral seams are brought closely to one (1) alignment at the joint, then they shall be staggered by at least 100mm.

5.6.2.3. Straightness of Piles

The deviation of pile from straightness shall be within the compliance provisions of *BS EN 10034* and in accordance with sub-section 5.5.2.2..

5.6.2.4. Fabrication of Piles on Site

When pile lengths are to be made up on Site, all test procedures and dimensional tolerances shall conform to the Specification for the supply of pipe materials. Adequate facilities shall be provided for supporting and aligning the lengths of pile.

5.6.2.5. Handling and Storage

All piles within a stack shall be in groups of the same length and on approved supports. All operations such as handling, transporting and pitching of piles shall be carried out in a manner such that no damage occurs to piles and their coatings. Piles that are damaged during handling and transporting shall be replaced by the Contractor at his own expense. All damaged and rejected piles shall be removed from the Site forthwith.

5.6.2.6. Marking of Piles

Each pile shall be clearly marked with white undeletable marking near the pile head showing its reference number and overall length. In addition, for pile installation monitoring purposes, each pile shall be marked at intervals of 300mm along its length before being driven.

5.6.3. Workmanship

5.6.3.1. Welding Procedures

(i) The Contractor shall submit for approval, full details of the welding procedures and electrodes with Drawings and schedules as may be necessary. Tests shall be undertaken as may be required by the S.O. and shall be in accordance with the requirements of *BS EN 288*

(ii) All welding procedures shall have been qualified to *BS EN ISO 15607, BS EN ISO 15609-1, BS EN ISO 15613* and *BS EN ISO 15614-1* and the Contractor shall make available full details of the welding procedures and electrodes, with Drawings and schedules as may be necessary. Tests shall be undertaken as may be required by the S.O..

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5.6.3.2. Weld Tests

(i) During production of welded tube piles, at least one (1) radiograph or ultrasonic test approximately 300mm long shall be required on each end of a length as a spot check on weld quality. This shall be taken on a circumferential or longitudinal weld and its position shall be as directed by the S.O..

(ii) For spirally welded piles, one (1) of the following tests shall be carried out:

a) For tubes of wall thickness 12mm or less, three (3) spot check radiographs, one (1) at each end of each length of the tube as manufactured and one (1) at a position to be chosen at the time of testing by the S.O. and spot check radiographs as required by the S.O. on the weld joints between strip lengths;

b) For tubes of any wall thickness, continuous ultra-sonic examination over the whole weld, supplemented where necessary by radiographs to investigate defects revealed by the ultrasonic examination.

Weld tests shall be performed by radiographic or ultrasonic methods as specified. Provided that satisfactory results are being obtained, one (1) test of a length of 300mm shall be made for 10% or more of the number of welded splices in the case where the load will be carried by the wall or section of the pile will not normally exceed 10%. Results shall be made available to the S.O. within ten (10) days of completion of the tests.

5.6.3.3. Standards for Welds

(i) Longitudinal Welds in Tubular Piles

For piles of longitudinal or spiral weld manufactured where the load will be carried by the wall of the pile, and if the pile will be subject to loads which induce reversal of stress during or after construction other than driving stresses, the standard for interpretation of non-destructive testing shall be the American Petroleum Institute Specification 5L. The maximum permissible height of weld reinforcement shall not exceed 3.2mm for wall thicknesses not exceeding 12.7mm and 4.8mm for wall thicknesses greater than 12.7mm.

(ii) Circumferential Welds

a) For circumferential welds in tubular piles the same maximum height of weld reinforcement as specified above for longitudinal welds in tubular piles shall apply, the standard for interpretation of non-destructive testing shall be the American Petroleum Institute Specification 5L.

b) If the results of any weld test do not conform to the specified requirements, two (2) additional specimens

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from the same length of pile shall be tested. In the case of failure of one (1) or both of these additional tests, the length of pile covered by the test shall be rejected.

5.6.4. Protective Coatings

The term 'coating' shall include the primer and the coats specified. If protective coatings are specified, the preparation of surfaces and the application of the coatings shall be carried out by skilled labour having experience in the preparation of the coatings specified.

Corrosion protection of permanent steel structure in accordance with environment classified as C4 according to *BS EN ISO 12944-2* shall require durability resistance of 25 years.

The protective coating system shall comply with *BS EN ISO 12944-5* and shall comprise of at least:

5.6.4.1. First Coating or Prime Coat Zinc Epoxy 0.08mm thick

5.6.4.2. Two (2) layers of Intermediate coating 0.08mm thick epoxy for each layer

5.6.4.3. Top coating of Polyurethane 0.08mm thick

5.6.4.4. Surface Preparation

(i) All surfaces to be coated shall be clean and dry

(ii) Surface preparation to cleanliness SA 2 ½ in accordance with *BS EN ISO 12944-4* and *BS EN ISO 8501-1*.

(iii) Blast-cleaning shall be done after fabrication. Unless an instantaneous-recovery blasting machine is used, the cleaned steel surface shall be air-blasted with clean dry air and vacuum-cleaned or otherwise freed from abrasive residues and dust immediately after cleaning.

5.6.4.5. Application and Type of Primer

(i) Immediately after surface preparation, the surface shall be coated with an approved primer or the specified coating to avoid recontamination. No primer coat shall be applied to a metal surface which is not thoroughly dry. Within 4 hours after surface preparation, before visible deterioration takes place, the surface shall be coated with an appropriate primer or the specified coating.

(ii) The primer shall be compatible with the specified coating and shall be such that if subsequent welding or cutting is to be carried out it shall not emit noxious fumes or be detrimental to the welding.

5.6.4.6. Control of Humidity during Coating

(i) No coating shall be applied when the surface metal temperature is less than 3°C above the dew point temperature or when the humidity could have an adverse effect on the coat.

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(ii) When heating or ventilation is used to secure suitable conditions to allow coating to proceed, care shall be taken to ensure the heating or ventilation of a local surface does not have an adverse effect on adjacent surfaces or work already done.

5.6.4.7. Part to Be Welded

The coating within 200mm of a weld shall be applied after welding. The method of application shall comply with the manufacturer's recommendations.

5.6.4.8. Thickness, Number and Colour of Coats

(i) The minimum dry film thickness of the finished coating, including the minimum dry film thickness of each coat and the minimum number of coats that are to be applied, shall be as specified and shown on the Drawings. Coatings shall be applied in accordance with the manufacturer's instructions.

(ii) The nominal thickness of the finished coating and each coat shall be as specified. The average coat or finished coating thickness shall be equal to or greater than the specified nominal thickness. In no case shall any coat or finished coating be less than 75% of the nominal thickness. Each coat shall be applied only after an interval that ensures the proper hardening or curing of the previous coat.

(iii) Where more than one (1) coat is applied to a surface, each coat shall be different colour from the previous coat. The colour sequence and final coating colour shall be established prior to application of coatings.

5.6.4.9. Inspection of Coatings and Acceptability

(i) The finished coating shall be generally smooth, of a dense and uniform texture and free from sharp protuberances or pin holes.

(ii) Any coat damaged by subsequent processes or which has deteriorated to an extent such that proper adhesion of the coating may not be obtained or maintained, shall be recleaned to the original standard and recoated with the specified sequence of coats.

(iii) The completed coating shall be checked for thickness and continuity by an approved magnetic gauge or detector. Areas where the thickness is less than that specified shall receive approved additional treatment.

(iv) When specified, the completed coating shall be checked for adhesion by means of an adhesion test to *BS EN ISO 2409, BS 3900-E6*, carried out on 10% of the piles. The adhesion of any completed coating shall not be worse than Classification 2. If adhesion tests on the initial batch are satisfactory, then on further batches only 1% of the piles shall be tested. Adhesion tests shall not be carried out until seven (7) days after coating.

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5.6.5. Installation of Steel Pipe Piles

5.6.5.1. Pitching and Driving of Piles

Pitching and driving of piles shall be in accordance with sub-sections 5.3.4.1. and 5.3.4.2..

5.6.5.2. Lengthening of Piles

Unless otherwise approved, where lengthening of piles is required, the piles shall be joined by butt welding along the entire periphery as detailed on the Drawings. All procedures shall be in accordance with sub-sections 5.5.3.2..

5.6.5.3. Cutting and Preparation of Pile Heads

When a pile has been driven to the required set or depth and before encasing in concrete, the pile shall be cut to within 20mm of the levels shown on the Drawings and protective coatings shall be removed from the surfaces of the pile head 100mm above the soffit of the concrete. Pile heads shall be constructed to details as shown on the Drawings. If a steel structure is to be welded to piles, the piles shall be cut square and to within +/- 5mm.

5.6.5.4. Concreting of Pile Shaft

(i) If concreting is specified or shown on the Drawings after the pile has been cut off to the specified level, the shaft shall be filled with concrete in a continuous operation. The method of placing shall be approved by the S.O..

(ii) The reinforcement cage in the pile shall be made sufficiently rigid and kept in its correct position during concreting.

(iii) The length of the reinforcing bars projecting above the pile cut-off level shall be as shown on the Drawings.

(iv) Mixing and placing concrete infill shall be done in accordance to sub-section 5.7.4..

5.7. Bored Cast-In-Situ Piles

5.7.1. Materials

5.7.1.1. Concrete

The materials and workmanship for concrete shall be as specified under SECTION D: CONCRETING of this Specification. The grade of the concrete shall be as shown on the Drawings.

5.7.1.2. Reinforcement

The steel reinforcement shall be as specified under SECTION D: CONCRETING of this Specification. The details of the steel reinforcement shall be as shown on the Drawings.

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5.7.2. Boring Operations

5.7.2.1. Diameter of Piles

(i) The diameter of piles shall not be less than the specified designed diameter at any level throughout its length.

(ii) The auger width shall be checked as necessary and recorded for each pile to ensure the specified diameter is achieved. A tolerance of 0% to +5% on the auger width is permissible.

5.7.2.2. Boring

(i) Boring shall be carried down to the depth as required and directed by the S.O.. When deemed necessary by the S.O., the Contractor shall take soil samples while the pile is being bored. The samples shall be taken to an approved Laboratory for testing, if necessary or as directed by the S.O..

(ii) Sampling and all subsequent handling and testing shall be carried out in accordance with *BS EN ISO 1997, BS EN ISO 14688, BS EN ISO 14689, BS EN ISO 22475* and *BS EN ISO 22476.*

(iii) Piles shall not be bored at a distance less than three (3) times diameter close to other piles which have been cast less than 24 hours or contain unset concrete.

5.7.2.3. Coring in Rock

(i) The Contactor shall submit a method statement when coring in rock. Chiselling of rock may cause micro cracks in surrounding rock and is not allowed. Rock coring shall mean coring of sound bedrock using a coring bucket or any other approved method. Confirmatory test to verify sound rock shall be carried out by the Contractor.

(ii) Definition of coring in rock shall fulfil all two (2) criteria below:

a) Change of tools to rock coring tools, and

b) The rock materials shall be verified by carrying out point load test on at least five (5) rock samples to achieve minimum corrected point load strength index Is(50) of 2.0 MPa on samples not less than 30mm and not more than 85mm with the preferred dimension about 50mm based on *ASTM D5731*. The Minimum five (5) samples shall be taken for every 1m depth of rock coring.

c) Any coring/boring in other materials that do not fulfil the definition of rock coring mentioned above shall be considered as boring in soils.

d) The provision of point load test equipment at site for the above-mentioned testing shall be by Contractor's own cost and time. The point load test equipment shall be

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calibrated, and a valid calibration certificate shall be made available to the S.O. upon requested.

5.7.2.4. Socketing in rock to fulfil design criteria

The socketed length shall be as specified in the Drawing or as directed by the S.O.. The starting of the socketing length may not be the same as the coring depth of rock. Rock socket length shall be measured from the flattened horizontal bedrock surface. This flat horizontal surface shall be proved using Kelly bar or steel bar at a minimum of five positions over the borehole.

5.7.2.5. Permanent Casing

Permanent casings which form part of the designed pile shall be as specified on the Drawings.

5.7.2.6. Temporary Casing

(i) Temporary casings of approved quality or an approved alternative method shall be used to maintain the stability of pile excavations which might otherwise collapse.

(ii) Temporary casings shall be free from significant distortion. They shall be of uniform cross-section throughout each continuous length. During concreting they shall be free from internal projections and encrusted concrete which might prevent the proper formation of the piles being cast.

(iii) If a temporary casing is required to stabilise the borehole, it shall be extended beyond the unstable strata for one (1) metre or more to prevent the inflow of soil and the formation of cavities in the surrounding ground.

5.7.2.7. Stability of Piling Excavations Using Support Fluid

(i) Where the use of support fluid or a column of water is approved for maintaining the stability of boring, the level of fluid or column of water in the excavation shall be maintained such that the fluid pressure always exceeds the pressure exerted by the soil and external ground water. The fluid water level shall be maintained at a level not less than 1m above the level of the external ground water.

(ii) An adequate temporary casing shall be used in conjunction with the method to ensure the stability of the strata near ground level until concrete has been placed.

(iii) In the event of a rapid loss of bentonite suspension, polymeric fluids or water from the piling excavation, the excavation shall be backfilled with lean concrete or well compacted sand as specified in SECTION D:CONCRETING of this Specification without delay and the instructions of the S.O. shall be obtained prior to resuming boring at that location.

5.7.2.8. Support Fluid

(i) Support fluid material, bentonite, shall comply with the

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manufacturer's certificate and mix proportion. A certificate shall be obtained by the Contractor from the manufacturer of the bentonite powder, showing the properties of each consignment delivered to the site. This certificate shall be made available to the S.O.. Test should be carried out at regular interval to ensure consistency of the batching process.

(ii) Polymer can be used as an alternative to bentonite to maintain stability of the bores with the approval of the S.O..

(iii) Bentonite or polymer shall be mixed thoroughly with water complying with MS 28 to make a suspension which will maintain the stability of the pile excavation for the period necessary to place concrete and complete construction. Preparation of the suspension shall comply with the manufacturer's instructions.

(iv) Where saline or chemically contaminated ground water occurs, special precautions shall be taken to modify the bentonite suspension or pre-hydrate the bentonite in fresh water to render it suitable in all aspects for the construction of piles.

(v) Minimum frequency of testing are as follows:

a) Fresh drilling fluid

b) Drilling fluid shall be tested before concreting

c) Recycle drilling fluid taken from desanding machine

d) Drilling fluid left in the bored hole for more than 12 hours

(vi) The frequency of testing drilling fluid and the method and procedure of sampling shall be proposed by the Contractor and agreed by the S.O. before the commencement of the work. The frequency may subsequently be varied with the approval of the S.O.. Control tests for density shall be carried out daily on the drilling fluid using suitable apparatus. The measuring device shall be calibrated to read within 0.01g/ml. The results shall be within the ranges stated in **Table C6** for bentonite and **Table C7** for polymer drilling fluids.

(vii) All reasonable steps shall be taken to prevent the spillage of drilling fluid on the site. Discarded drilling fluid shall be removed from the site without delay and such removal shall comply with the regulations of the relevant Authorities.

(viii) If sand content is more than 5%, the Contractor shall carry out desanding to screen out sand from drilling fluid before concreting.

5.7.2.9. Spillage and Disposal

(i) All reasonable steps shall be taken to prevent the spillage of bentonite suspension or water on the site in areas outside the immediate vicinity of the boring operations. Discarded

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bentonite water shall be removed from the site without delay. The disposal of bentonite water shall comply with the regulations of the Local Authorities and other related Government Agencies.

(ii) Entrained solids shall be removed from the polymeric fluid by use of flocculants before disposal of the remaining fluid to the approved designated disposal sites by the Authorities.

5.7.2.10. Pumping of Boreholes

Pumping from the borehole shall not be permitted unless casings have been placed into the stable stratum to prevent the further ingress of water in significant quantities from other strata into the borehole, or, unless it can be shown that pumping will not have a detrimental effect on the surrounding soil or its properties.

5.7.2.11. Continuity of Construction

(i) A pile constructed in the stable soil, without the use of temporary casings or other support, shall be bored and concreted without delay to ensure that the soil characteristics are not significantly altered. The time interval between completion of boring and placing of concrete should preferably be within six (6) hours. Where prolonged delay in construction arises, the bore may have to be backfilled with lean concrete as specified in SECTION D: CONCRETING of this Specification or well compacted sand to minimise deterioration of the shaft.

(ii) If the bored pile installation is carried out using permanent or temporary casing, the time period between completion of boring operation and completion of concreting is recommended not to exceed twenty-four (24) hours.

5.7.2.12. Enlarged Pile Bases

The enlarged pile base shall not be smaller than the dimensions specified and shall be concentric with the pile shaft to within 10% of the shaft diameter. A sloping surface of the frustum forming the enlargement shall make an angle to the horizontal of not less than 55º. At the specified diameter of the under ream at the perimeter of the base there shall be a minimum height of 150mm.

5.7.2.13. Cleanliness of Pile Bases

On completion of boring, loose, disturbed or remoulded soil or fragments of rock shall be removed from the base of the pile.

5.7.2.14. Inspection

For dry boreholes, each hole shall be inspected prior to the placing of concrete in it. The inspection shall be carried out from the ground surface in the case where the borehole diameter is less than 1500mm. Where the borehole diameter exceeds 1500mm, adequate equipment shall be provided to enable the Contractor and the S.O. to descend into the borehole for the purpose of inspection. All works shall conform to the requirement of *BS 5573:1978* Safety Precaution in the Construction of Large

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Diameter Borehole for Piling and Other Purposes. For wet boreholes, i.e. holes filled with drilling fluid or water, a suitable probe shall be provided to ascertain the evenness and cleanliness of the pile base.

5.7.3. Placing of Reinforcement

5.7.3.1. Joints in Longitudinal Bars

Reinforcement shall be such that the full strength of the bar is effective across the joint and the joint shall be made so that there is no relative displacement of the reinforcement during the construction of the pile and the spacing of the reinforcing bars shall be maintained in such a way that proper concreting shall not be impeded.

5.7.3.2. Positions of Reinforcement

Adequate spacer blocks, guide tubes, and lifting wires shall be provided so as to maintain the reinforcing steel in the positions as specified.

Where temporary casings are employed, the longitudinal reinforcement shall extend at least 1m below the bottom of the casing so that movement of the reinforcement during extraction of the casing is minimised.

5.7.4. Concreting Operations

5.7.4.1. Placing Concrete

The method of placing and the workability of concrete shall be such that a continuous monolithic concrete shaft of the full cross-section is formed.

5.7.4.2. Workability of Concrete

The workability of the concrete shall be determined by the slump test as described in MS EN 206.

The suggested slump details for typical concreting situations shall be as specified in **Table C3** of this Specification. The slump shall be measured at the time of discharge into the borehole.

5.7.4.3. Compaction

Internal vibrators shall not be used to compact concrete unless it can be satisfied that they will not cause segregation or arching of the concrete.

5.7.4.4. Placing Concrete in Dry Borings

(i) Approved measures shall be taken to avoid segregation and bleeding and to ensure that the concrete at the bottom of the pile is not deficient in grout.

(ii) Where piles are vertical, concrete may be poured through a tremie so that the flow is directed and does not hit reinforcement bars or the side of the hole. Chutes extending

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to near the base shall be employed for raking piles of large diameter.

5.7.4.5. Placing Concrete under Water or Support Fluid

(i) Concrete to be placed under water or support fluid shall be placed by tremie unless otherwise approved and shall not be discharged freely into the water or support fluid. Before placing concrete, measures shall be taken to ensure that there is no accumulation of silt or other material at the base of the boring.

(ii) The hopper and pipe of the tremie shall be clean and watertight throughout. The pipe shall extend to the base of the boring and a sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the pipe of the tremie and the water or support fluid. The tremie pipe outlet shall be kept at least 1.5 metres below the surface of the concrete at all stages in the pour. The Contractor shall develop a system of level checks for the concrete and pipe outlet to ensure that this requirement is met. The tremie pipe shall be withdrawn upward gently below the concrete level and shall not be subject to any shock or violent movement either in dislodging the concrete within the pipe or for any other reason.

(iii) At all times, a sufficient quantity of concrete shall be maintained within the tremie pipe to ensure that the pressure from it exceeds that from the water or support fluid. The internal diameter of the tremie pipe shall not be less than 150mm for concrete made with 20mm aggregate and not less than 200mm for concrete made with 40mm aggregate.

(iv) The tremie pipe shall be so designed that external projections are minimised, allowing the tremie pipe to pass through the reinforcing cage without causing damage or uplifting. The internal face of the tremie pipe shall be free from projections.

5.7.5. Extraction of Casing

5.7.5.1. Workability of Concrete

Temporary casings shall be extracted while the concrete within them remains sufficiently workable to ensure that the concrete is not lifted together with the casing.

5.7.5.2. Concrete Level

(i) When the casing is being extracted, a sufficient quantity of concrete shall be maintained within it to ensure that the pressure from external water, drilling fluid or soil is exceeded and that the pile is neither reduced in section nor contaminated.

(ii) No concrete shall be placed in the bore once the bottom of the casing has been lifted above the top of the concrete. It shall be placed continuously as the casing is extracted until the desired head of concrete is obtained.

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(iii) The top of concrete level shall be brought to at least 1000mm or more as specified on the Drawings above the cut-off level of the pile or the concrete be allowed to be flushed out from the bore to permit all laitance and weak concrete to be removed and thus ensure that it can be properly keyed into the pile cap.

(iv) Adequate precautions shall be taken in all cases where excess heads of water or drilling fluid could be a cause for concern as the casing is withdrawn because of the displacement of water or fluid by the concrete as it flows into its final position against the wall of the pile shaft. Where double casings are used in the boring, the proposed method of working shall be with the approval of the S.O..

5.7.5.3. Vibrating Extractors

The use of vibrating extractors shall be permitted subject to S.O.'s approval. The work shall be carried out in such a manner and times to ensure the quality of concrete in the bore, minimise nuisance and disturbance to the surrounding.

5.7.6. Construction of Pile Heads

5.7.6.1. Water Levels

In the event of the ground water level being higher than the required pile head casting level shown on the Drawings, the Contractor shall submit his proposals for approval prior to placing concrete. The pile head shall not be left below the ground water level unless approved precautions are taken.

5.7.6.2. Cutting and Preparation of Pile Heads

Pile head shall be cut using handheld cutting equipment or hydraulic splitters. Pile heads after cutting shall consist of sound concrete and free from debris. Pile heads shall be constructed to the details shown on the Drawings.

5.7.6.3. Temporary Backfilling Above Pile Casting Level

After each pile has been cast, any empty bore remaining shall be protected and shall be carefully backfilled as soon as possible with well compacted sand.

5.7.6.4. Piling Records

(i) Complete piling records shall be kept by the Contractor during pile installation. The Contractor shall submit in duplicate the following information to the S.O.:

a) Signed records of all piles as the work proceeds. Individual pile record shall be submitted not later than noon of the next working day after the pile was installed. The signed records shall form record of the work. Any unexpected installation condition shall be noted in the record.

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b) Upon completion, compile a record of the work as carried out and provide As-built Drawings. The Drawings shall be prepared and endorsed by the Licensed Surveyor.

(ii) The format of the record shall be approved by the S.O. and shall contain, but not be limited to the following information where applicable:

a) Date and time of boring, speed of boring for every meter

b) Type of boring machine

c) Date and time of concreting

d) Depth of borehole, detail of soil/rock strata penetrated, soil/rock samples taken, and in-situ tests carried out

e) Concrete mix

f) Type of stabilizing fluids

g) Method of concreting

h) Standing ground water level

i) Length of temporary/permanent casing

j) Length and details of reinforcement.

k) Estimated and actual volume of concrete required to form the pile shaft.

(iii) All record shall bear the names of person who records and person who checks.

5.7.7. Pressure Grouting of Piles

5.7.7.1. Grouting of piles shall be done if encounter any unstable shaft or base disturbance to ensure compatible performance of piles. Method of grouting shall be carefully controlled to prevent pile uplift and avoid other potential problems with prior approval of the S.O..

5.7.7.2. Pressure grouting shall not be used to compensate for poor pile construction practice.

5.8. Micropiles

5.8.1. Materials

5.8.1.1. Reinforcement

The type of reinforcement to be used, the diameter and/or thickness, grade, yield strength and working stress shall be as specified or as shown on the Drawings.

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5.8.1.2. Grout

(i) Unless otherwise specified, the grout shall be non-shrink cement grout. The grout mix design such as the water-cement ratio, the minimum cement and grout strength at 7 and 28 days shall be as specified and shown on the Drawings.

(ii) If admixtures are used, details of admixtures shall be submitted to the S.O. for approval before commencement of works. The use of the admixture shall fully comply with the manufacturer's instructions.

5.8.2. Drilling Operation

5.8.2.1. Diameter of Piles

The diameter of piles shall not be less than the specified/designed diameter at any level throughout its length and shall be in accordance with sub-section 5.7.2.1..

5.8.2.2. Drilling

The Contractor shall submit to the S.O. details of drilling equipment and drilling procedure for approval before commencement of works. Drilling operations shall be carried out in accordance with the relevant requirements of sub-section 5.7.2..

5.8.3. Grouting Operations

5.8.3.1. Mixing and Placing Grout

(i) The Contractor shall provide details of the method and equipment used in grout mixing. Further information such as grouting pressure, grouting procedure, grouting equipment and techniques employed in grouting underwater shall also be furnished for approval.

(ii) Grout shall be mixed on Site and shall be free from segregation, slumping and bleeding. Grout shall be pumped into its final position in one (1) continuous operation as soon as possible and in no case more than half an hour after mixing.

(iii) Micropile shall be grouted in one continuous process. If there is significant loss of grout, the Contractor may choose to carry out pre-grouting in stages as necessary to prevent further loss of grout for the construction of micropile. Method statement of pre-grouting including details of equipment, materials and procedures have to be reviewed and approved by the S.O.. If after the process of pre-grouting and re-drilling of the hole is required, the Contractor has to bear the cost and the time of the pre-grouting and re-drilling.

5.8.3.2. Testing Grout

(i) Grout shall be tested in accordance with *BS EN 445* and *ASTM C939*.

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(ii) If the grout cube as tested fails to satisfy the criteria as prescribed in the Specification and Drawings, the pile constructed using this batch of grout shall be rejected. The Contractor shall undertake all necessary additional and consequential remedial works to the approval of the S.O..

5.8.4. Construction of Pile Heads

5.8.4.1. Lengthening of Piles

Where lengthening is required, the pile reinforcement unit shall be connected on Site to the details as shown on the Drawings. Other means of jointing reinforcement shall be to the approval of the S.O..

5.8.4.2. Cutting and Preparation of Pile Heads

Pile heads shall be constructed to the details as shown on the Drawings.

5.8.5. Casing

Where permanent casing or temporary casing is specified or required upon approval of S.O., the requirements shall be in accordance with sub-section 5.7.5..

5.9. Caisson

5.9.1. Materials

5.9.1.1. Concrete

The material and workmanship for concrete shall be as specified under SECTION D: CONCRETING of this Specification. The grade of the concrete shall be as shown on the Drawings.

5.9.1.2. Reinforcement

The steel reinforcement shall be as specified under SECTION D: CONCRETING of this Specification. The details of steel reinforcement shall be as shown in the Drawings.

5.9.1.3. Permanent Liner

Lining shall be constructed sufficiently quickly after excavation and in sufficiently short section to prevent inflow of soil or excessive inflow of water. In-situ concrete tapered rings used as permanent liners shall be at least 100mm thick and shall not exceed 1m deep. The ring shall be constructed with well compacted concrete. The concrete shall be cast tight up against the side of excavation. The material and workmanship for concrete shall be as specified under SECTION D: CONCRETING of this Specification. The grade of the concrete shall be as shown on the Drawings.

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5.9.2. Excavation operations

5.9.2.1. Diameter of piles

The effective diameters of the caisson shaft and bell out shall not be less than those shown on the Drawings nor exceed the specified dimension by more than 50mm at any level of the whole shaft.

5.9.2.2. Depth of excavation

The anticipated depth of all caissons is as indicated in the Drawings. All caissons shall be taken to a depth pre-determined by the Drawings into the required bearing stratum over the full area of the caisson base. The caisson base shall be levelled. Where bell-outs are required they shall be formed entirely within the bearing stratum

5.9.2.3. Method statement

The Contractor shall adopt a method of construction that will not cause settlement or disturbance of any kind to adjacent structures, pavement, public or private services. The Contractor shall establish an approved monitoring system and take regular readings and prepare and submit reports to the S.O. in the format and quantity as requested. The Contractor shall modify the method of construction if the effects of ground movement are detected in any such structures, pavements and services.

5.9.2.4. Minimum clear working space

The minimum clear working space inside a caisson (i.e. excluding the lining) shall not less than 1.8m. Caissons with enlarge base shall not be used unless otherwise specified.

5.9.2.5. Method of excavation

Excavation for caissons shall be carried out using manual methods or power tools. Blasting shall not be used unless agreed by the S.O.. If blasting is adopted, the following have to be adhered to;

(i) Obtain approval from relevant Authorities and comply with the requirement of statutory Authorities,

(ii) The position of blast holes and the size of charges shall be such that shattering of rock beyond the caisson is minimized,

(iii) The rock face shall not be shattered within the toe-in or bell-out zone at the bottom of the caissons, and

(iv) The caisson opening shall be covered to prevent the projection of fragments of material.

5.9.2.6. Rock Proving

(i) Rock proving load test machine shall be provided at site for testing of recovered rock sample for shaft and base selected by S.O..

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(ii) In addition, the rock below each shall be proved before concreting by sinking minimum 'N' size drill holes, as specified in MS1056, to a minimum of 5m below the proposed caisson base or 3 times the bell out diameter of the caisson whichever is the greater.

(iii) Socket length shall be measured from the flattened horizontal bedrock surface.

5.9.2.7. Inspection and record of caisson shaft and base

(i) Each caisson base shall be inspected, logged and photographed by qualified Engineer from the Contractor before inspection and checking by the S.O.. CV of the Engineer from the Contractor shall be submitted for review and approved by the S.O..

(ii) The shaft of every caisson shall be properly logged, especially one encountering rock surface during excavation.

(iii) Prior to any concreting works, the shaft and base (for rock only) for the caisson shall be properly cleaned by using water jet or other approved method so that no debris or soil stains the shaft surface or base. The base of each completed excavation shall be carefully trimmed and levelled to the minimum required toe level. Approval of the base of any caisson by the S.O. shall not relieve the Contractor of his responsibilities and obligations under the terms of the Contract.

(iv) Photographs at 4 sides of the shaft, i.e. $0^{o,}$ 90°, 180° and 360° and rock base shall be taken by the Contractor after the cleaning works and attached together with the inspection forms for the S.O..

(v) The shaft and base of each caisson must be approved by S.O. before any reinforcement and concreting works are carried out.

5.9.2.8. Stability of the excavation

(i) The shaft and base of each caisson must be approved by S.O. before any reinforcement and concreting works are carried out.

(ii) The stability of excavations for caissons shall be maintained where necessary by linings.

(iii) Shaft lining shall be placed as soon as practicable and not more than 24hours after each increment of excavation is complete.

(iv) Voids between the lining and face of excavation shall be filled with concrete of the same grade as the lining or with others material as agreed by the S.O..

(v) Any unstable layers of subsoil encountered shall be stabilized by grouting or similar methods. No further excavation will be permitted to proceed until the stabilization

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works are completed.

5.9.2.9. Dewatering

(i) The shaft and base of each caisson must be approved by S.O. before any reinforcement and concreting works are carried out.

(ii) A comprehensive Method Statement on dewatering for caisson construction shall be submitted by the Contractor for approval.

(iii) As a minimum measure, individual caissons shall be kept dry during excavation and inspection by pumping from a sump or pilot hole within each caisson as necessary. Submersible pumps shall be used and placed in a sump not more than 0.6m deep and approximately 0.5m diameter sunk in advance of the main excavation. Pump operation shall be continuous until the caisson is concreted.

(iv) The Contractor shall at all times use, to a minimum degree, of dewatering that is required for the works to proceed. It will be the Contractor's responsibility to ensure that draw down outside the site does not exceed the limits as specified by the S.O.. The Contractor's method statement shall include details of measures proposed to meet this requirement. All such measures shall be subject to approval by the S.O..

5.9.2.10. Water pumped from caissons

(i) The Contractor shall at all times use, to a minimum degree, of dewatering that is required for the works to proceed. It will be the Contractor's responsibility to ensure that draw down outside the site does not exceed the limits as specified by the S.O.. The Contractor's method statement shall include details of measures proposed to meet this requirement. All such measures shall be subject to approval by the S.O..

(ii) Water sample pumped from caissons shall be screened through sedimentation or settling tank and quantities of sediment shall be monitored to ensure that excessive fines are not removed from the soil. Should excessive fines be observed from any caisson, pumping from that caisson shall cease and the S.O. notified immediately.

(iii) When required by the S.O., the Contractor shall record the rate of pumping from the individual caissons and shall submit two copies of the records on the following day. The Contractor shall report immediately to the S.O. any marked change in the rate of flow of water from any caisson.

(iv) Water pumped from caissons or the ground shall not be discharged directly onto the ground surface without suitable and adequate provisions for drainage being made.

(v) The Contractor shall be responsible for obtaining all necessary permissions from statutory authorities for discharging water into the public drainage system.

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5.9.2.11. Cessation of excavation

(i) If the excavation and pumping from caissons results in settlement outside the site of more than 25mm, or as otherwise specified by the S.O., caisson construction and dewatering at the appropriate locations shall immediately cease and the S.O. notified.

(ii) The Contractor shall not recommence caisson construction or dewatering until the construction sequence has been reviewed and measures taken to prevent further settlement occurring. In all cases, work shall not be recommended to proceed without the approval of the S.O..

(iii) The Contractor shall be responsible for any damage, and any claims arising from such damage, which may result from settlement caused by caisson construction. The Contractor shall make good the damage as quickly as possible.

5.9.2.12. Emergencies

(i) The Contractor shall submit Emergency Response Plan (ERP) for review and approval by the S.O..

(ii) If the sides of a caisson start to collapse or an emergency arises which could lead to instability of the excavation, the Contractor shall immediately inform the S.O. and implement measures to preserve the stability of the caisson and of neighbouring structures and services.

5.9.2.13. Disposal of spoil

Soil removed from the excavation shall be removed from the site and disposed off in accordance with statutory requirements.

5.9.2.14. Sealing and Scaling of caissons

(i) The Contractor shall submit Emergency Response Plan (ERP) for review and approval by the S.O..

(ii) Leakage of groundwater through liners or into unlined shafts of hand-dug caissons shall be stopped by a method agreed upon by the S.O..

(iii) Loose rock on the face of unlined shaft shall be scaled off and removed before concreting.

(iv) On completion of excavation, spoils shall be removed from the base of caisson before concreting.

5.9.2.15. Inspection of excavations

(i) Each hole shall be inspected prior to the placing of concrete in it. Adequate equipment shall be provided to enable the Contractor and the S.O. to descend into the hole for the purpose of inspection. All works shall conform to the requirement of *BS 5573*: Safety Precaution in the Construction of Large Diameter Boreholes for Piling and Other Purposes.

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(ii) Prior to any concreting works, the shaft and base (for rock only) for the caisson shall be properly cleaned by using water jet or other approved methods so that no debris or soil stains the shaft surface or base. The base of each completed excavation shall be carefully trimmed and levelled to the minimum required toe level and approved by the S.O..

5.9.3. Placing of reinforcement

5.9.3.1. Joints in longitudinal bars

Reinforcement shall be such that the full strength of the bar is effective across the joint and the joint shall be made so that there is no relative displacement of reinforcement during construction of the pile and the spacing of the reinforcing bars shall be maintained in such a way that proper concreting shall not be impeded.

5.9.3.2. Positions of reinforcement

Adequate spacer blocks, guides tubes and lifting wires shall be provided so as to maintain the reinforcing steel in the position as specified.

5.9.4. Concreting operations

5.9.4.1. Placing concrete

(i) All subsoil and debris shall be removed from the caisson to the satisfaction of S.O.. No concrete shall be placed without approval of the S.O..

(ii) The method of placing and the workability of concrete shall be such that a continuous monolithic concrete shaft of the full section is formed.

5.9.4.2. Workability of concrete

(i) The workability of the concrete shall be determined by the slump test as described in *MS EN 206*.

(ii) The suggested slump details for typical concreting situations shall be as specified in **Table C3** of this Specification. The slump shall be measured at the time of discharge into the borehole.

5.9.4.3. Compaction

Internal vibrators shall not be used to compact concrete unless it can be proven that they will not cause segregation or arching of the concrete.

5.9.4.4. Placing concrete in dry borings

(i) Approved measures shall be taken to avoid segregation and bleeding and to ensure that the concrete at the bottom of the pile is not deficient in grout.
(ii) Concrete may be poured through a funnel with a length of tube so that the flow is directed and does not hit

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reinforcement bars or the side of the hole.

5.9.5. Construction of pile heads

5.9.5.1. Water levels

Water levels shall be in accordance with sub-sections 5.7.6.1..

5.9.5.2. Cutting and preparation of pile heads

Cutting and preparation of pile heads shall be in accordance with sub-sections 5.7.6.2..

5.9.5.3. Temporary backfilling above pile casting level

Temporary backfilling above pile casting level shall be in accordance with sub-sections 5.7.6.3..

5.9.6. Piling records

5.9.6.1. Complete piling records shall be kept by the Contractor during pile installation. The Contractor shall submit in duplicate the following information to the S.O.:

(i) Signed records of all piles as the work proceeds. Individual pile record shall be submitted not later than noon of the next working day after the pile is installed. The signed records shall form documented record of the work. Any unexpected installation condition shall be noted in the record.

(ii) Upon completion, compile a record of the work as carried out and provide As-built Drawings. The Drawings shall be prepared and endorsed by the Licensed Surveyor.

5.9.6.2. The format of the record shall be approved by the S.O. and shall contain, but not limited to the following information where applicable:

(i) Caisson number.

(ii) Level of top of concreted caisson shaft referred to Principal Datum.

(iii) Level of top concrete lining referred to Principal Datum.

(iv) Depth to base of caisson from top of concreted shaft.

(v) Date(s) and time(s) of starts and finishes of excavations and concreting.

(vi) Minimum internal diameter of caisson lining.

(vii) Full details of any bell-out and minimum diameter of caisson base.

(viii) Thickness and details of concrete lining.

(ix) Description of ground excavated, and methods employed.

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(x) Length and details of reinforcement.

(xi) Estimated and actual volume of concrete required to form the pile shaft

(xii) Details of all obstructions, delays and other interruptions.

(xiii) Complete record of bedrock proving test.

(xiv) Final log and photographic record of caisson base.

(xv) Results of core test.

(xvi) All tests made on materials used in the works.

5.9.6.3. All records shall bear the names of person who records and person who checks.

5.9.7. Safety precaution

5.9.7.1. General

The Contractor shall at all times comply with the Government regulations for safety on work sites. The working facilities provided and the manner in which the works are conducted shall conform to the requirements of *BS 5573*: Safety Precaution in the Construction of Large Diameter Boreholes for Piling and Other Purposes.

5.9.7.2. Electrical Equipment

All electrical equipment shall be wired in accordance with *'Regulations for the Electrical Equipment of Buildings'*, Latest Edition, published by the *Institution of Electrical Engineers*.

5.9.7.3. Caisson Shafts

(i) The Contractor shall ensure that construction of the concrete caisson lining follows the excavation sufficiently closely to ensure the stability of the works.

(ii) The Contractor shall ensure that the concrete caisson lining extends a minimum of 0.25m above and adjacent surrounding ground at all times.

(iii) The Contractor shall keep all caissons not being worked covered at all times by a stout safety cover capable of supporting a uniformly distributed load of 1.5kN/m2 and preventing entry of water into the caisson. The cover shall be attached rigidly to the top of the concrete lining to fully cover the caisson.

(iv) If an access platform is provided at the top of the caisson the hole through which access to the caisson is gained shall be equipped with a stout 150mm high kicker board around the full perimeter. The area adjacent to the kicker board shall be kept clear at all times of all loose rubble, tools or other objects which may be knocked into the caisson.

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(v) The Contractor shall at all times ensure that there is a hessian rope of minimum diameter 20mm securely fixed at ground level and passing over a block on the frame above the caisson and reaching the bottom of the caisson.

5.9.7.4. Ventilation

(i) The Contractor shall provide sufficient compressors, air pumps, etc. including an adequate number of standby spares, in order to ensure complete ventilation of all shafts whilst work is in progress and prevent the build-up of noxious gases or de-oxygenation.

(ii) Exhaust pipes from boring machines, winches and other equipment shall be so positioned that no exhaust gas enters the caisson or the intake of the air compressors supplying the fresh air to the base of the caisson.

5.9.7.5. Lighting

The Contractor shall maintain adequate artificial lighting at all times in all caisson shafts being worked.

5.9.7.6. Water in Caisson Shafts

The Contractor shall provide suitable methods approved by the S.O. to ensure the safety of the works.

5.9.7.7. Access and Communications

The Contractor shall provide access to all levels of shafts at all times whilst work is in progress and a means of communication with workmen in the shafts of a type that gives immediate notice to and from the surface of hazards which directly affects safety in the shaft.

5.9.7.8. Removal of Persons from Caisson Shafts

The Contractor shall provide a means whereby persons, including those semi-conscious or unconscious, may be removed rapidly and safely from caissons.

5.9.7.9. Oxygen

The Contractor shall provide at all times equipment and spares to enable oxygen to be administered to persons in an asphyxiated condition. The Contractor shall ensure the permanent presence on site during hours of work of an operator fully trained in the use of this equipment.

5.10. Static Pile Load Testing

5.10.1. General

5.10.1.1. To verify the working load, the Contractor shall carry out pile load test as shown on the Drawings and / or as instructed by the S.O..

5.10.1.2. The design and construction of the load application system shall be satisfactory for the required test. These details shall be made

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available prior to the commencement of testing.

5.10.2. Construction of Pile to Be Tested

5.10.2.1. Notice of Construction

The Contractor shall give at least 48 hours' notice of commencement of construction of any preliminary pile which is to be tested.

5.10.2.2. Method of Construction

Each preliminary test pile shall be constructed in a manner similar to that to be used for the construction of the working piles and by the use of similar equipment and material. Extra reinforcement and concrete of increased strength will be permitted in the shafts of preliminary piles where necessary and agreed by the S.O. for carrying out the testing.

5.10.2.3. Boring or Driving Record

For each preliminary pile which is to be tested, a detailed record of the conditions experienced during boring or of the progress during driving, shall be made available daily, not later than noon on the next working day. Where soil samples are required to be taken or in-situ tests to be made, the Contractor shall present the results without delay.

5.10.2.4. Concrete Test Cube

Three (3) test cubes shall be made from the concrete used in the preliminary test pile and from the concrete used for building up the working pile. If the concrete pile is extended or capped for the purpose of testing, a further three (3) cubes shall be made from the corresponding batch of concrete. The cube shall be made and tested in accordance with SECTION D: CONCRETING of this Specification.

5.10.2.5. Cut-Off Level

(i) The cut-off level for the preliminary test pile/working piles shall be as specified on the Drawings or as directed by the S.O..

(ii) Where the cut-off level of working piles is below the ground level at the time of pile installation and where it is required to carry out a load test from that installation level, either allowance shall be made in the determination of the twice working load for friction which may be developed between the cut-off level and the existing ground level, or the piling may be sleeved appropriately or otherwise protected to eliminate friction which can develop over the extended length.

5.10.2.6. Preparation for Pile Head for Testing

(i) For a pile that is tested in compression, the pile head or cap shall be formed to give the plane surface which is normal to the axis of the pile, sufficiently large area to accommodate

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the loading and settlement measuring equipment and adequately reinforced or protected to prevent damage from the concentrated application of load from the loading equipment.

(ii) For a pile that is tested in tension, means it shall be provided for transmitting the test load axially without inducing moments in the pile. The connection between the pile and the loading equipment shall be constructed in such a manner as to provide strength equal to the maximum load which is to be applied to the pile during the test with an appropriate factor of safety on the structural design.

5.10.2.7. Supervision

(i) The setting up of pile testing equipment shall be carried out under competent supervision and the equipment shall be checked to ensure that the setting-up is satisfactory before the commencement of load test.

(ii) All tests shall be carried out only under the direction of an experienced and competent supervisor conversant with the test equipment and test procedures. All personnel operating the test equipment shall have been trained in its use. The Curriculum Vitae (CV) of Tester(s) shall be submitted 48 hours prior to testing works being carried out.

5.10.2.8. Notice of Test

The Contractor shall give at least 24 hours' notice of the commencement of the test. No load shall be applied to the test pile before the commencement of the specified test procedure.

5.10.3. Protection of Testing Equipment

5.10.3.1. Protection from Weather

Throughout the test period, all equipment for measuring load and movement and beams shall be protected from adverse effects of sun, wind and precipitation. Temperature readings shall be taken at the start, end and at the maximum load of each loading cycle.

5.10.3.2. Prevention of Disturbance

Construction activities and persons who are not involved in the testing processes shall be kept at a sufficient distance from the test location to avoid disturbance.

5.10.4. Method of Loading

5.10.4.1. Test Load

(i) The test load shall be applied in one (1) of the following ways:

a) By means of a jack which obtains its reaction from kentledge heavier than the required load.

b) By means of a jack which obtains its reaction from tension piles or other suitable anchors.

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c) By means of a jack which obtains its reaction through bi-directional axial load from the top and bottom section of the tested pile.

(ii) In all cases, the reaction load or its supports shall be placed sufficiently far from the proposed test position to reduce the influence on the results to a tolerable level. Care shall be taken to ensure that the reaction load remains stable throughout the test without the possibility of load tilting or collapsing.

(iii) In addition to the reaction load, it shall be necessary to provide a loading frame, a bearing plate, a loading column and a hydraulic jack or other appropriate type of load measuring device. The loading column shall be of sufficient strength to prevent undue buckling under the maximum load. The total weight of the kentledge or reaction force provided shall be at least 1.2 times the maximum test load.

(iv) In all cases the Contractor shall ensure that when the hydraulic jack and load measuring device are mounted on the pile head, the entire system shall be stable up to the maximum load to be applied.

(v) If in the course of carrying out a test, any unforeseen occurrence should take place, further loading shall not be applied until a proper engineering assessment of the prevailing conditions has been made and steps taken to rectify any fault.

(vi) Where an inadequacy in any part of the system might constitute a hazard, means shall be provided to enable the test to be controlled from a position clear of the kentledge stack or test frame.

(vii) Where method (a) or (b) is used; The hydraulic jack, pump, hoses, pipes, couplings and other apparatus (jack assembly) to be operated under hydraulic pressure shall be capable to withstand a pressure of 1.5 times the maximum pressure used in the test without leaking. For method (c), the rated nominal capacity of jack assembly shall exceed the maximum anticipated jack load by at least 10%. Test certificate shall be submitted before carrying the test.

(viii) The maximum test load expressed as a reading on the gauge in use shall be displayed and all operators shall be made aware of this limit.

(ix) When method (a) is used, care shall be taken to ensure that the centre of gravity of the kentledge is on the axis of the pile. The nearest edge of the crib supporting the kentledge stack shall not be closer than 1300mm to the surface of the test pile. Kentledge shall not be used for testing raked pilesRefer **Figure 10.1** for typical set up requirement.

(x) When method (b) is used, all anchor piles shall be at a distance of at least three (3) pile shaft diameters from the test pile, centre to centre, and in no case, shall they be less than 2000mm from the test pile.

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(xi) If the anchor piles are to be permanent working piles, their levels shall be observed during application of the test load to ensure no residual uplift occurs.

(xii) When method (c) is used,

a) Bi-directional axial compression test shall be carried out in compliance with ASTM D8169-18 unless otherwise approved by S.O..

b) The test shall be carried out only under the direction of an experienced and competent supervisor conversant with the test equipment and test procedures. All personnel operating the test equipment shall have been trained in its use. The Curriculum Vitae (CV) of Tester(s) shall be submitted 48 hours prior testing works.

c) The method consists of bi-directional pile load test; the jack load unit is installed within the pile body and bi-directional base load test; the jack load unit is installed at the pile base.

d) The jack load unit shall be placed in plane surface which is normal to the axis of the pile. The elevation of the load unit shall be located at the approved calculated equilibrium geotechnical capacity of upper and lower segments of the test pile as verified by a Professional Engineer.

e) The steel bearing plates, stiffeners or equivalent as needed to distribute the jack load evenly over the pile cross-section.

f) The upper displacement tell-tale shall be fixed in sufficient distance at the top section of the tested pile.

g) The lower displacement tell-tale for bi-directional pile load test shall be fixed in sufficient distance at the bottom section of the tested pile. Whereas the lower displacement tell-tale for bi-directional base load test shall be fixed at the bottom of the pile base plate.

h) The connection in between the top and bottom section of the tested pile to the jack load unit shall be allowed for opening mechanism at the split zone for the purpose of testing.

i) Tell-tale or any other tests to the pile such as sonic logging, the instrumentation pipes or cabling which is located at the jack load unit shall be in such extendable during the split zone gap opening during pressurizations.

j) The protection measures such as funnel rebar or other methods as approved by the S.O. shall be fixed to the main rebar cage to protect the jack load unit from damages during concreting.

k) The jack load unit shall be fully welded together with the upper steel rebar cage. The bearing plates shall be spot-

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welded with the load unit. The plate shall be made to receive uniform load distribution prior to testing.

l) Minimum two (2) grouting pipes shall be installed together with the jack load unit. The pipes shall be pre-cut at the split zone of the load unit to enable the pipes to split and allow the cement grout to flow and grouting takes place. The sonic logging pipes may also be treated as grouting pipes.

m) Post grouting shall be done to fill up the gap at the split zone. Clean water shall be initially pumped to remove the debris left at the split zone after testing. Grouting shall start when the water returned to the nearby grouting pipe becomes clean. Grouting operation shall be terminated when the returned cement grout is most likely similar to previous grout applied.

n) The test result shall be plotted as load versus displacement curves for the upward and downward displacement independently. The two (2) component curves shall be utilized to construct an equivalent pile-top load versus displacement curve.

o) To simulate compressive load, established correction factor for shaft resistance and reduction of pile weight shall be considered at the pile top section which is formally subjected to tension load behaviour during bi-directional testing. In addition, established correction factor and elastic shortening shall be considered at the pile top section for settlement computation due to the load.

p) The test report shall be endorsed by a Professional Engineer with Practicing Certificate prior to submission to the S.O..

(xiii) Alternatively, the Contractor may propose the use of other types, patented or otherwise, in which case the requirements as below shall be fully complied with.

5.10.4.2. Contractor's Load Test System

The Contractor may propose to use other different types from those specified. The proposal shall be submitted to the S.O. at least 90 days before the date of testing. The suitability or adequacy of any system shall be determined by the S.O.. In the event that the testing system proposed by the Contractor is acceptable, the Contractor shall obtain a Professional Engineer's endorsement on load settlement results.

5.10.4.3. Measurement of Load

(i) The test load shall be measured by calibrated load cell(s) or proving ring calibrated in divisions not exceeding 1% of the maximum load to be applied. If an electronic transducer is used, each reading shall be immediately saved so that in case of power failure the readings are not lost.

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(ii) The load cell or proving ring to be accepted for use shall be calibrated within the test load range without extrapolation and certificate of calibration within a validity of 6 months shall be made available before the load test commences.

(iii) All increments of load shall be maintained to within 1% of the specified load.

(iv) A spherical seating or pivot bearing of appropriate size shall be used to avoid eccentric loading. Care shall be taken to avoid any risk of buckling of the load application and measuring system. Load measuring and application devices shall be in short axial length in order to secure stability. The Contractor shall ensure that axial loading is maintained.

(v) The loading equipment shall enable the load to be increased or decreased smoothly or to be held constant at any required value.

5.10.4.4. Measurement of Settlement

(i) The Contractor shall provide apparatus for measuring settlement consisting of a primary system, at least one (1) auxiliary system for pile head and reference frame scale. Minimum one (1) independent temporary benchmark at least 15m (unless otherwise approved by the S.O. that nearer undisturbed and stable temporary benchmark can be established) from the test site to monitor the settlement reference point, shall be established. If desired, the auxiliary system may also be referenced to these benchmarks.

(ii) All measuring devices, scales and reference points with numbers or letters to ensure accurate data recording shall be clearly identified.

(iii) Settlements shall be measured by use of a reference beam supported independently of the load test pile, reaction pile or piles supporting reaction loads. Settlements shall be measured to the nearest 0.1mm accuracy. The reference beams shall be protected from the effects of temperature changes

5.10.4.5. Primary System

Reference Beams and Displacement Measuring Devices

(i) At least four (4) Linear Voltage Displacement Transducers (LVDT) and a Readout Unit are to be used for measuring the displacement. DC/DC–type displacement transducer having at least 75mm of travel and a linearity of 0.5% or less shall be used. A Readout Unit having a minimum display of three (3) digits, capable of monitoring output from DC/DC – Type LVDT shall be provided.

(ii) The measurement devices parallel to the longitudinal axis of the test pile and the axis of load application shall be aligned.

(iii) An independent reference beam or beams shall be set up to enable measurement of the movement of the pile to be

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made to the required accuracy and shall not be interfered by the load application system.

(iv) Reference beam supports shall be embedded securely and firmly into the ground, at a horizontal distance of not less than 2m from the closest face of the test pile, or 1.5m from the nearest corner of the support crib or platform/reaction pile, whichever is greater.

(v) A clear distance of 150mm to 300mm from the test pile to the reference beam or any projection used to support LVDT shall be maintained. The beam and projections should be at about the same elevation as the attachments to the pile on which the measuring devices will bear.

(vi) The LVDT supports to reference beam shall be attached so as to allow the stem of each device to rest on an attachment to the pile sides.

(vii) Hardware and pile attachment for LVDT devices shall be mounted using materials such as brass, aluminium or 303 series stainless steel, to avoid magnetic interference which the instruments. The pile attachments are angles, about 75mm x 100mm with the 100mm dimension projecting from the pile. For round pile, these attachments shall be placed on the perimeter of the pile at 90 degrees and an equal radial distance. For pile of other cross section, the attachments shall be placed at a convenient location as approved by the S.O..

(viii) Surfaces on which the gauge stems bear should have a smooth finish, such as glass or sheet acrylic, attached by an epoxy or other suitable material approved by the S.O..

(ix) Observation of any movements of the reference beam or beams shall be made and checking of the movement of the pile head relative to a remote reference datum shall be made and stopped at maximum load for each loading.

Refer **Figure C1** for typical set up requirement.

5.10.4.6. Auxiliary Systems

This measuring system shall consist of one (1) or more of the following: wire, mirror and scale; surveyor's level and target road; or, as alternatives, electrical or optical levels.

(i) Wire, Mirror and Scale

Pile movement shall be determined by means of a single strand of wire drawn in front of graduated scale mounted on a mirror. This scale, at least 150mm long and machine-divided in graduations of 250µm, is mounted on a 75mm x 150mm mirror with metal and glass bonding adhesive or electrical tape. The mirror shall be attached directly to the pile oriented so that the mirror face is parallel to the reference beam. The mirror shall be mounted to the wire between the ends of the reference beam, with one (1) end fixed and the other is placed over a pulley with a weight in

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order to maintain tension. The wire shall be located so that it is level and within 20mm of the mirror face.

(ii) Surveyor's Level and Target Rod

Use a level and levelling rod with a Vernier target that can be read to 0.5mm. Determine deflections by readings on the two fixed independent benchmarks, and on an established scale or fixed point on the pile top.

(iii) Alternative Systems

Any other type of electrical or optical gauge yielding a precision equivalent to the primary system is acceptable as an alternative, provided prior written approval is obtained from the S.O..

5.10.4.7. Tell-tale Strain Measurements

(i) When specify, strain measurements on the pile to determine elastic shortening of the pile shall be obtained by tell-tale strain measuring devices.

(ii) Tell-tales extensometer or vibrating strain gauges or other suitable measuring system shall be installed according to the drawing shown or as directed by the S.O..

5.10.5. Testing Procedure

5.10.5.1. General

Prior to the performance of any load test, the Contractor shall submit to the S.O. for his approval, working Drawings showing the method and equipment he proposes to use in the performance of the load test and the measurement of settlements. Such submission shall include design calculations of lateral supports or other methods to be used in ensuring against buckling. Horizontal supports to ensure bucking stability shall be provided to the pile to be loaded whenever the ratio of the unsupported height to the least cross-sectional dimension is 20 or more. Horizontal supports shall provide full support without restraining the vertical movement of the pile in any way.

5.10.5.2. Maintained Load Test

The Maintained Load Test shall be carried out as follows:

(i) The Full Test Load (FTL) on a pile shall be twice the Working Load (WL) noted on the Drawings unless otherwise stated, or directed by S.O..

(ii) The test shall be carried out in two (2) cycles, with first cycle test up to working load and second cycle test up to full test load as specified in **Table C4** of this Specification.

(iii) The load shall be applied in increment of 25% of the working load. Each increment of load shall be applied as smoothly and as expeditiously as possible. Settlement readings and time observations shall be taken before and after each new

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load increment.

(iv) The minimum period for maintaining a load at each increment before reaching the working load or test load is 30 minutes. A further increment of load shall be applied when rate of settlement is less than 0.05mm in 15 minutes.

(v) Time-settlement readings shall be taken at 2, 8, 15 and 30 minutes, and at 15 minutes interval thereafter. A time-settlement graph shall be plotted to indicate when the rate of settlement of 0.05mm in 15 minutes is reached before load increment is applied.

(vi) The working load shall be decreased in two (2) equal stages, and time-settlement readings shall be as specified a foresaid, until the rate of settlement is less than 0.05mm in 15 minutes. At least 30 minutes interval shall be allowed between the unloading decrements while minimum one (1) hour shall be allowed when unloading to zero load.

(vii) The maximum working load in first cycle shall be maintained for a minimum of 6 hours and time-settlement readings shall be taken at regular intervals of every 15 minutes for the first two (2) hours and every hour thereafter.

(viii) The maximum test load shall then be maintained for a minimum of 24 hours, and time-settlement readings shall be taken at regular intervals for every 15 minutes for the first two (2) hours and every hour thereafter.

(ix) The maximum test load shall be decreased in four (4) equal stages, and time-settlement readings shall be as specified a foresaid, until the rate of settlement is less than 0.05mm in 15 minutes. At least 30 minutes interval shall be allowed between the unloading decrements while minimum one (1) hour shall be allowed when unloading to zero load.

(x) If large discrepancies occur between different measurement system in sub-section 5.10.4.5. and 5.10.4.6. the test shall be halted and the cause for the discrepancy corrected. The test shall be restarted from the beginning in this instance.

(xi) Settlement readings shall be taken immediately after and before every load increment is applied or removed.

Refer **Table C4** for Load Increments and Minimum Holding Time.

5.10.6. Submission of Results

Full test data, complete field test records and results from the readout unit shall be jointly signed by the S.O.'s representative and the Contractor's authorised agent and submit to the S.O. immediately upon completion of the load test. The submission shall also consist of the following:

(i) Stage of Loading

(ii) Period for which the load was held

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(iii) Final load and load increment

(iv) Maximum settlement

These are to be plotted as load versus settlement and load - settlement versus time graphs.

5.10.6.1. Interpretation of Test Results

The S.O.'s interpretation and conclusions on the test results shall be final. Unless otherwise specified, the pile so tested shall be deemed to have failed if:

(i) The total settlement under the Working Load exceeds 12.50mm; or

(ii) The total settlement under twice the Working Load exceeds 38.0mm, or 10% of pile diameter / width whichever is the lower value, or

(iii) The residual settlement after removal of the test load at working load exceeds [(diameter of pile or diagonal width for non-circular pile / 120) + 4]mm or 12.50mm whichever is the lower value; or

(iv) For pile longer than 30m, the limit for maximum allowable settlement (i) and (ii) above can be increased by 2.2% for every meter length of pile beyond 30m.

5.10.7. Completion of a Test

5.10.7.1. Removal of Test Equipment

(i) On completion of a test, all measuring equipment and load application devices shall be dismantled and checked. All other test equipment, including kentledge, beams and supporting structures shall be removed from the test pile location. Measuring and other demountable equipment shall be stored in a safe manner so that it is available for further tests, if required, or removed from site.

(ii) Temporary tension piles and ground anchorages shall be cut off below ground level and all cut-off materials removed from the site. The ground shall be made good to the original commencing surface level.

5.10.7.2. Preliminary Test Pile Head

Unless otherwise specified, the head of each preliminary test pile shall be cut off below ground level, and all cut-off materials removed from the site. The ground shall be made good to the original commencing surface level.

5.11. High Strain Dynamic Pile Testing

5.11.1. General

5.11.1.1. The Dynamic pile testing using Pile Driving Analyzer (PDA) equipment is a high strain non-destructive load test method which

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can be performed during initial pile driving and during pile restrike to provide dynamic analyses using Case Pile Wave Analysis Program (CAPWAP) or equivalent and Wave Equation analyses programs approved by S.O.. The analyses programs shall be performed for the purposes of obtaining ultimate pile bearing capacity, pile stresses, pile integrity, and pile driving system performance. PDA testing is undertaken in conformance with latest ASTM Standard D-4945.

5.11.1.2. The Contractor shall supply all material, equipment, and labour to perform the dynamic monitoring. The Contractor shall obtain the dynamic measurements with the PDA of monitor piles and furnish the necessary dynamic data to the S.O..

5.11.2. Construction of Pile Head to be Tested

5.11.2.1. Driven Concrete piles

For a concrete pile subjected to PDA testing, the original pile head is to be used. For a damaged pile head, it shall be cut off square at sound concrete, and all loose particles shall be removed by wire brushing, followed by washing with water. Care shall be exercised to ensure that the reinforcement in the pile head is not in any way damaged. Any damaged reinforcement shall be made good to the satisfaction of the S.O.. The head shall be replaced with concrete of similar grade or higher.

5.11.2.2. Cast In-Situ Piles

(i) For cast in-situ piles, a spiral welded steel casing of at least 6mm thickness, same diameter as the cast in-situ pile and one diameter in depth is used to prepare the pile head for testing. Concrete of the same quality or better is used to build up the pile head with the finished level just above the steel casing (with the steel casing forming part of the pile head). Care should be taken so that there is no cold joint between the build up pile head and the pile.

(ii) The completed pile surface shall be flat and perpendicular to the applied force.

5.11.2.3. Steel pile

The pile top shall be flat.

5.11.3. Method of Testing

5.11.3.1. Equipment and Personnel Qualification

(i) The dynamic monitoring shall be performed using a Pile Driving Analyzer (PDA) system or equivalent approved by S.O.. All equipment necessary for the dynamic monitoring such as sensors, cables or wireless transmitters, etc., shall be furnished by Contractor and well calibrated at the time of testing. The equipment shall conform to the requirements of the latest ASTM D-4945.

(ii) Dynamic testing shall be performed by an independent specialist firm approved by S.O..

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5.11.3.2. Preconstruction Wave Equation Analysis

(i) Wave Equation Analysis shall be carried out to access the ability of the proposed driving system to install the pile to the required capacity and desired penetration depth within the allowable driving stresses.

(ii) Ten working days prior to testing, the Contractor shall submit the Wave Equation Summary Report and the report shall be endorsed by Professional Engineer with Practicing Certificate and submitted to the S.O. for review and approval.

(iii) The output shall be:

a) In the form of a relationship between pile capacity and driving behaviour

b) An estimate of final set (mm/blow)

c) Relationship between driving stresses in the pile and penetration resistance.

(iv) Approval of the proposed driving system by the S.O. shall be based upon the wave equation analyses indicating that the proposed driving system can develop a pile capacity of twice the pile design load at driving resistance. The hammer should also be sized or adjustable such that the penetration per 10 blows at the required ultimate capacity does not exceed 25mm.

(v) A new pile driving system, modifications to existing system, or new pile installation procedures shall be proposed by the Contractor if the pile installation stresses calculated by Wave Equation Analysis or derived from the PDA measurements exceed the maximum values specified by the S.O. or shown in **Table C5.**

5.11.3.3. Apparatus for Applying Impact Force

(i) The driving apparatus shall be positioned so that the impact is applied axially to the head of the pile and concentric with the pile. The device used to apply the impact force should provide sufficient energy to cause pile penetration during the impact event adequate to mobilize the desired capacity.

(ii) Conventional pile driving hammer, drop weight, or similar impact device based on predictive dynamic analysis, experience, or both shall be approved by S.O.. The impact shall not result in dynamic stresses that will damage the pile. The S.O may require cushions, variable control of the impact energy (drop height, stroke, fuel settings, hydraulic pressure, etc.), or both, to prevent excessive stress in the pile during all phases of pile testing.

5.11.3.4. Gauges for Obtaining Dynamic Measurement

(i) Dynamic measurement shall be carried out by attaching at least two strain transducers and two accelerometers for pile sizes less than 1000mm and at least four strain transducers

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and four accelerometers for pile larger than 1000mm diameter.

(ii) Care shall be taken to ensure that the gauges are securely attached at least 1.5 pile diameter from the pile head for pile diameter less than 1000mm and at least 1 pile diameter for pile exceeding 1000mm. The gauges shall be attached above the existing ground level and at opposite sides for a pair of gauges and at every quarter of pile circumference for two (2) pairs of gauges.

(iii) The gauges shall be calibrated to an accuracy of 2% throughout the applicable measurement range. The frequency of calibration is as per stated in the latest ASTM D-4945. If damage is suspected during use, the gauges shall be replaced.

5.11.3.5. Apparatus for Recording, Processing and Displaying Data

(i) The Contractor shall provide apparatus for measuring the acceleration and strain of the pile head and the energy transferred to the pile. The signals from the transducers during the impact event, shall be transmitted to the PDA to allow determination of the force and velocity versus time.

(ii) A cable or wireless transmission which connects the sensors near the pile head with the PDA shall be located at safe distance from the pile, but not more than 100m from the pile.

(iii) The PDA shall include a screen for displaying the force and velocity, a hard disk for obtaining a record for future analysis, and a means to process the data.

(iv) The apparatus shall have the capability of making an internal calibration check of force, velocity and time scales. No error shall exceed 2% of the maximum signal expected.

5.11.4. Testing Procedures

5.11.4.1. General

(i) Dynamic Test shall be conducted on test piles as selected by the S.O.. The test shall be carried out in accordance with sub-section 5.11.4.2.

(ii) Prior to the performance of any dynamic test, the Contractor shall submit the specialist testing firm company profile and working drawings showing the method statement and equipment proposed to be used in the performance of conducting the test together with all relevant calibration certificates to the S.O. for approval. The S.O. may request additional piles to be dynamically tested if the hammer and/or driving system is replaced or modified, the pile type or installation procedures are modified, the pile capacity requirements are changed, unusual blow counts or penetrations are observed, or any other piling behaviour differing from normal installation. The Contractor shall bear the cost and time for all necessary additional test.

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5.11.4.2. Dynamic Load Test

The Dynamic Load Test shall be carried out as follows:

(i) Driven Piles

a) Continuous pile monitoring as indicated in the Drawing or as requested by the S.O..

b) Dynamic pile test shall be conducted on piled foundations at the end of driving or at restrike for selected piles.

c) The pile shall to be at least 3 diameters or 100mm above the ground level. The Contractor shall drill and prepare holes for sensor attachment near the pile top after the pile has been driven to the penetration depths as specified on Drawing.

d) The Contractor shall supply and operate the piling hammer to induce a driving force on to the pile. Dynamic measurement of force and velocity shall be processed by the PDA to give immediate visual and permanent record on-site.

(ii) Cast In-Situ Piles

a) Dynamic pile test shall be conducted on cast in-situ piles at 28 days after pile concreting. Piles which are to be tested prior the 28 days shall be proven that it has achieved the required concrete compressive strength and subjected to approval by the S.O.. However, no testing shall be allowed for piles less than 14 days after concreting.

b) The pile shall be casted so as to leave a height of at least one (1) diameter above the ground or excavated level.

c) Contractor shall supply and operate the drop hammer to induce a driving force on to the pile. Dynamic measurement of force and velocity shall be processed by the PDA to give immediate visual and permanent record on-site. The proposed hammer weight shall be at least 1% to 2% of the maximum test load.

5.11.5. Submission of Results

5.11.5.1. Full test data, complete field test records and results from the readout unit shall be jointly signed by the S.O.'s representative and the Contractor's authorised agent and submit to the S.O. immediately upon completion of the Dynamic Test.

5.11.5.2. The Contractor shall submit preliminary results within three (3) days after completion of the test to the S.O..

5.11.5.3. The Contractor shall also submit the raw data file (W01) or equivalent, upon completion of the test at the site.

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5.11.5.4. For all testing, CAPWAP analysis or equivalent shall be carried out. The S.O.'s acceptance of the interpretation and conclusion based on the results submitted shall be final.

5.11.6. CAPWAP Computer Analysis Programme and Final Report

5.11.6.1. The final analysis and report shall consist of matches of forces and velocities, resistance distribution, static simulation and complete tables of numeric values. The Final Report shall be submitted to the S.O. within at least 7 working days upon completion of field testing. The specialist Contractor shall complete and provide the following:

(i) Static Capacity of pile including the toe resistance and shaft friction

(ii) Hammer Efficiency

(iii) Integrity of Pile

(iv) Case Damping Factor

(v) Predicted Load Vs Settlement Plots

(vi) Match Quality

(vii) Slack Value, efficiency & location (if used)

(viii) Force Wave Traces of measured and computed

(ix) Shaft Resistance Distribution

5.11.6.2. A PDA plot indicating all the gauges used for the testing and all the output of the field results and the subsequent signal matching on the same blow for all the piles are to be included in the Test Report. These reports should only be prepared by an engineer who has achieved Advanced Level or higher.

5.11.6.3. The report shall contain complete analysis, results and their interpretation with Professional Engineer with Practicing Certificate’s endorsement.

5.11.7. Completion of a Test

5.11.7.1. On completion of a test, all measuring equipment and load application devices shall be dismantled and removed from the test pile.

5.11.7.2. Unless otherwise specified, the head of each test pile shall be cut off below ground level, and cut-off materials removed from the site. The ground shall be made good to the original commencing surface level.

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6. Subterranean Termites Treatment

6.1. The Contractor shall only appoint termite management company (TMC) that has adequate equipment, competency and skilled workers to perform expeditiously. The Contractor shall also ensure that the TMC engage workers who are licensed to apply the termiticide by the relevant authorities.

6.2. All methods of application and chemicals to be used for the treatment of subterranean termite infestation shall be in accordance to MS 8215: Protection of Buildings against Subterranean Termites - CP for Prevention, Detection and Treatment of Infestation.

6.3. The Contractor shall submit a termite management programme and provide the following in writing:

6.3.1. A termite infestation report;

6.3.2. Details of methods proposed and termiticides to be used.

6.4. The Contractor's termite management company shall submit the above proposal with the Material Safety Data Sheet, product label and brochure indicating the termiticide to be used to the S.O.'s for approval.

6.5. Termiticide chemicals shall be applied in accordance with the manufacturer's recommendation and label instructions prior to the pouring of concrete to construct the ground slab or for binding. Notwithstanding the manufacturer's recommendation, the minimum surface application rate shall be five (5) litres/m^2 on all ground floor built-up areas including apron areas, and also on all areas extending one (1) m beyond the perimeter drain all around the building. In addition, termiticide chemical shall be sprayed on interfaces between the concrete ground beam and the hardcore at a minimum rate of one (1) litre/m.

6.6. Treatment shall not be performed just before or after heavy rain, unless the area to be treated can be physically protected to avoid leaching and runoff before the termiticide chemical has bound to the soil.

6.7. Immediately after spraying the chemical, all surfaces exposed to direct sunlight or rain shall be covered with an impervious black PVC sheet of minimum thickness of 0.08 mm to reduce the loss of chemical by UV light, alkaline wet concrete, leaching and runoff caused by rain on exposed treated soil. In the case of areas receiving blinding, the coverings shall be removed immediately prior to the placement of the blinding concrete.

6.8. As soon as practicable after the completion of anti-termite treatment and prior to the issuance of the Certificate of Practical Completion, the Contractor shall submit to the S.O., the anti-termite treatment specialist's Guarantee against any termite attack to the Works which may arise during a period of two (2) years from the date of Practical Completion of Works due to any defect, fault or ineffective anti-termite treatment. The terms of the Guarantee shall be such as shall be approved by the S.O..

6.9. The Contractor shall verify the ground-water table before soil treatment. For this purpose, the Contractor shall excavate trial holes of not less than 0.5 meter deep measured from the level below the level of the soil to be treated. The restriction to soil treatment by virtue of this requirement shall not in any way affect or diminish the Contractor from any indemnity against termite attacks.

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7. Damp Proof Membrane (DPM)

7.1. DPM shall be installed below the ground concrete floor level or as shown on the Drawings to prevent the rise of moisture or damp through the structure flooring.

7.2. Unless otherwise specified in the Drawings, the DPM shall be extruded polythene film with a nominal thickness of 0.5mm. The nominal weight shall not be less than 0.45kg/m² and the tensile strength shall be not less than 44MPa in accordance with ISO 527.

7.3. Unless the application surface is smooth it shall be blinded with compacted soft sand to guarantee a soft bed, free from any objects that may puncture the membrane during the installation or when concrete is applied.

7.4. When laying two (2) sheets of DPM, a minimum of 150mm overlap shall be provided between each of the sheets and sealed with 100mm wide jointing tape.

7.5. Any punctures in the membrane shall be patched with sheets of identical thickness lapped at least 150mm away from the perforation edge and sealed with double sided pressure sensitive tape.

7.6. The DPM shall be covered with a protective layer or screed as soon as possible after the membrane has been installed. Care shall be taken when applying concrete or screed on top the DPM to avoid stretching or the DPM being displaced.

8. Damp Proof Course (DPC)

DPC shall comply with BS 8215: CP for design and installation of DPC in masonry construction and as specified in SECTION E: WALL SYSTEM.

9. Filling Under Floors, Aprons Etc.

Filling shall be provided and laid under floors, aprons, etc. where required. Filling shall be of suitable material as specified hereinbefore, deposited in layers not exceeding 155mm loose thickness, and each layer well watered where necessary, rammed and compacted. No clay shall be used for filling under floors and aprons.

10. Hardcore

Where shown and required, approved hardcore consisting of good, sound broken bricks or stones shall be provided and laid to the thickness shown on the Drawings, well rammed, compacted and blinded with sand. All hardcore shall be well watered immediately prior to the depositing of concrete thereon.

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Table C1. Plate Bearing Test – Load Increments and Minimum Holding Time

No.	Load (% of working load)	Time Interval (minute)
1.	20	15
2.	40	15
3.	60	15
4.	80	15
5.	100	120
6.	80	15
7.	60	15
8.	40	15
9.	20	15
10.	0	15
11.	20	15
12.	40	15
13.	60	15
14.	80	15
15.	100	15
16.	120	15
17.	140	15
18.	160	15
19.	180	15

No.	Load (% of working load)	Time Interval (minute)
20.	200	120
21.	160	15
22.	120	15
23.	80	15
24.	40	15
25.	0	15
26.	40	15
27.	80	15
28.	120	15
29.	160	15
30.	180	15
31.	240	15
32.	280	15
33.	300	120
34.	240	15
35.	160	15
36.	80	15
37.	0	15

Note: The rate of settlement for each load increment should be based on the preliminary test

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Table C2. Specification of Precast Concrete Piles (after MS1314)

Piles		Minimum Concrete Strength (N/mm^2)	Minimum Longitudinal Reinforcement	Minimum Cement Content (kg/m^3)	Method of Installation
Type	Class				
RC	M	45	1.2 % of cross sectional area	400	Hammer driven
	J	45	1.0 % of cross sectional area	400	Hammer driven
Spun pile	A	60	Minimum effective prestressed of 4 N/mm^2	420	Hammer driven
	B	60	Minimum effective prestressed of 5 N/mm^2	420	Hammer driven
	C	60	Minimum effective prestressed of 7 N/mm^2	420	Hammer driven
PC	X	60	Minimum effective prestressed of 5 N/mm^2	420	Hammer driven
	Y	60	Minimum effective prestressed of 7 N/mm^2	420	Hammer driven
PCS	1	60	Minimum effective prestressed of 3.5 N/mm^2	420	Hammer driven
	2	55	Minimum effective prestressed of 3.5 N/mm^2	420	Jacked-in
RCS	1	45	1.0 % of cross sectional area	400	Hammer driven
	2	45	0.8 % of cross sectional area	400	Jacked-in

NOTES:
Concrete strength means *characteristic compressive strength* at 28 days.
The nominal sizes and length for each class of piles are specified in Parts 3, 4, 5 or 6 of Malaysian Standard, whichever relevant.

Definitions:
Precast reinforced concrete square pile (RC pile)
A pile made of concrete cast in a uniform four-sided cross section before driving into the ground. It shall be suitably reinforced mainly with steel bars.
Precast prestressed concrete square pile (PC pile)
A pile described in definition No. 1 but suitably reinforced mainly with prestressing steel.
Precast pretensioned spun concrete pile (Spun pile)
A hollow cylindrical pile made of concrete cast by centrifugal spinning before driving into the ground. It shall be suitably reinforced mainly with pretensioned prestressing steel.
Small prestressed concrete square pile (PCS pile)
A small PC pile for sizes 200 mm and less.
Small reinforced concrete square pile (RCS pile)
A small RC pile for sizes less than 200 mm.

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Table C3. Slump Range for Typical Concreting Situations

Typical Conditions of Use	Slump Range (mm)
Placed into water-free unlined bore. Widely spaced reinforcement leaving room for free movement between bars.	75 to 125
Where reinforcement is not spaced widely enough to give free movement between bars. Where casting level of concrete is within the casing. Where pile diameter is less than 600 mm.	100 to 175
Where concrete is to be placed by tremie under water or drilling fluid.	150 to collapse

Table C4. Static Load Test – Load Increments and Minimum Holding Time

LOAD INCREMENTS AND MINIMUM PERIODS OF OBSERVATION		
Load Cycles	Load Increment (% WL)	Minimum Holding Time
1st cycle	0	
	25	30 minutes*
	50	30 minutes
	75	30 minutes
	100	6 Hours**
	50	30 minutes
	0	60 minutes
2nd cycle	25	30 minutes
	50	30 minutes
	75	30 minutes
	100	30 minutes
	125	30 minutes
	150	30 minutes
	175	30 minutes
	200	24 Hours***
	150	30 minutes
	100	30 minutes
	50	30 minutes
	0	60 minutes

NOTES
* Time-settlement readings shall be taken at 2, 8, 15 and 30 minutes, and at 15 minutes interval thereafter.
**Time-settlement readings shall be taken at regular intervals of every 15 minutes for the first 2 hours and every hour thereafter during load holding time at working load.
***Time-settlement readings shall be taken at regular intervals for every 15 minutes for the first 2 hours and every hour thereafter during load holding time at test load.

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Table C5. Typical Allowable Driving Stresses

Pile Material	Compression Stress	Tension Stress (psi)	Tension Stress (MPa)
Steel	0.9 F_y	0.9 F_y	0.9 F_y
Prestressed Concrete	0.85 f'_c - f_{pe}	3 $(f'_c)^{1/2}$ + f_{pe}	0.25 $(f'_c)^{1/2}$ + f_{pe}
Precast Concrete*	0.85 f'_c	0.70 f_y (A_s / A_c)	0.70 f_y (A_s / A_c)
Timber	3 σ_a	3 σ_a	3 σ_a

*Allows for tension cracks; for uncracked section allow prestressed concrete tension stress with f_{pe} = 0.

F_y = Steel Yield Strength
f'_c = Concrete Compressive Strength (MPa or psi)
f_{pe} = Effective Prestress (after losses) (MPa or psi)
A_s = Reinforcement Steel Cross Sectional Area
A_c = Concrete Cross Sectional Area
f_y = Reinforcement Steel Yield Strength
σ_a = Allowable Timber Design Stress

Table C6. Tests for Bentonite Drilling Fluids

Property	**Units**	**Stages**			**Test Equipment**
		Fresh	**Ready for re-use**	**Before concreting**	
Density	g/ml	< 1.10	< 1.25	< 1.15	Mud balance
Marsh viscosity (946 ml)	sec	32 to 50	32 to 60	32 to 50	Marsh funnel
Fluid loss (30 min)	ml	< 30	< 50	NA	Filter press
pH		7 to 11	7 to 12	NA	pH meter
Sand content	%	NA	NA	< 4	Sand content set
Filter Cake	mm	<3	<6	NA	Filter Press

Table C7. Tests for Polymer Drilling Fluids

Property	**Units**	**Stages**	**Test Equipment**
		Before concreting	
Density	g/ml	≤ 1.1	Mud balance
Marsh viscosity (946 ml)	sec	32 to 140	Marsh funnel
pH		7 to 12	pH meter
Sand content	%	≤ 1	Sand content set

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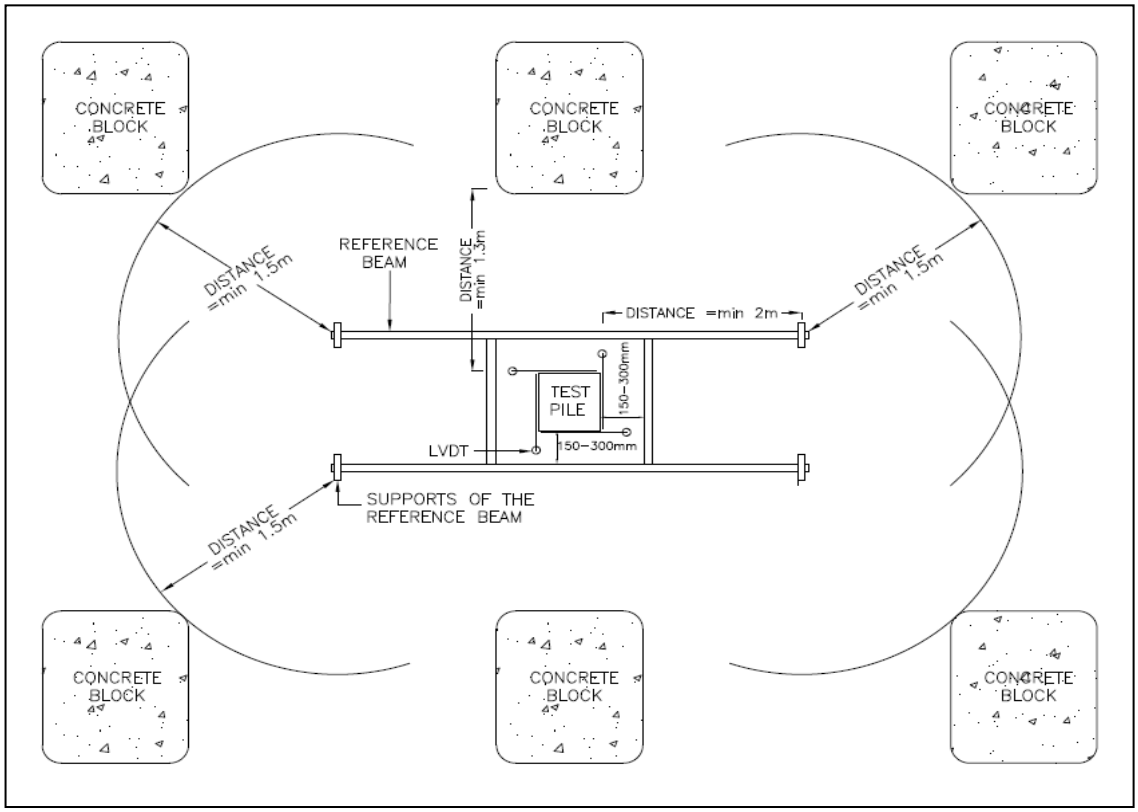
Figure C1. Plan View of Typical Pile Load Test Set Up



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APPENDIX C/1

Bending Strength for Precast Concrete Piles

Pile Body Strength Test

General

Bending strength test on the pile body shall be done to determine the ability of the pile to withstand the cracking bending moment (*M*c) and the ultimate bending strength (*M*u). The bending strength test of pile body shall be made by the application of vertical load *P* to the centre of the span, on the pile laid on two (2) supports which has a span equal to 3/5 of its length.

The applied bending moment shall be calculated from the following equation: -

Where,
$$M = \frac{1}{40}WL + \frac{P}{4}\left(\frac{3L}{5} - 1\right)$$

M is the applied bending moment (kNm);
W is the weight of pile (kN);
L is the length of pile (m); and
P is the applied load (kN)

The cracking bending moment (M_c)

The pile shall be designed to withstand the cracking bending moment calculated based on the maximum allowable crack width as shown in Table 1. The pile is considered to have passed the requirement to withstand the cracking bending moment if when subjected to a test load equal to the cracking load (P_c) corresponding to the appropriate M_c, no crack exceeding the values in Table 1 occurs. The calculated values of M_c are given in Table 2, Table 3 and Table 4.

Table 1: Maximum Allowable Crack Width

Types of pile	Maximum crack width (mm)
1 RC pile	0.20
2 Spun pile	0.05
3 PC and PCS pile	0.10
4 RCS pile	0.20

The ultimate bending moment (M_u)

The pile shall be tested to the largest applied load (P_{max}) until the pile failure occurs or until the applied load slightly exceeds the minimum ultimate load (P_{min-u}) which corresponds to the minimum ultimate bending strength, whichever comes first.

The minimum ultimate bending strength (P_{min-u}) is obtained by multiplying the cracking bending moment (M_c) by the factor *'f'* as given in.

The pile is considered to have passed the bend test if the pile does not fail when subjected to P_{min-u} load.

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Testing

Apparatus setup

The pile manufacturer shall design and fabricate a suitable set-up for carrying out the bend test. The test shall be carried out using any suitable equipment of sufficient capacity and capable of applying the loads continuously and vertically.

The loading arrangement and the device for applying the loads shall consist of two supporting rollers and two load-applying rollers as in Figure 1.

All rollers shall be manufactured from steel and shall have a circular cross-section with a diameter of 20 mm to 120 mm; the rollers shall be at least 20 mm longer than the width of the test specimen. All rollers except one shall be capable of rotating around their axes and of being inclined in a plane normal to the longitudinal axis of the test specimen. All rollers shall be adjusted in their correct positions with all distances having an accuracy of ± 5 mm. Suitable safety precaution should be taken to ensure that the rollers do not fall off while adjustment is made and during the testing.

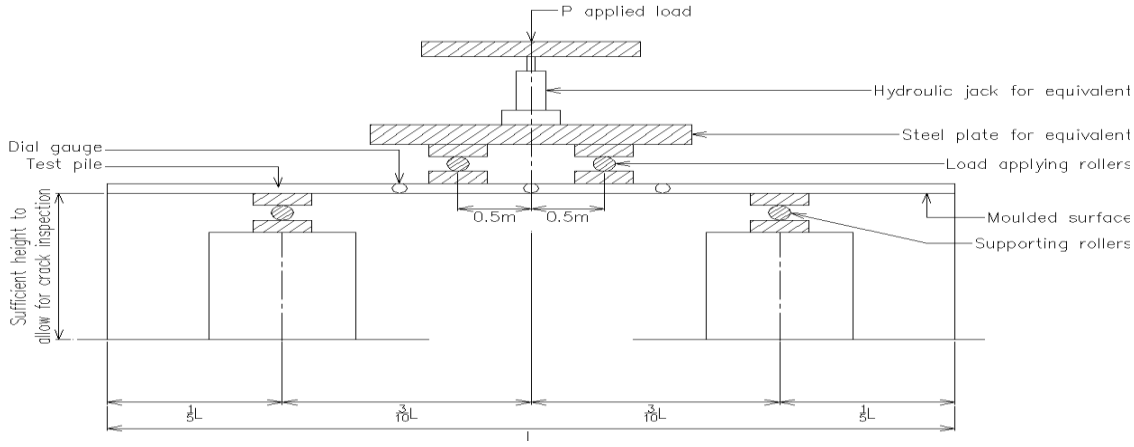

Figure 1- Loading Method

Rate of loading

The load shall be applied at the rate of (0.06 ± 0.04) N/mm2s using suitable equipment which shall be capable of applying the load uniformly without shock using manual or automatic control.

Load pacers

If the equipment is not equipped with a device to maintain, automatically, the specified rate of increase of load on the specimen, a load pacer shall be fitted or alternatively the control shall be done by manual method to ensure the rate of loading as described in the paragraph above is complied. If the pacer has a scale, this scale shall be basically linear such that 1 mm represents not more than 100 N/s. Over the operating range of the scale the accuracy shall be within ± 5 %.

NOTE. The pacer may incorporate a scale with an indicator or alternatively, it may be, for example, a marked disc or pointer, which rotates at the rate at which, the load pointer should move on the load scale being used. If the pacer is fitted with a variable speed control or has preset speeds, then once the variable speed control has been set, or preset speed has been chosen, the pacer speed shall remain within ± 5 % of the specified speed over the operating range. Alternatively if the rate of loading is controlled manually then the manufacturer shall prepare the table of loading application against time.

Load scale indicators or digital displays

The equipment shall be provided with either: -
a) Easily read dials or scales; or

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b) Electrical load indicators, which shall include a visual display.

These load scale indicators or digital displays shall be calibrated by an accredited laboratory.

Test specimens

Test specimens shall be selected randomly from piles casted and results shall be properly documented for inspection. The number of piles to be sampled is to be decided in accordance with the agreement between the parties concerned.

Procedure

1. Prior to testing, select a suitable load and time increment for a selected loading rate for particular hydraulic equipment such that it will facilitate inspection of the pile at the calculated crack load and at the required minimum ultimate load.

2. Check the specimens thoroughly for initial crack before testing. Wipe clean the bearing surfaces of the supporting and loading rollers.

3. Place the test specimen on the support rollers, correctly centred with the longitudinal axis of the specimen at right angles to the rollers. The trowelled surface direction shall be normal to the direction of loading and the moulded surface is in tension (see Figure 1). The moulded surface may not therefore be orientated with its position in the structure. For Spun piles, the test specimen can be placed at any surface position. Do not use packing between the specimen and the rollers.

4. Place the loading equipment and the load applying rollers correctly in the testing setup. Do not begin to apply the load until all loading and supporting rollers are in even contact with the test specimen.

5. Apply the load steadily and without shock at a rate of (0.06 ± 0.04) N/mm2s. Choose the lower loading rates for low strength concrete and the higher loading rates for high strength concrete (i.e. for RC Piles, *f*cu more than 45 N/mm2).

6. Once the loading rate has been adjusted, maintain the rate of loading without change until the applied crack load (*P*c) corresponding to crack moment (*M*c) from the respective tables 2, 3 and 4 as shown below is reached. Then hold the load for a sufficient time to inspect the pile for possible cracking. If crack is present, it shall be checked by means of the test crack measuring gauge and crack width and the location shall be recorded.

7. After step 5.6, continue the loading at the same uniform rate until failure occurs or when the applied load is slightly greater than the minimum ultimate load (*P*min-u), whichever comes first. The minimum ultimate load (*P*min-u) is a value corresponding to the value of *M*c multiplied by the factor *f* from the respective tables 2, 3 and 4 as shown below.

8. If pile failure comes first, the test specimen is considered fail. Record the maximum load (*P*max) applied. *P*max is the maximum applied load (kN), if and when pile failure occurs during the bend test.

9. If the pile does not fail, and when the applied load is slightly greater than *P*min-u is reached, then hold the load for sufficient time to allow for inspection of pile body for cracking. If crack is present, it shall be checked by means of the test crack-measuring gauge and crack width and location shall be recorded.

10. For record purposes, record all the deflection of test specimen shown by dial gauge during loading and unloading.

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Table 2 - Cracking Bending Moment (Mc) and Factor *'f'* for Precast Reinforced Concrete Square Piles (RC Piles)

Nominal Pile Size (mm x mm)	Cracking Bending Moment, Mc (kN-m)		*'f'*	
	Class M	Class J	Class M	Class J
200 x 200	8.3	7.3	1.5	
225 x 225	-	-		
250 x 250	13.1	11.6	1.8	
275 x 275	-	-		
300 x 300	22.1	19.6	2.0	
325 x 325	-	-		
350 x 350	33.7	29.8		
375 x 375	-	-		
400 x 400	47.9	42.5		
450 x 450	65.0	57.8		

Table 3 - Cracking Bending Moment (M_c) And Factor *'F'* For Precast Pretensioned Spun Concrete Piles (Spun Piles)

Nominal Diameter (mm)	Class	Minimum Concrete Strength (N/mm^2)	Cracking Bending Moment (M_c) (kNm)	Factor *'f'*	Effective Prestress (N/mm^2)
250	B	60	12	1.5	5.0
300	A	60	17	1.5	4.0
	B	60	20	1.5	5.0
350	A	60	26	1.5	4.0
	B	60	30	1.5	5.0
400	A	60	38	1.5	4.0
	B	60	43	1.5	5.0
	C	60	54	1.8	7.0
450	A	60	53	1.5	4.0
	B	60	60	1.5	5.0
	C	60	76	1.8	7.0
500	A	60	74	1.5	4.0
	B	60	84	1.5	5.0
	C	60	106	1.8	7.0
600	A	60	123	1.5	4.0
	B	60	141	1.5	5.0
	C	60	177	1.8	7.0
700	A	60	191	1.5	4.0
	B	60	218	1.5	5.0
	C	60	273	1.8	7.0
800	A	60	278	1.5	4.0
	B	60	318	1.5	5.0
	C	60	399	1.8	7.0
900	A	60	390	1.5	4.0
	B	60	445	1.5	5.0
	C	60	558	1.8	7.0
1000	A	60	527	1.5	4.0
	B	60	601	1.5	5.0
	C	60	755	1.8	7.0
1200	A	60	853	1.5	4.0
	B	60	973	1.5	5.0
	C	60	1217	1.8	7.0

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Table 4: Cracking Bending Moment (M_c) And Factor *'F'* For Precast Prestressed Concrete Square Piles –Class Pc-X, Class Pc-Y, Small Piles

Size (mm)	Class of Pile	Minimum Concrete Strength (N/mm^2)	Minimum Effective Prestress (N/mm^2)	Cracking Bending Moment, M_c (kNm)	Factor *'f'*
125	PCS-1	60	3.5	2.9	1.5
	PCS-2	55	3.5	2.9	1.5
150	PCS-1	60	3.5	4.9	1.5
	PCS-2	55	3.5	1.5	1.5
175	PCS-1	60	3.5	7.8	1.5
	PCS-2	55	3.5	7.8	1.5
200	PCS-2	55	3.5	11.7	1.5
	PC-X	60	5.0	13.7	1.5
	PC-Y	60	7.0	16.4	1.7
250	PC-X	60	5.0	26.5	1.5
	PC-Y	60	7.0	31.7	1.7
300	PC-X	60	5.0	45.2	1.5
	PC-Y	60	7.0	54.2	1.7
350	PC-X	60	5.0	70.9	1.5
	PC-Y	60	7.0	85.2	1.7
400	PC-X	60	5.0	104.5	1.5
	PC-Y	60	7.0	125.9	1.7
450	PC-X	60	5.0	147.0	1.5
	PC-Y	60	7.0	177.4	1.7

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TABLE OF CONTENTS

SECTION D: CONCRETING		PAGE
1.	General	D/1
2.	Material	D/4
3.	Concrete Conformity and Identity Testing	D/7
4.	Handling of Concrete	D/13
5.	Construction with Concrete	D/18
6.	Steel Reinforcement	D/23
7.	Formwork and Surface Finish for Structure	D/26
8.	Building Accuracy	D/32
9.	Apparatus	D/32
10.	Precast Concrete Works	D/33
11.	Other Concrete Works	D/35

1. General

This section shall apply to the construction of all structures or parts of structures to be composed of concrete with or without steel reinforcement. The work shall be carried out all in accordance with this specification and the lines, levels, grades, dimensions and cross-sections shown on the Drawings and as required by the S.O..

1.1. Classification of Concrete Mixes

Concrete mixes are classified into designed concrete and proprietary concrete.

1.1.1. Designed Concrete

1.1.1.1. Designed concrete shall comply with *MS EN 206, MS 523-2, MS 523-3* and the Drawings. The exposure classes, durability recommendations, minimum cement content and maximum free water to cement ratio to be used shall be as shown on Table D5, Table D6, Table D7 and Table D8.

1.1.1.2. Any types of cement as specified in Table D1 can be used for designed concrete.

1.1.1.3. Designed concrete shall be produced at a certified concrete plant or a non-certified concrete plant.

(i) A certified concrete plant; the plant that is certified by agency that is accredited by Department of Standards Malaysia or any certification body complying with MS ISO/ IEC 17065; and has certificate of Perakuan Pematuhan Standard (PPS) by CIDB.

(ii) A non-certified concrete plant; the plant that is temporarily set up based on the nature of the site, conforming to sub-section 1.1.1.4.

1.1.1.4. For sites located in remote areas where there are logistical difficulties in obtaining concrete supply, on-site concrete batching is allowed to be used. Prior approval from the S.O. is required and concrete mix shall conform to sub-section 3.2.3.2.

1.1.1.5. The Contractor shall comply with the following requirements:

(i) Notify the S.O. the name of the supplier, location of the plant, journey time to transport the concrete to the site and production capacity of the plant.

(ii) Submit designed concrete report covering all concrete mixes to the S.O. for approval. The designed concrete shall comply with the requirements specified in **Table D5, Table D6, Table D7** and **Table D8** as stated in the Drawings.

(iii) The Contractor shall ensure that the S.O. be permitted to visit or station his representatives at the plant at any stage of the concrete production.

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1.1.2. Proprietary Concrete

1.1.2.1. Proprietary concrete shall conform to *MS EN 206, MS 523-2 and MS 523-3*.

1.1.2.2. Where proprietary concrete is specified, the constituent material and requirement of concrete shall comply with sub-section 2.

1.1.2.3. The Contractor shall provide the information of the proprietary concrete to the approval of the S.O. but not limited to the following documents:

(i) Name of the supplier;
(ii) The type and standard compressive strength class;
(iii) Product warranty;
(iv) Testing result of product; and
(v) Any other identification deemed necessary.

1.1.2.4. The specification for proprietary concrete shall contain the following requirements:

(i) Verification of product conformity by an agency that is accredited by the Department of Standards Malaysia or any certification body complying with *MS ISO/IEC 17065*, to confirm that the proprietary concrete satisfies the limiting value specified or declared based on project requirement.

(ii) The proprietary concrete plant shall be certified by an agency that is accredited by the Department of Standards Malaysia.

1.2. Production of Concrete

1.2.1. General

1.2.1.1. All concrete shall be subjected to production control under the responsibility of the Contractor.

1.2.1.2. Production control shall comprise all measures necessary to maintain the properties of concrete in conformity to the specified requirements. It includes:

(i) Selection of materials;

(ii) Concrete design;

(iii) Concrete production;

(iv) Inspection, sampling and testing;

(v) The use of the results of tests on constituent materials, fresh and hardened concrete and equipment;

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(vi) Inspection of equipment used in transporting for fresh concrete.

1.2.2. Production Control System

Production Control System shall contain adequate documented procedures and instructions. These procedures and instructions shall, where relevant, be established in respect of the control requirement as given in the **Table D18, Table D19** and **Table D26**.

1.2.3. Designed Concrete

1.2.3.1. Designed concrete shall comply with the requirements as stated in the Drawings, *MS EN 206, MS 523-2* and *MS 523-3*.

1.2.3.2. Designed concrete shall be batched, either dry or wet. In wet batching, the primary mixing of the concrete shall be performed in a plant mixer and the secondary mixing shall be done in the truck mixer before discharging the concrete from the truck mixer. Whereas in dry batching, the primary mixing and secondary mixing of the concrete shall be performed in a truck mixer before discharging the concrete from the truck mixer. No extra water or admixtures shall be added after the concrete leave the plant.

1.2.3.3. Designed concrete delivered to the Site shall be accompanied by delivery ticket and manufacturer's batching record stating the details of mix proportions by weight, the grade of concrete, type and size of aggregate, date and time of loading at plant, type and dosage of chemical admixtures and other relevant production details such as, but not limited to, details listed in **Table D26** in suitable format. If the Contractor fails to provide this information, the S.O. or his representative shall immediately reject the total load of the concrete. The S.O. or his representative and the Contractor shall ensure the information provided in the delivery tickets and the manufacturer's batching record complies with the requirement as stated in sub-section 1.1.1 before discharging the concrete.

1.2.3.4. Rejected concrete shall be removed from the Site. The delivery ticket shall be marked 'REJECTED'.

1.2.4. Proprietary Concrete

1.2.4.1. Proprietary concrete shall be batched, either dry or wet, at a ready-mixed plant and transported in purpose-made agitators operating continuously or truck mixers to the Site.

1.2.4.2. Proprietary concrete shall comply with the requirements as stated in the Drawings, *MS EN 206, MS 523-2* and *MS 523-3*. All concrete materials, including water and admixtures shall be mixed in the plant and delivered to Site in purpose made truck mixers.

1.2.4.3. Proprietary concrete delivered to the Site shall be accompanied by delivery ticket and manufacturer's batching record stating the details of the grade of concrete, name of proprietary concrete, date and time of loading at plant, and other relevant production

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details. If the Contractor fails to provide the information, the S.O., or his representative shall immediately reject the total load of the concrete. The S.O., or his representative, and the Contractor shall ensure the information provided in the delivery tickets and the manufacturer's batching record complies with the requirement as stated in sub-section 1.1.2 before discharging the concrete.

2. Material

2.1. Cement

2.1.1. The cement to be used throughout the Work shall be obtained from the manufacturer that is certified from SIRIM or any certification body that is accredited by Jabatan Standards Malaysia and has certificate of *Perakuan Pematuhan Standard* (PPS) by CIDB. The cement shall be described and complied with *MS EN 197-1* as shown in **Table D1** and **Table D2**.

2.1.2. Certificates of Test

2.1.2.1. Manufacturers' certificates of test shall in general be accepted as proof of soundness. Additional tests shall be carried out on any cement which appears to have deteriorated through age, damaged containers, improper storage, or any other reason. The test shall be carried out at any approved laboratory in accordance with *MS EN 196* at the expense of the Contractor. Any batch of cement that has been sampled and tested and found not to have complied with the requirements shall be rejected and removed from the Site.

2.1.2.2. The S.O. may, without tests being made, order that any bag of cement, a portion of the contents of which has hardened, or which appears to be defective in any other way, be removed from the Site.

2.1.3. Transportation and Storage

The cement shall be transported to the Site in covered vehicles adequately protected against water. It shall be stored in a weatherproof cement store to the approval of the S.O.. Cement stored in bags shall not be laid directly on the ground. It shall be taken for use in the Work in the order of its delivery into the store. Cement delivered in bulk shall be stored in purposely built silos of an approved design.

2.2. Aggregates

2.2.1. Aggregates shall be naturally occurring sand or granite crushed or uncrushed, except otherwise specified, and shall comply with *MS EN 12620*. They shall be obtained from a source approved by the S.O.. Marine aggregates shall not be used.

2.2.2. Coarse Aggregates

Coarse aggregates shall comply with *MS EN 12620* and tests shall be carried out according to *MS EN 933, BS EN 1744* and *MS EN 1097* as specified in **Table D3**. For work below ground level, only crushed granite

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shall be used unless otherwise specified in the Drawings. The maximum nominal size of aggregate shall be as specified in the Drawings.

2.2.3. Fine Aggregates

Fine aggregates shall comply with *MS EN 12620*. In the context of *MS EN 12620*, the term sand refers to 'fine aggregate'. Unless otherwise specified in the Drawings, tests shall be carried out in accordance with *MS EN 933, BS EN 1744* and *MS EN 1097* as specified in **Table D3**.

2.2.4. Grading

2.2.4.1. Coarse Aggregates

The grading of coarse aggregates shall be analysed as described in *MS EN 12620* and shall be within the limits specified in **Table D4**.

2.2.4.2. Fine Aggregates

The grading of fine aggregates shall be analysed as described in *MS EN 12620* and shall be within the limits specified in **Table D4**.

2.2.5. Sampling and Testing of Aggregates

Where site mixing is performed, samples of fine and coarse aggregates approved by the S.O. shall be kept on Site. These samples shall give a fair indication of the general quality of the aggregates for comparison with the aggregates delivered during the course of executing the Work. Tests shall be carried out on samples of the latter, taken at intervals as required by the S.O., or whenever there is a change of source. The appropriate method of sampling and testing shall be in accordance with the standards as specified in **Table D3**. Any batch of aggregate rejected by the S.O. shall be removed from the Site.

2.2.6. Storage of Aggregates

2.2.6.1. Separate storage facilities with adequate provision for drainage shall be provided for each different size of aggregate used.

2.2.6.2. Aggregate shall be handled and stored to minimize segregation and contamination.

2.3. Water

Water shall comply with the requirements of *MS EN 1008*. It shall be clean and free from materials deleterious to concrete in the plastic and hardened state and shall be from a source approved by the S.O.. The S.O. may instruct the Contractor to carry out chemical tests at any approved laboratory at the expense of the Contractor. The Contractor shall make adequate arrangement to supply and store sufficient water at the Site for use in mixing and curing of concrete.

2.4. Admixtures

2.4.1. The admixtures, the sampling and testing of the admixtures and the information to be provided with the admixture supplied shall comply with

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MS EN 934.

2.4.2. All admixtures shall be used strictly in accordance with manufacturer's recommendation.

2.4.3. For admixture to be used in design concrete, the Contractor shall carry out initial test to verify the concrete mix as required in sub-section 3.1.2.

2.5. Requirements for Concrete

2.5.1. Concrete Grade

The grade of concrete to be used in the Works shall be as stated in the Drawings and/or in the Bill of Quantities. Normal concrete shall be designated as C X/Y; light weight concrete shall be designated as LC X/Y, where X is minimum characteristic cylinder strength (N/mm^2) and Y is minimum characteristic cube strength in (N/mm^2).

2.5.2. Cement Content

2.5.2.1. Cement content in this specification shall refer to the total quantities of cement as approved in sub-section 2.1, or the total quantities of cementitious materials comprising CEM I and other constituents complying to *MS EN 197-1*.

2.5.2.2. Minimum Cement Content

The minimum cement content shall be in accordance with **Table D5, Table D6** and **Table D7**, unless otherwise shown on the Drawings.

2.5.3. Consistence

2.5.3.1. The consistency of the fresh concrete shall comply to *MS EN 206* and suitability for the condition of handling and placing so that after compaction, it surrounds all reinforcement, tendons and ducts and completely fills the formwork. Consistency of the concrete shall be within one of the following limits:

(i) Slump classes (Refer **Table D9**)

(ii) Compacting classes (Refer **Table D10**)

(iii) Flow classes (Refer **Table D11**)

(iv) Slump Flow Classes (Refer **Table D12**)

2.5.3.2. Unless otherwise specified in the Drawings, consistency values expressed as slump and flow classes appropriate to different uses of concrete shall be as given in **Table D13**.

2.5.4. Total Chloride Content

The Total Chloride Content of the concrete mix arising from the aggregate or any other source shall not in any circumstances exceed the limits in **Table D14** expressed as a percentage relationship between chloride ions and weight of cement in the mix. The tests shall be carried out in

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accordance with **Table D15** for each grade of concrete, to demonstrate that these limits are not exceeded.

2.5.5. Sulphate Content

The sulphate content for aggregate and water shall not exceed the value given in BS EN 12620 and MS EN 1008 respectively. Tests shall be carried out in accordance with *BS EN 1744-1* and *MS EN 196-2* to demonstrate that this limit is not exceeded.

3. Concrete Conformity and Identity Testing

3.1. Evaluation of Conformity

3.1.1. General

3.1.1.1. The Contractor is only responsible for the conformity evaluation of specified requirements of non-certified concrete. For this purpose, the Contractor shall refer to *MS EN 206* to carry out the following task:

(i) Initial test

(ii) Production control including conformity control

3.1.1.2. All tests shall refer to the respective concrete compressive strength test (cube or cylinder).

3.1.1.3. The designed concrete testing flow chart can be referred to **Figure D1a** and **Figure D1b**.

3.1.2. Initial Test

3.1.2.1. Initial test is required, and the Contractor shall be responsible for the test.

3.1.2.2. In the event of new concrete composition is used, initial test shall be performed to provide a concrete that achieves the specified properties or intended performance with a margin of 1.64 x standard deviation.

3.1.2.3. The concrete composition shall be reviewed periodically to provide assurance that all concrete designs are still in accordance with the actual requirements.

3.1.2.4. Initial test shall be repeated if there has been a significant change either in the constituent materials, admixtures or in the specified requirements on which the previous test was based on.

3.1.2.5. Test Conditions

(i) In general, initial test shall be carried out on fresh concrete with a temperature 27±3 ºC.

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(ii) For the initial test of single concrete composition, at least three (3) specimens from each of three (3) batches, totalling nine (9) specimens shall be tested at 28 days.

(iii) The compressive strength of a concrete composition shall be taken to be the average of the nine (9) specimens.

3.1.2.6. Criteria for Adoption of Initial Tests

(i) The compressive strength of concrete with the composition to be adopted for the actual case shall exceed the values f_{ck} as specified in **Table D16** or **Table D17**. The margin should be at least 6 N/mm^2 to 12 N/mm^2 depending on the production facilities, material and the available background information about the variation. If there are insufficient data, the margin for the initial mix design shall be taken as 12 N/mm^2.

(ii) The consistency of the concrete shall be within the limits of the consistency class as in **Table D13**, at the time at which the concrete likely to be placed or delivered.

(iii) For assessing the properties of fresh concrete, the differences between the type of mixer and mixing procedure applied during the initial test and those applied during actual production shall be taken into account.

(iv) For other properties that are specified, the concrete shall meet the specified values with an appropriate margin.

3.1.3. Conformity Control for Designed Concrete

3.1.3.1. General

(i) For normal-weight and heavy-weight concrete of strength classes from C8/10 to C55/67 or light-weight concrete from LC8/9 to LC55/60, sampling and testing shall be performed on concrete compositions.

(ii) In the sampling and testing plan, the conformity criteria of concrete shall be distinct in compositions between initial production and continuous production, where:

a) Initial production covers the production until at least 35 test results are available.

b) Continuous production is achieved when at least 35 test results are obtained over a period not exceeding 12 months.

(iii) If the production of a concrete composition has been suspended for more than 12 months, the criteria, sampling and testing plan given for initial production shall be adopted.

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(iv) If the strength is specified for a different age, the conformity is assessed on specimens tested at the specified age.

(v) During continuous production, the sampling and testing plan and the criteria for initial production may be adopted if approved by the S.O..

(vi) Identity testing shall be carried out in accordance with sub-section 3.2 in order to verify that a defined volume comes from a conforming population.

3.1.3.2. Sampling and Testing

(i) Samples of concrete shall be randomly selected in accordance with *BS EN 12350*. The minimum rate of sampling and testing of concrete shall be in accordance with **Table D18** at the rate that gives the highest number of samples for initial or continuous production.

(ii) The samples shall be taken after adding any water or admixtures to the concrete, but sampling before adding plasticizer to adjust the consistence is permitted where there is proof by initial testing that the plasticizer or super plasticizer in quality to be used has no negative effect on the strength of the concrete.

(iii) The test result shall be obtained from an individual specimen or the average of the results when two or more specimens made from one sample are tested at the same age.

(iv) Where two or more specimens are made from one sample and the range of the test values is more than 15% of the mean, the result shall be disregarded.

3.1.3.3. Conformity Criteria for Compressive Strength

(i) Conformity assessment shall be made on test results over a period not exceeding the period given by one of the following options depending on the rate of testing:

a) Plants with lower testing rates

Number of test results for designed concrete (less than 35 per three months), the assessment period shall comprise at least 15 results and not more than 35 consecutive results taken over a period not exceeding 6 months.

b) Plants with higher testing rates

Number of test results for designed concrete (35 or more per three months), the assessment period shall

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comprise at least 15 consecutive results and does not exceeding 3 months.

(ii) Conformity of concrete compressive strength is assessed on specimens tested at 28-days in accordance with:

a) Groups of n overlapping consecutive test results f_{cm} (Criterion 1)

b) Each individual test result f_{cl} (Criterion 2)

(iii) Conformity is confirmed if both the criteria given in **Table D19** for either initial or continuous production are satisfied.

(iv) At the end of initial production, the standard deviation (σ) of the population shall be estimated from at least 35 consecutive test results taken over a period exceeding three months. When continuous production commences, this value of standard deviation shall be used to check the conformity over the first assessment period. At the end of the first and subsequent assessment periods, the standard deviation is checked to determine whether it has changed significantly using the limits given in **Table D20**. If it has not changed significantly, the current estimate of the standard deviation applies to the following assessment period. When there is a significant change in standard deviation, a new standard deviation is calculated from the most recent 35 consecutive results and applied to the following assessment period.

3.1.4. Permeability Requirement

For marine structures, Chloride Diffusion Test shall be carried out in accordance with *BS EN 12390-11* to assess the potential chloride resistance to chloride ingress for a concrete mix. The precision estimates for calculated chloride content, C_s and non-steady state chloride diffusion coefficient, D_{nss} are given in **Table D21**.

3.2. Identity Test

3.2.1. General

3.2.1.1. Identity testing indicates whether the defined volume of concrete under review belongs to the same population verified as conforming to the characteristic strength via conformity assessment.

3.2.1.2. Identity testing is conducted at the Site upon delivery of concrete.

3.2.2. Sampling and Testing

3.2.2.1. Designed Concrete

(i) The sampling rate for identity testing specified in **Table D22**.

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(ii) A sample is made up of three (3) specimens.

(iii) Samples shall be taken from different batches in accordance with *BS EN 12350*. Test specimens shall be prepared and cured in accordance with *MS EN 12390-2*. The compressive strength of the specimens shall be determined in accordance with *MS EN 12390-3*.

(iv) One (1) specimen from the sample shall be tested for the 7-days compressive strength. The compressive strength shall not fall below two-third (2/3) of the 28-days compressive strength as given in **Table D16** and **Table D17**.

(v) The remaining two (2) specimens shall be tested at 28-days. The compressive strength of the specimens shall be obtained from the average of the results of the two specimens.

(vi) For 28-days compressive strength test, if the difference between the two (2) test result divided by their mean exceeds 15%, the test result, shall be deemed invalid.

3.2.3. Conformance identity criteria for compressive strength

3.2.3.1. Concrete under production control certification

(i) Identity of concrete is assessed for each individual strength test result and the average overlapping discrete results as identified in **Table D23**.

(ii) Concrete is deemed to come from a conforming population if both the criteria in **Table D23** are satisfied for n results derived from strength tests on samples taken from the defined volume of concrete.

3.2.3.2. Concrete not under production control certification

(i) At least three (3) samples shall be taken for testing from the defined volume of concrete.

(ii) Concrete is deemed to come from a conforming population if both the criteria in **Table D24** are satisfied for n results derived from strength tests on samples taken from the defined volume of concrete.

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3.2.4. Identity Testing for Slump and Flow

3.2.4.1. Sampling and Testing

(i) Sampling of fresh concrete using spot sample shall be obtained from the initial discharge, if concrete is delivered in a truck mixer or agitating equipment. The spot sample shall be taken after a discharge of approximately 0.3 m^3 by taking six increments from the moving stream of the concrete. Take at least 1.5 times the quantity required for the tests in accordance with *BS EN 12350*.

(ii) The sample shall be remixed on a non-absorbent surface before carrying out the test.

(iii) For slump test, the test is only valid if it yields a true slump. The slump value (h) is measured in accordance with *BS EN 12350* and shown in **Figure D2**.

(iv) For flow test, the maximum dimension of the concrete spread shall be measured in the two directions as shown in **Figure D3**. The flow value (f) is the average dimension of the two directions in accordance with *BS EN 12350*.

3.2.5. Conformance Identity Criteria for The Slump and Flow of an Individual Batch

3.2.5.1. If the measured slump meets the requirements specified in **Table D25**, the identity test shall confirm that the batch conforms to *MS EN 523-2* with respect to its consistency.

3.2.5.2. If the measured flow meets the requirements specified in **Table D11**, the identity test shall confirm that the batch conforms to *MS EN 523-2* with respect to its consistency.

3.3. Action to be Taken for Non-Conformity of the Product

3.3.1. The following actions shall be taken by the Contractor in the event of non-conformity:

3.3.1.1. Check test results and if invalid, take action to eliminate errors.

3.3.1.2. If non-conformity is confirmed e.g., by retesting, take corrective actions including a management review of relevant production control procedures.

3.3.1.3. Where there is confirmed non-conformity with the specification unidentified/ unnoticed at delivery, notice shall be given to the S.O. in order to avoid any consequential damage.

3.3.1.4. Record actions on the sub-sections above.

3.3.2. In the event that the compressive strength results of the test do not meet the specified requirements mentioned in sub-section 3.2, the S.O. shall determine the action to be taken:

3.3.2.1. If the 7-days concrete strength is less than the specified strength

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requirements (2/3 of characteristic strength), no more concrete shall be placed on the suspect concrete and no removal of propping on the affected area shall be allowed until the 28-days strength result compliance is available, or unless otherwise approved by the S.O. in writing.

3.3.2.2. For non-compliance of 28- days compressive strength, the S.O. may direct other measures to be taken to rectify the situation to make the work secure.

3.3.2.3. The S.O. may instruct additional tests to be carried out on the hardened concrete to determine the quality of the suspected concrete. The test may include non-destructive and destructive tests. All methods of testing shall conform to *MS EN 12504* and results shall be assessed according to *MS EN 13791* and *MS 1242.*

3.3.2.4. If the results from the additional test did not meet the requirements, the S.O. may instruct the Contractor the following actions:

(i) The section which fails the test shall be removed; or

(ii) The Contractor shall submit recommendations for remedial work to the suspected concrete. All the recommendations shall be certified by a Professional Engineer.

3.3.3. All works instructed under this sub-section shall be at the Contractor's expense and no extension of time shall be granted for such works.

4. Handling of Concrete

4.1. Supervision

The Contractor shall ensure the required standard of control over materials and workmanship. The S.O. shall be afforded all reasonable opportunities and facilities to inspect the constituent materials and the production of concrete and to take samples for testing.

4.2. Transporting

Concrete shall be transported from the mixer to the formwork as rapidly as practicable by methods, which will prevent segregation or loss of any constituents or ingress of foreign matter or water while maintaining the required workability. It shall be deposited as near as practicable in its final position to avoid rehandling or moving the concrete horizontally by vibration. The concrete shall be conveyed by chutes or concrete pumps only with permission from the S.O..

4.3. Placement

4.3.1. Placement of Concrete in Dry Condition

4.3.1.1. For all concrete whether mixed on or off the site of the Work, each batch shall be placed and compacted within two (2) hours after the time of loading were transported in truck mixers or

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agitators or within one (1) hour after the time of loading where non-agitating equipment is used, unless a shorter time is specified or a longer time permitted by the S.O.. Concrete shall not be placed in any part of the structure until the approval of the S.O. has been obtained. If concreting is not started within 24 hours of approval given, approval shall again be obtained from the S.O..

4.3.1.2. All formwork and reinforcement bar shall be clean and free from standing water immediately before placing of concrete. Concreting shall be carried out continuously between and up to predetermined construction joints in one sequence of operation. It shall be thoroughly compacted by either hand tamping or mechanical vibration or both and shall be thoroughly worked into the corners. After tamping into place, the concrete shall not be subjected to disturbance other than such as incidental to compaction by vibration. In the event of unavoidable stoppage in positions not predetermined, the concreting shall be terminated on a horizontal plane and against vertical surfaces using stop boards. The location for termination shall be subjected to the approval of the S.O..

4.3.1.3. Fresh concrete shall not be placed against in-situ concrete which has been in position for more than 45 minutes unless a construction joint is formed in accordance with sub-section 5.1. When in-situ concrete has been in place for four (4) hours, no further concrete shall be placed against it for a further 20 hours. Where retarding admixture has been used, the S.O. may approve variation to this limit.

4.3.1.4. Unless otherwise approved by the S.O., concrete shall be deposited in horizontal layers to a compacted depth not exceeding 450 mm when internal vibrators are used or 300 mm in all other cases. The surface of the concrete shall be maintained reasonably levelled during placing.

4.3.1.5. Concrete shall not be poured into place from a height exceeding 1.5 m. However, higher pouring may be allowed provided the mix has been well designed and proportioned. When trunking or chutes are used, they shall be kept clean and used in such a manner as to avoid segregation.

4.3.1.6. The Contractor shall maintain an experienced steel fixer at the Site of reinforced concrete works during the placing of concrete to reposition any reinforcement which may be displaced.

4.3.1.7. Where concrete is placed directly against ground, the fresh concrete shall be protected against intermixing with the substrate by a 50mm blinding layer.

4.3.2. Placement of Concrete Under Water

4.3.2.1. No concrete shall be placed in flowing water. Underwater concrete if deemed unavoidable, shall be placed in position by Tremie pipes from the mixer. During and after concreting under water, pumping or dewatering operations in the immediate vicinity shall be suspended until the S.O. permits them to

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continue. Where the concrete is placed by a Tremie pipe, the following requirements shall be applicable:

(i) The hopper and Tremie pipe shall be a closed system. The bottom of the Tremie pipe shall be kept as far as practicable beneath the surface of the placed concrete.

(ii) The Tremie pipe shall be large enough with due regard to the size of aggregate. For 20 mm aggregates, the Tremie pipe shall be of a diameter not less than 150 mm and for larger aggregates, a bigger diameter Tremie pipe approved by the S.O. shall be used.

(iii) Unless otherwise agreed by the S.O., the first charge of concrete shall be placed with a sliding plug pushed down the Tremie pipe ahead of it to prevent mixing of concrete and water.

(iv) The Tremie pipe shall always penetrate well into the concrete with an adequate margin of safety against accidental withdrawal if the pipe is surged to discharge the concrete.

(v) The concrete shall be deposited wholly by Tremie pipe and the method of deposition shall not be changed part way up to prevent the laitance from being entrapped within the structure.

(vi) All Tremie pipes shall be properly cleaned after use.

4.4. Placement Temperature

4.4.1. Placement temperature shall comply with *MS 523-3* to prevent premature setting and loss of water during placing of concrete in the formwork.

4.4.2. At the time of placing, no part of the fresh concrete shall have a temperature exceeding 36°C.

4.4.3. After placement of the concrete, the temperature of the concrete shall not be more than 70°C.

4.4.4. The procedure used to measure the temperature of the fresh concrete shall be as follows:

4.4.4.1. Within 2 min of taking the sample at delivery, insert a Type A 100 mm immersion thermometer having a range of -5°C to +110°C, graduated in intervals of 1°C and conforming to *BS 1704*, in the sample to a depth of not less than 100 mm. When steady conditions have been maintained for 1 min, record the temperature to the nearest 1°C; and

4.4.4.2. Use an alternative form of temperature measurement device with a precision at least that of a thermometer conforming to *BS 1704*, to record the steady-state temperature to the nearest 1°C.

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4.4.5. Freshly placed concrete shall be protected from direct sunlight and from loss of moisture by covering, shading or other means.

4.4.6. The Contractor shall provide the method statement for temperature control in the case of large volume and/ or continuously concrete pour exceeding 100m^3 or as deemed necessary by the S.O. for approval before commencement of Works.

4.5. Compaction

4.5.1. Unless otherwise approved by the S.O., concrete shall be thoroughly compacted by vibration and thoroughly worked around the reinforcement, tendons or duct formers, around embedded fixtures and into corners of the formwork to form a dense, homogenous mass, free from voids and which will have the required surface finish when the formwork is removed. Vibration shall be applied continuously during the placing of each batch of concrete until the expulsion of air has practically ceased and in a manner, which does not promote segregation of the ingredients.

4.5.2. The concrete maintained between the two walls of formwork shall be compacted by internal or external vibrators. Concrete in slabs with no formwork on its upper surface shall be compacted either by vibrators of the pan type or by a vibrating screen.

4.5.3. The internal vibrators shall be inserted and withdrawn slowly and at a uniform pace of approximately 100 mm per second. Compaction shall be deemed to be completed when cement mortar appears in an annulus around the vibrator. Over vibration leading to segregation of the mix must be avoided. The internal vibrators shall be inserted at points judged by the area of mortar showing after compaction, with a certain allowance made for overlapping and they shall not be allowed to come into contact with the formwork or the reinforcement and shall be inserted at a distance of not less than 75 mm from the formwork.

4.5.4. The pan vibrator shall be placed on the surface of the concrete, which shall have previously been tamped and levelled leaving an allowance in height for compaction until the cement mortar appears under the pan. The vibrator shall then be lifted and placed on the adjoining surface and this operation shall be repeated until the whole surface has been compacted. Alternatively, a vibrating screen spanning the full width of the surface may also be used.

4.5.5. Whenever vibration has to be applied externally, the design of formwork and disposition of vibration shall receive special consideration to ensure efficient compaction and to avoid surface blemishes. The vibration shall be such that there will be no excess water on the top surface on completion of compaction.

4.5.6. External vibrators shall be firmly secured to the formwork which must be sufficiently rigid to transmit the vibration and strong enough not to be damaged by it. Internal vibrators shall be capable of operating at not less than 10,000 cycles per minute and external vibrators at not less than 3,000 cycles per minute. Sufficient vibrators in serviceable condition shall be on Site so that spare equipment is always available in the event of breakdowns. Vibrators shall be operated by workmen skilled in their use.

4.5.7. Concrete shall not be subjected to any disturbance within 24 hours after

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compaction. No standing or flowing water shall be allowed to come into contact with exposed concrete surfaces during the first two (2) hours after placing and compaction of the concrete.

4.5.8. In the event where inadequate or improper compaction is suspected, the S.O. has the right to inspect and to carry out further tests. The tests may include non-destructive and destructive methods. All expenses incurred in carrying out such sampling, testing and remedial works shall be borne by the Contractor irrespective of whether the tests prove the structure to be sound or otherwise.

4.6. Curing and Protection

4.6.1. All concrete work shall be cured for the full period of curing which shall not be less than seven (7) days for F1, F2, F3 and F4 surfaces, but not less than five (5) days for F11, F12, F13, F14 and F15 surfaces. Duration of curing for unformed finishes shall not be less than seven (7) days.

4.6.2. Curing and protection shall start immediately after compaction of the concrete to protect it from:

4.6.2.1. Impact damage such as shock, overloading or falling earth which may disrupt the concrete and interface with its bond to reinforcements.

4.6.2.2. Premature drying out from direct sunlight and wind to minimise plastic shrinkage.

4.6.2.3. Leaching out by rain and flowing water.

4.6.2.4. High internal thermal gradients.

4.6.2.5. Harmful contact against aggressive agents e.g., chloride.

4.6.2.6. Harmful weather conditions

4.6.3. Normal Curing and Protection

4.6.3.1. Concrete, after it is placed and until the expiration of the curing duration, shall not be allowed to dry out. Provision shall be made for adequate protection against direct sunlight and wind to allow the process of curing to complete within the specified period.

4.6.3.2. The following methods are suitable for curing used separately or in sequence after concrete is placed without delay:

(i) keeping the formwork in place;

(ii) covering the concrete surface with vapour-proof sheets which are secured at the edges and joints to prevent draughts;

(iii) placing of wet coverings on the surface and protection of these coverings against drying out;

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(iv) keeping the concrete surface visibly wet with suitable water;

(v) application of a curing compound of established suitability;

(vi) Other curing methods of equal effectiveness may be used.

4.6.3.3. The use of other methods of curing may be deemed necessary when the concrete is subjected to high internal thermal gradient, or with large, exposed surface area. The Contractor shall submit method statement to the S.O. for approval.

4.6.3.4. In the event where the Contractor does not do proper curing, the S.O. has the right to inspect and to carry out further tests which may include destructive methods. All expenses incurred in carrying out such sampling, testing and remedial works shall be borne by the Contractor irrespective of whether the tests proved the structure to be sound or otherwise.

4.6.4. Accelerated Curing

4.6.4.1. Steam curing may be used for precast concrete element at the factory.

4.6.4.2. After the completion of the placing of concrete, four (4) hours shall elapse before its temperature is raised, unless the Contractor is able to prove that curing can start earlier by furnishing all the relevant supporting data to the S.O.. The rise in temperature within any period of 30 minutes shall not exceed 10°C and maximum temperature attained shall not exceed 70°C unless it can be proven that any deviation from this provision shall not result in any detrimental effect to the concrete work. The rate of subsequent cooling shall not exceed the rate of heating.

4.6.4.3. The use of accelerated curing methods for concrete containing other types of cement or any admixture or any additional materials shall be to the approval of the S.O..

5. Construction with Concrete

5.1. Construction Joints

5.1.1. Construction joints shall be made at the location as shown on the drawing and concreting work shall be carried out continuously up to the construction joints. If the position and detail of any construction joints is not described in the drawings, the Contractor shall propose and obtain the approval of the S.O. prior to commencement of concreting. The construction joints shall be made as few as possible with reasonable precautions against shrinkage. The joints shall be at right angles to the general direction of the member and shall take due account of shear and other stresses.

5.1.2. Concrete shall not be allowed to run to a feather edge and vertical joints shall be formed against a stop end. The top surface of a layer of concrete shall be level and flat unless design considerations make this undesirable. Joint lines shall be so arranged that they coincide with features of the

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finished work, wherever possible.

5.1.3. At horizontal construction joints, gauge strips about 25 mm width shall be placed inside the forms along all exposed surfaces to ensure a straight joint on those surfaces. Where a kicker (that is a starter stub) is used for the construction of walls and columns, it shall be at least 75 mm high, to be constructed monolithically with the base concrete.

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5.1.4. Where vertical construction joints are necessary in mass concrete structures, reinforcing bars shall be placed across the joints to make the structure monolithic, all to the approval of the S.O..

5.1.5. Prior to recommencement of concreting on a joint, the surface of the concrete against which new concrete will be cast shall be free from laitance and shall be roughened to the extent that the coarse aggregate is exposed but not disturbed. Care shall be taken to avoid damaging the lines of the joint. Care shall also be taken that the joint surface is clean and damp but not wet and the exposed adjoining surfaces shall be of consistent colour. Immediately before the fresh concrete is placed against the joint, fresh rich cement mortar (1:2) shall be applied to the exposed surface.

5.1.6. Where the S.O. considers that special preparation is necessary, e.g., for an in-situ structural connection, preparation shall be carried out, preferably when the concrete has set but not hardened, by spraying with a fine spray of air and water or brushing with a stiff brush sufficiently to remove the outer mortar skin and expose the larger aggregates without disturbing them. Where this treatment is impracticable, sand blasting or a needle gun shall be used to remove the surface skin and laitance. Hardened surfaces shall be chipped manually or mechanically to be free from laitance and properly roughened to the extent that the coarse aggregates are being exposed.

5.2. Fixing Blocks, Brackets, Built in Bolts, Holes, Chases, Et Cetera

5.2.1. All fixing blocks, brackets, built in bolts, holes, chases, et cetera shall be accurately set out and formed and carefully sealed prior to the concrete being placed. It is the responsibility of the Contractor to obtain all such information for these sub-sections of work and to obtain the approval of the S.O. before incorporating such work prior to the concrete being placed.

5.2.2. Bolts and other inserts to be cast into the concrete shall be securely fixed to the formwork in such a way that they are not displaced during the concreting operations and that there is no loss of materials from the wet concrete through holes in the formwork.

5.2.3. Unless otherwise shown on the Drawings or instructed by the S.O., reinforcement shall be locally moved so that the minimum specified cover is maintained at the locations of inserts, holes, chases, et cetera. In the event where the minimum cover cannot be maintained, the Contractor shall take the necessary precautions to protect the reinforcements against corrosion by applying an approved coating material to the reinforcements and the concrete cover.

5.2.4. Temporary plugs shall be removed and the threads of built-in bolts shall be cleaned and greased before handing over any part of the Work.

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5.3. Movement Joints.

5.3.1. Movement Joints, Expansion joints, contraction joints or other permanent structure joints shall be provided in the positions and constructed and sealed with waterproofing materials as detailed in the Drawings.

5.3.2. When forming movement joints, joint filler shall be fixed firmly to the first-placed concrete. If more than one strip is used within a joint, it is essential to butt the ends tightly or tape them together to prevent grout leakage restricting the closure of the joint.

5.3.3. It is essential that the concrete on both sides of the joint, when placed, is thoroughly compacted to form a dense uniform mass. Where stop ends comprise more than one element, particular care is necessary to ensure that joints between elements are sufficiently tight to allow no grout loss through them during compaction of the concrete.

5.3.4. Where flexible water stops are used, they shall be fixed to ensure that they are not displaced from their intended position during compaction of the concrete and that the concrete surrounding them is fully compacted. The design of the water stop should be practical and take account of the problems often associated with integral water stop construction in difficult placing conditions.

5.3.5. Water stops laid horizontally and located within the concrete mass shall be avoided since they attract the greatest risk of local honeycombing.

5.3.6. Unless otherwise shown on the Drawings, all exposed expansion joints shall be covered with 0.7 mm thick aluminium cover strips fixed with masonry nails at 300 mm centres.

5.4. Sealants and Special Materials

5.4.1. General

The installation method and the selection, mixing, application and curing of all joint waterproofing materials shall be in accordance with the manufacturer's recommendations. The Contractor may propose to use alternative joint waterproofing materials by submitting supporting technical information, test reports and samples of the proposed waterproofing materials to the S.O. for approval.

5.4.2. Waterproofing Materials

All waterproofing materials used at public access areas shall be protected with non-shrink grout covering.

5.4.3. Water stops

5.4.3.1. The material for water stop can be made of rubber or flexible plastics in accordance with *MS 1292*.

5.4.3.2. Water stops shall be as specified in the Drawings and shall be installed in accordance with *BS EN 1992-3* and the manufacturer’s recommendation to the approval of the S.O..

5.4.3.3. Water stops shall be securely positioned in the formwork to

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prevent displacement during concreting.

5.4.3.4. The selection and requirements of a water stops are as below:

(i) The overall width of water stops shall be greater than the smallest structural concrete cast;

(ii) The distance between the surface of the concrete and the water stops shall be greater than half the width of the water stops;

(iii) The width of the water stops shall be more than 150 mm;

(iv) The distance between the water stops and steel reinforcement shall be more than 50 mm.

5.4.4. Two-part Polysulphide or Two-part Polyurethane Sealant

5.4.4.1. Two-part Polysulphide or two-part polyurethane sealant for external use shall comply with the following requirements:

(i) Conformance to *BS 4254*;

(ii) Minimum joint movement capacity of ± 27.5% of joint width at 27.5ºC;

(iii) Shore 'A' Hardness of 25 ± at 27.5ºC;

(iv) Resistance to dilute acids, alkali and all kind of fuel.

5.4.5. Preformed Flexible Strip Sealant

5.4.5.1. Preformed flexible strip sealant shall comply with the following requirements:

(i) Shall only be used in horizontal joints and be subjected to pressure;

(ii) Throughout its length;

(iii) Good adhesion;

(iv) Water resistant;

(v) Non-staining.

5.4.6. Bitumen/Rubber Cold Applied Membrane

5.4.6.1. Bitumen/rubber cold applied membrane shall comply with the following requirements:

(i) Minimum joint movement capacity of ±10% of joint width at 27.5ºC;

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(ii) 90% solid content;

(iii) Resistant to dilute acid and alkali.

5.4.7. Hot-Poured Rubber/Bitumen Sealing Compound.

5.4.7.1. Hot-poured rubber/bitumen sealing compound shall comply with *BS 2499*.

5.4.8. Bituminous Sheeting

5.4.8.1. Bituminous sheeting with non-asbestos fibre shall comply with the following requirements:

(i) Resistant to lime water (no visual effect after two (2) weeks immersion);

(ii) Maximum water absorption of 10% of dry weight;

(iii) Minimum tensile strength of 50 kg/cm^2;

(iv) Ozone and ultraviolet resistant.

5.4.9. Neoprene Bearing Pads

5.4.9.1. Neoprene bearing pads shall comply with the following requirements:

(i) Shore 'A' Hardness of 60 ± 5 at 27.5^{o}C;

(ii) Minimum rupture strength of 105 kg/cm^2;

(iii) Minimum rupture elongation of 300%.

5.4.10. Polyurethane Foam Backing Rods

5.4.10.1. Polyurethane foam backing rods used as sealant stops in panel joints shall have the following properties: -

(i) Minimum compressibility of 75% of original volume at 27.5^{o}C;

(ii) Excellent resilient properties;

(iii) Density between 35 kg/cm^3 and 45 kg/cm^3;

(iv) Total resistance to common acids, lubricants and detergents;

(v) Total resistance to water infiltration by capillary action;

(vi) Suitability for up to 70°C.

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6. Steel Reinforcement

6.1. General

The Work shall consist of furnishing and placing reinforcing steel in accordance with this specification and in conformity with the Drawings or as directed by the S.O..

6.2. Materials

The reinforcing steel to be used throughout the Work shall be obtained from the manufacturer that is certified from SIRIM or any certification body that is accredited by Jabatan Standards Malaysia and has certificate of *Perakuan Pematuhan Standard* (PPS) by CIDB.

6.2.1. Hot rolled mild steel and high yield bars shall comply with the requirements of *MS 146*. Cold worked steel bars shall comply with the requirements of *BS 4461*. Hard drawn mild steel wire shall comply with the requirements of *MS 144*.

6.2.2. Steel fabric reinforcement shall comply with the requirements of *MS 145* and shall be delivered to the Site in flat sheets, unless otherwise specified.

6.2.3. Dowel bars shall be plain, round bars conforming to the requirements of *MS 146*. They shall be free from burring or other deformations restricting slippage in the concrete. Dowel bar sleeves used for debonding shall be of approved synthetic material. The closed end of the sleeve shall be filled with 25 mm thick compressible foam fillers and the sleeve shall fit tightly over the length of the bar to be debonded.

6.2.4. Before any reinforcement steel is brought to Site, the Contractor shall furnish the mill certificates of tests and these shall be submitted for acceptance by the S.O. In addition, Contractor shall on request, furnish the S.O. with a test sheet from approved laboratories for any batch of bars, giving the results of each of the mechanical tests and/or chemical composition analysis required under the MS or any equivalent international standards approved by the S.O.. The specified characteristic strength of steel reinforcement shall be as given in **Table D27**.

6.2.5. During the course of the Work, any reinforcement found not to be in accordance with the MS or BS may be rejected by the S.O. notwithstanding any previous acceptance on the strength from the test certificates. The S.O. may call for additional tests to be made at the Contractor's expense on samples taken from the batch of the defective reinforcement. If the samples do not comply with the MS or BS, then the S.O. may reject the whole batch and instruct its removal from the Site.

6.2.6. Steel reinforcement shall be stored in clean and dry conditions. When placed in the work it shall be clean and free from loose rust, mill scale, oil, grease, paint, dirt or anything which may reduce its bond with concrete. If directed by the S.O., the steel bars shall be brushed or otherwise cleaned before use, at the Contractor's expense.

6.2.7. Binding wire shall be 1.6 mm diameter soft annealed steel wire complying with the requirements of *BS 1052*.

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6.3. Construction Methods

6.3.1. Cutting and Bending of Reinforcement

6.3.1.1. Bars shall be of their correct lengths and bent to the exact shapes required before being fixed in the Work.

6.3.1.2. Bars shall be cut and bent cold by the application of slow, steady pressure or in an approved bar-bending machine. Bending at temperatures exceeding 100ºC may only be carried out with the S.O. approval and under his supervision. Except where otherwise indicated in the Drawings, bars shall be bent and measured in accordance with *MS 1438*.

6.3.1.3. Cold worked and hot rolled bars shall not be straightened or bent again once having been bent. Where it is necessary to bend the free end of mild steel reinforcement already cast in the concrete, the internal radius of the bend shall not be less than twice the diameter of the bar.

6.3.1.4. Special care shall be taken that the overall length of bars with multiple bends is accurate and that after bending and fixing in position the bars remain in place without wrap or twist.

6.3.2. Fixing of Reinforcement

6.3.2.1. The number, size, length, shape, type and position of all reinforcing bars, links, spacer bars and other parts of the steel reinforcement, shall be in accordance with the Drawings.

6.3.2.2. Reinforcements shall be secured against displacement. Unless specified otherwise, the actual concrete cover shall be taken as the distance between face of concrete and the nearest steel surface. All intersecting bars shall be tied together with binding wire and the ends of the wire shall be turned into the main body of the concrete.

6.3.2.3. Reinforcement temporarily left projecting from the concrete at construction or other joints shall not be bent out of position during the periods in which concreting is suspended except with the approval of the S.O..

6.3.2.4. The Contractor shall take particular care that the reinforcement is laid out correctly in every aspect and temporarily suspended by annealed wire or supported on concrete blocks or other approved spacers in the forms to prevent displacement during the placing and compacting of concrete. Links shall tightly embrace the longitudinal reinforcement to which they shall be securely wired or spot welded. The top reinforcement in slabs shall be rigidly supported on mild steel 'chairs' or equivalent spaced in each direction to prevent sagging during concreting.

6.3.2.5. No concrete shall be placed until the reinforcement has been inspected and approved by the S.O..

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6.3.3. Splicing

6.3.3.1. Joints to reinforcement bars shall be in accordance by lapping of bars at positions shown in the Drawings. Where other types of joints are to be used, it shall be strictly in accordance with manufacturer's recommendation, at the positions approved by the S.O..

6.3.3.2. Splicing or lapping of bar shall not impair the flow of concrete surrounding the reinforcement bar including the concrete cover.

6.3.4. Spacer Blocks

6.3.4.1. The size of spacer blocks required shall be 50mm x 50mm (LxW) to ensure that the reinforcement is correctly positioned and consistent with their purpose, of a shape approved by the S.O., and designed so that they will not overturn when the concrete is placed. The thickness of spacer will depends on durability design of the structure.

6.3.4.2. Concrete and cementitious spacers should have at least the same strength and should at least give the same corrosion protection as the concrete in the structure. Spacers shall not be made on the construction site. Wires cast in these blocks for the purpose of tying them to the reinforcement shall be free from any corrosion or any other elements that may affect the integrity of the reinforcement bars.

6.3.4.3. Spacers left in situ shall not impair the desired appearance or durability of the structure by causing spalling, rust staining or allowing the passage of moisture.

6.3.4.4. Plastic chairs and spacers may be used only with the approval of the S.O.. The material of manufacture shall have an equivalent durability when it is in place to that of the concrete itself. Plastic spacers shall satisfy the condition that any cross-section perpendicular to the bar has at least 25% voids within the enclosed perimeter.

6.3.4.5. Steel spacers in direct contact with the concrete surface are only permitted in a dry environment i.e. exposure class XC1 of EN 206-1.

6.3.4.6. The distance between spacers for each structural component are given in **Table D28** and **Table D29.**

6.3.5. Welding of Reinforcement Bar

6.3.5.1. Welding workmanship, including welder qualification shall comply with the *Specification for Structural Steelworks JKR No. 20601-0191-12*.

6.3.5.2. Reinforcement bar in structures shall not be welded except where detailed in the Drawings or permitted in this specification.

6.3.5.3. Welding shall be carried out in accordance with *BS EN 1011* and *BS EN 60974*. Butt welds shall be of the double V type and two

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butt weld bond tests shall be carried out on a specimen prepared to represent each form of the butt-welded joint used in welding the reinforcement and for each position of welding. The method of making butt weld tests shall be as laid down in *BS EN 17637*. The specimen shall pass the test to the approval of the S.O. before using the joint, which the specimen represents. Welded joints shall not be made at bends in reinforcement. Unless otherwise approved by the S.O., joints in parallel bars of the principal tensile reinforcement shall be staggered in the longitudinal direction at a distance not less than the end anchorage length for the bar.

6.3.5.4. The S.O. shall be informed in advance of when welding is to be carried out so that he may supervise and inspect the work. Welding shall not be performed in the field during rain or other adverse conditions.

7. Formwork and Surface Finish for Structure

7.1. Design and Construction

7.1.1. Description

7.1.1.1. Formwork shall include all temporary or permanent forms required for forming the concrete, together with all temporary construction required for their support.

7.1.1.2. The Contractor is deemed to have made a study of the Drawings at tender stage and is aware of all areas of construction, requiring heavy and specially designed propping to provide the support and the necessary bracing for the stability of such propping.

7.1.1.3. The design and construction of formwork shall be carried out by a competent person. The Contractor shall identify all critical formwork design and submit the strength and deflection calculations and Drawings or the proposed design, certified by a Professional Engineer to the S.O. for prior approval. Notwithstanding any approval by the S.O. with respect to the design submitted by the Contractor, the responsibility or the adequacy and safety of the design shall remain with the Contractor. The Contractor shall also appoint a competent formwork coordinator whose duties would be similar to those outlined in *BS 5975*.

7.1.1.4. When the use of proprietary type of formwork is proposed by the Contractor, the design shall be certified by a Professional Engineer.

7.1.1.5. The formwork shall be sufficiently rigid and tight to prevent loss of grout or mortar from the concrete at all stages of construction and shall be appropriate for the methods of placing and compacting.

7.1.1.6. Formwork (including supports) shall be sufficiently rigid to maintain the forms in their correct position, shape, profile and dimensions. The supports shall be designed to withstand the

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worst combination of forces due to self-weight, formwork weight, formwork forces, reinforcement weight, wet concrete weight, construction and wind loads, together with all incidental dynamic effects caused by placing, vibrating and compacting the concrete. Guidance on these loadings is given in *The Concrete Society Manual Formwork - Guide to good practice*, and in *CIRIA Report 108*, *Concrete Pressure in Formwork*, and in *BS 5975*. Vertical propping to formwork shall be sufficiently constructed to provide the necessary support without overstressing the completed concrete structure.

7.1.1.7. Metal ties may only be used with prior approval from the S.O.. Where metal ties are permitted, the use of storey height steel soldiers shall be used to reduce the number of tie bolts required. Tie bolts with rubber or plastic cone against the form face are to be used to prevent unsightly grout loss. No metal part of any device for maintaining formwork in the correct location shall remain permanently within the specified concrete cover to the reinforcement. Except for ties used for anchoring void formers, all ties shall be at least 1.2 m apart and through bolts will not be permitted on exposed form finished faces. All holes left by ties shall be made good within one day of the removal of the formwork using a mortar of the same strength as the cast concrete. Metal ties which allow for holes through the concrete being cast shall not be permitted to be used in concrete for water-retaining structure, roof slabs and walls.

7.1.1.8. The formwork shall be so arranged as to be readily dismantled and removed from the cast concrete without shock, disturbance or damage. Where necessary, the formwork shall be so arranged that the soffit form, properly supported, can be retained in position for such period as may be required by the condition of the maturing concrete or the specification. If a component is to be prestressed whilst still resting on the soffit form, provision shall be made to allow for elastic deformation and any variation in weight distribution. As far as practicable, formwork joints shall coincide with construction joints.

7.1.2. Form Lining

7.1.2.1. The type and treatment of any lining (plywood, metal, plastic, Controlled Permeability Formwork liner, et cetera) of the forms shall be appropriate to the concrete finish required.

7.1.2.2. The Controlled Permeability Formwork (CPF) liner shall have the following requirements:

(i) The requirement for a special finish shall be as for traditional formwork finishes except that the formwork shall be covered by a CPF liner.

(ii) CPF liner shall be used on all surfaces as detailed on the Drawings.

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(iii) The CPF liner shall be a Water Bylaws Scheme - Approved Product for use with potable water in accordance with *BS 6920*.

(iv) The CPF liner shall have the following properties:

a) Compression of less than 10% under a pressure 200 kPa;

b) Maximum pore size of less than 0.030 mm;

c) Minimum water retention capacity of 0.35 l/m^2;

d) Result in bleed water from the liner which is free from cement and fine aggregate particles.

(v) The concrete cast against the CPF liner shall have an even uniformly textured matt finish and shall be free of blowholes and other surface blemishes. The use of the CPF liner shall meet the following performance requirements which should be demonstrated by the supply of test certificate:

a) The mean surface strength for the CPF cast face shall exceed that for the control face by at least 70%.

b) The mean 10 minutes ISAT result for the CPF cast face shall be not more than 15% of that for the control face.

c) The mean depth of carbonation for the CPF cast face shall be not more than 15% of that for the control face.

d) The mean concentration of chlorides at a depth of 11mm from the CPF cast face shall be not more than 15% of that for the control face.

(vi) The CPF liner shall be used once only. Release agents shall not be used with the liner and any residual release agent remaining on forms from previous use shall be removed.

(vii) To ensure conformity with the performance requirements, the CPF liner is to be used in accordance with the manufacturer's technical guidelines.

(viii) The CPF liner shall unless otherwise directed, be left in place on the concrete after formwork removal for the curing period specified by the S.O.. It shall be kept wet and covered with plastic sheeting to promote efficient curing.

7.1.3. Projecting Reinforcement, Fixing Devices

Where holes are needed in form to accommodate projecting reinforcement or fixing devices, care shall be taken to prevent loss of grout when concreting or damage when removing forms.

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7.2. Surface Finishes for Concrete

7.2.1. Control of Colour

When specified in the Drawings, the Contractor shall obtain each constituent material from a single consistent source. The aggregates shall be free of any impurities that may cause staining. The mix proportions and the grading, particularly of the fine aggregate, shall be maintained constant. The same type of plywood or timber shall be used in formwork throughout similar exposed areas.

7.2.2. Formed Surfaces

7.2.2.1. Formed concrete surfaces shall have one of the following classes of finish.

7.2.2.2. Unless otherwise specified, all exposed concrete surfaces shall be of Class F12, all unexposed surfaces shall be of Class F1. Other classes of finishes shall be used only where shown on the Drawings:

(i) Class F1

This finish shall be obtained using properly designed forms of closely joined sawn timber or other approved material. Small blemishes caused by entrapped air or water may be expected but the surface shall be free from voids and honeycombing.

(ii) Class F2

This finish shall be obtained using properly designed forms of closely jointed wrought boards, approved plywood or other approved material. Only very minor surface blemishes shall occur, with no staining or discoloration.

(iii) Class F3

a) This finish shall be obtained using properly designed steel forms or plastic-coated plywood or wrought boards or other approved material that can be used not less than 20 times.

b) The surface shall be improved by carefully removing all fins and other projections, thoroughly washing down and then filling the most noticeable surface blemishes with a cement and fine aggregate paste to match the colour of the original concrete. Form release agents shall be carefully chosen to ensure that the surface shall not be stained or discoloured. After the concrete has been properly cured, the surface shall be rubbed down where necessary, to produce a smooth and even surface.

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(iv) Class F4

The requirements for Class F4 are as for Class F3 except that internal ties and embedded metal parts will be permitted. The ties shall be positioned only in rebates, or in other positions as shown on the Drawings or as agreed by the S.O..

(v) Class F11

The requirements for Class F11 surface finish are identical to those for Class F1 except that it shall be achieved using Controlled Permeability Formliners.

(vi) Class F12

The requirements for Class F12 surface finish are identical to those for Class F2 except that it shall be achieved using Controlled Permeability Formliners.

(vii) Class F13

The requirements for Class F13 surface finish are identical to those for Class F3 except that it shall be achieved using Controlled Permeability Formliners.

(viii) Class F14

The requirements for Class F14 surface finish are identical to those for Class F4 except that it shall be achieved using Controlled Permeability Formliners.

(ix) Class F15

The requirements for Class F15 are as for Class F4 except that plywood shutters lined with an approved patterned formliner shall be used to produce a patterned profile finish. Where possible, full height formliners shall be employed so that no horizontal joints in the liners are required. Tie holes shall be spaced so that they occur at overlap joints in the lining sheet.

7.2.3. Unformed surfaces

7.2.3.1. Class U1

The concrete shall be uniformly levelled and screened to produce a plain, ridged or broom roughened surface. No further work shall be applied to the surface unless it is used as the first stage for a Class U2 or Class U3 finish.

7.2.3.2. Class U2

After the concrete has hardened sufficiently, the concrete Class U1 surface shall be floated by hand or machine to produce a uniform surface free from screed marks.

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7.2.3.3. Class U3

When the moisture film has disappeared, and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, a Class U1 surface shall be steel trowelled under firm pressure to produce a dense, smooth uniform surface free from trowel marks.

7.2.3.4. Class U4

This finish is for surfaces that are to receive waterproofing systems. The concrete shall be levelled and floated to produce a uniform surface and immediately before the waterproofing operation this surface shall be water jetted or grit blasted to provide a lightly textured finish. The finished surface shall not deviate from the required profile by more than 5 mm over a 3 m gauge length or have any abrupt irregularities of more than 3 mm.

7.2.4. Trial Panels for Exposed Form Finished Surfaces

7.2.4.1. In order to ensure that the specified formed finishes can be obtained by the method of construction proposed and to provide a standard by which the finishes in the Works can be assessed, trial panels shall be cast on Site. These panels shall be subjected to the S.O. approval before similar casting is permitted in the Works.

7.2.4.2. The trial panels shall employ the materials, plant and concrete mix proposed for the Works. They shall be at least a storey height and 1 m wide. They shall be of similar thickness and similarly reinforced as the elements they represent and shall incorporate all features which contribute to the final appearance of the Works.

7.3. Preparation of Forms Before Concreting

7.3.1. Before concreting, all forms shall be thoroughly cleaned out, free from sawdust shavings, dust, mud or other debris. The inside surfaces of forms shall, unless otherwise approved by the S.O., be coated with an approved non-staining form oil or other approved material to prevent adhesion of the concrete. Such release agents shall be applied strictly in accordance with the manufacturer's recommendation and shall not come into contact with the reinforcement or prestressing tendons and anchorages. For any exposed surface only one release agent shall be used throughout the entire area.

7.3.2. All formworks shall be inspected by the S.O. after preparation and immediately prior to depositing concrete and no concrete shall be deposited until approval of the formwork has been obtained.

7.4. Removal of Forms

7.4.1. The Contractor shall inform the S.O. and obtain his approval before striking any formwork, but such approval shall not relieve the Contractor of his responsibilities on the safety of the work.

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7.4.2. Formwork shall be removed without such shock or vibration that would damage the concrete. A period of time shall elapse between the placing of the concrete and the removal of the formwork for various parts of the structure so as to suit the requirements for its curing.

7.4.3. The minimum period~~s~~ between concreting and the removal of forms are given in **Table D30**. The periods stated in this table are based on the use of CEM 1. They may be changed with the approval of the S.O., if other types of cement as described in sub-section 2.1, admixtures as described in sub-section 2.4 are used. The result of the compressive strength obtained from cube strength at 7 days as described in sub-section 3.2 may also be used for early removal of forms. The Contractor shall provide proof of calculation to the S.O for approval prior to removal of forms.

7.4.4. For prestressed in-situ components, temporary supports shall not be removed until the components are stressed to the approval of the S.O..

7.4.5. Where it is intended the forms are to be reused, they shall be cleaned and made good to the approval of the S.O..

7.4.6. Following the removal of forms, no further loads shall be imposed upon the concrete until at least after completion of the curing period or until such later time as in the opinion of the S.O. the concrete shall have attained sufficient strength to safely withstand such loads. Full design loads shall not be applied to any structure until all load bearing concrete is at least 28 days old.

7.5. Inspection and Making Good

7.5.1. The surface of the concrete shall be inspected for defects and for conformity to the surface finish specified and where appropriate, with approved sample finishes.

7.5.2. Subject to the strength and durability of the concrete being unimpaired, the making good of surface defects may be permitted but the level of acceptance shall be appropriate to the type and quality of the finish specified and ensure satisfactory permanence and durability.

7.5.3. Any remedial treatment of surfaces shall be approved by the S.O. following inspection immediately after removing the formwork and shall be carried out without delay.

8. Building Accuracy

After removal of formwork, the Contractor shall take measurements as directed by the S.O. to check the deviation of the reinforced concrete works from specified dimensions shown on the Drawings. All measurements shall be recorded and submitted to the S.O. Any deviation in building accuracy shall comply with *BS EN 13670*.

9. Apparatus

The Contractor shall provide the following apparatus at Site at all times:

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9.1. Concrete slump test apparatus and flow test apparatus complying with *BS EN 12350-2*. One set of the apparatus shall be provided for each concreting location.

9.2. At least twelve (12) numbers of moulds (steel, cast iron or ABS) for casting 150 mm concrete test cubes in accordance with *BS EN 12390-1.* A minimum number shall be provided such that no stripping of cubes is required prior to 24 hours setting and hardening period.

9.3. At least six (6) numbers of prismatic specimen 40 x 40 mm in cross section and 160 mm in length for mortar or grout test moulds in accordance with *BS EN 445*. A minimum number shall be provided such that no stripping of cubes is required prior to 24 hours setting and hardening period.

9.4. Three (3) measuring cylinders of 250 ml capacity, graduated to measure to the nearest 2.0 ml., for determination of silt content (field setting method).

9.5. An approved apparatus for measuring moisture content in fine aggregate.

9.6. One (1) electronic calculator with statistical functions.

9.7. One (1) 300 mm steel rule.

9.8. One (1) set of sieves in compliance with *BS ISO 3310*.

9.9. Scale or balance 25 kg maximum capacity and weights.

9.10. Trowel, shovel, spanner and other tools.

9.11. One (1) Electromagnetic Concrete Cover Meter.

10. Precast Concrete Works

10.1. The Contractor shall employ manufacturers registered with CIDB to supply or cast on site precast component to the respective project. All precast concrete components to be used in the works shall be approved by the S.O./P.D. prior to installation. The full requirement is outlined in the *Specification for Precast Concrete Works (JKR 20601-0251-18)*.

10.2. Industrialized Building System (IBS) Requirements

The calculation shall comply based on the latest version of *Manual for Industrialized Building System (IBS) Content Scoring System (IBS Score)*: *Construction Industry Standard, CIS 18 published by the Construction Industry Development Board (CIDB) Malaysia*.

10.3. Assembly Drawing

10.3.1. All assembly drawing produced by the manufacturer and verified by a Professional Engineer (P.E.) to the S.O./ P.D. for approval before the commencement of the manufacturing of the component. The list of drawings that needs to be endorsed are as below:

10.3.1.1. Layout drawing;

10.3.1.2. Section drawing;

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10.3.1.3. Connection details;

10.3.1.4. Element types;

10.3.1.5. General drawing.

10.3.2. Assembly Drawings shall show all necessary details and dimensions to enable assembly of components to proceed.

10.4. Installation

10.4.1. The Contractor shall inform the S.O./P.D. at least one month in advance of launching or installation operation and submit the following documents to the S.O. for approval:

10.4.1.1. Method statement including launching systems and transportation;

10.4.1.2. Proposal for traffic diversion, if appropriate;

10.4.1.3. Detailed program of launching and installation operation;

10.4.1.4. Installation operation safety program.

10.4.2. Inspection of Precast Unit.

The elements shall be inspected for cracking and other defects or damage. The dimensional properties of the components shall be checked in accordance with the Drawings.

10.4.3. Lifting and Handling

A lifting method statement shall be prepared by the Contractor and submitted for approval. The elements shall be lifted from the mould according to the locations of the lifting devices and instructions on the production drawings. The recommended minimum concrete strength for lifting and handling are shown in **Table D31**.

10.5. Connection

10.5.1. The Contractor shall be responsible to ensure the connection between components (in situ and precast / precast and precast) are properly installed in accordance with the Drawings and method statement.

10.5.2. Designed mixes of grout shall be submitted to the S.O./P.D. for approval. The grout shall be of high fluidity and cohesive at plastic and shrinkage resistant during hardening.

10.5.3. The grout shall be a mixture of blended cement, water and approved admixture. The acceptance strength shall be deemed to be satisfied when the strength is equal or greater than the specified characteristic strength of precast concrete.

10.5.4. If the Contractor chooses to use proprietary product, he shall submit to the S.O./P.D. the name of manufacturer/supplier, type and specification of the product for approval. The grout shall be mixed on site in accordance with the manufacturer’s requirements.

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10.5.5. The grout shall be tested in accordance with the following method:

10.5.5.1. Fluidity Test by using Cone Method (*BS EN 445*) or;

10.5.5.2. Fluidity Test by using Grout Spread Method (*BS EN 445*) or;

10.5.5.3. Flowability Test using Flow Cone Method (*ASTM C939*) and;

10.5.5.4. Compressive Strength Test (*BS EN 445*).

10.5.6. Placement

10.5.6.1. Vertical Placement (Pressure Grouting)

Grout shall be pumped into each sleeve until grout pours out of the outlet and pumping shall be continued until a pressure of minimum 100 kN/m² is attained. The high-pressure cork shall remain closed and in position for a period of one hour after grouting.

10.5.6.2. Vertical Placement (Gravity Flow)

This method shall only be allowed for shallow sleeve, such as the connection between corbel and precast beam, nib and precast beam. The diameter of corrugated sleeve and the appropriate dowel bar size shall be as shown in **Table D32**.

10.5.6.3. Horizontal Placement (Gravity Flow Grouting)

Gravity flow grout shall be applied to areas that convenient and easy for grouting works such as, longitudinal joint between precast components. It can be poured by hand directly along the joint and swept into the gap with suitable tools.

11. Other Concrete Works

11.1. Foundation

11.1.1. All reinforced concrete footings and pile caps shall be constructed according to the Drawings and to the exact depths required. The Contractor shall supply, maintain and remove any necessary planking and strutting, sheet piling and coffer dams, and shall by pumping or other approved means, keep the excavation free from water.

11.1.2. The bottom of excavation shall be cleaned or if in loose or disturbed ground shall be well rammed, and the whole shall be approved before it is covered with a blinding layer of lean concrete not less than 50 mm thick. The required cover of concrete under the reinforcement shall not be inclusive of the blinding layer's thickness.

11.2. Pile Caps

11.2.1. Before commencing to construct pile caps, the Contractor shall check and verify the eccentricities and the cut-off levels of all piling works in the ground are as provided in the Drawings and shall notify the S.O. in the event of any discrepancy.

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11.2.2. The Contractor shall straighten the steel reinforcement projecting above the piles for anchoring pile caps, carry out excavation, erect formwork and temporary timbering for the construction of pile caps and ground beams.

11.3. Structural Elements Below Ground Level

11.3.1. For structural elements, lift shaft and lift pits below ground level, the concrete in the base slab and walls shall be of reinforced concrete with minimum cement content and maximum free water to cement ratio in accordance with the exposure XC3 in **Table D5, Table D6, Table D7** and **Table D8** shall be constructed in operations which shall ensure water tightness.

11.3.2. All external and internal wall surfaces of lift pits shall be waterproofed with three (3) coats of bitumen solution complying with *BS 3416* or any other type of waterproofing material as approved by the S.O.. The concrete surface shall be thoroughly cleaned and dried before application of the waterproofing material.

11.3.3. Lift shaft and structural wall enclosures shall be made of reinforced concrete on all sides and constructed using steel formwork to ensure the accuracy of the structure in terms of verticality, shape, profile and dimensions. Refer to **Figure D4**.

11.3.4. For lift shaft enclosure, all the inner surfaces shall form a continuous flush surface without projection or recesses. Refer to **Figure D4**.

11.3.5. The lift shaft shall have a high degree of verticality. The limit of accuracy of shaft plumb for the full stretch of the lift shaft shall not exceed ±30 mm. Refer to **Figure D5**.

11.3.6. The structural openings shall be vertically aligned one above the other for the full travel of the lift.

11.3.7. The structural opening shall be accurate to the specified dimensions. Deviations from the specified dimensions shall not exceed +12.5mm, -0mm. Refer to **Figure D6**.

11.4. Floors

11.4.1. After initial set, the upper surface of cast-in-situ reinforced concrete floors shall be trowelled smooth with a steel float to true level and even surface. No screeding of any kind shall be applied to the floor slabs except where specified. Care shall be taken to ensure that the steel reinforcement is not displaced or lowered during trowelling.

11.4.2. For areas, which are to receive rendering or other finishes, the fresh concrete shall be trowelled to true level or as required using a long timber trowel. Before it hardens it shall be brushed with a stiff broom in one direction to give a rough and tidy surface.

11.4.3. The reinforced concrete ground floor slab shall not be laid directly onto earth surfaces. A blinding layer of 50 mm minimum thick of lean concrete shall be laid on well prepared firm ground. Plastic sheeting or other suitable material with sufficient overlaps at joints, shall be laid on the blinding layer before any reinforcement is placed in position.

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11.5. Toilet Floors

11.5.1. The Contractor shall ensure that all suspended floor for toilet areas are constructed to be watertight and leak proof. All construction method or alternative details proposed by the Contractor must be based on his acceptance of and compliance with the requirements for watertightness. The Contractor shall ensure that holes and fixings are properly constructed.

11.5.2. The floor must be concreted in one sequence of operation. No construction joints for toilet floor are to be allowed. All pipes and fittings encased in the concrete floor shall be provided with sleeves to the approval of the S.O and shall be built in-situ. No holes shall be left for later incorporation of fittings and no subsequent hacking of floor shall be made. Notwithstanding whatever shown on the Drawings, all toilet floor slabs shall have a minimum thickness of 150 mm.

11.5.3. Testing for Watertightness

The toilet floor areas shall be ponded with minimum 25mm depth of water and shall be maintained continuously over a period of 24 hours. During this period, the exposed soffit shall show no signs of leakage and remain dry. If any area is found not to be watertight, the Contractor must repair at his own expense.

11.6. Roofs

11.6.1. Reinforced concrete roofs shall be constructed to fall as shown on the Drawings and finished with steel trowelling, leaving the surface smooth and free from mortar droppings.

11.6.2. The base slab shall be concreted as described for concrete generally, ensuring thorough compactions using a pan vibrator or a vibrating screen. Concrete shall be poured continuously between pre-determined construction joints as decided by the S.O., or as shown on the Drawings. Expansion joints, where applicable, shall be allowed and constructed exactly as indicated in the Drawings.

11.6.3. Unless otherwise specified or shown on the Drawings, waterproofing screed to reinforced concrete flat roof shall consist of a 32 mm thick screed reinforced with temperature steel.

11.6.4. The waterproofing screed shall consist of one (1) part of cement and three (3) parts of clean well-graded sand (1:3) and shall be mixed with an approved waterproofing agent and approved plasticizer in the proportion recommended by the manufacturer.

11.6.5. The temperature steel shall consist of a mesh 6 mm diameter steel bars at 100 mm centres each way, or alternatively steel fabric of *MS 145*. The temperature steel shall be placed directly on top of the base slab, and a minimum cover of 20 mm to top bars of the temperature steel shall be maintained.

11.6.6. The screed shall be laid after the base slab concrete has sufficiently hardened but not later than 36 hours after the concreting of the base slab, to obtain a thorough bond between the screed and the base slab. The surface shall be finished with a wood float and followed by a steel trowel

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to a smooth finish.

11.6.7. Unless otherwise specified or shown on the Drawings, joints in the screed shall be constructed and located over the main roof beams and shall be filled with approved bituminous compound as soon as possible.

11.6.8. After the screed has been placed, the full area shall be properly protected and cured for a period of at least seven (7) days. Alternatively, as soon as the screed has sufficiently hardened to withstand a man's weight without marking, an approved plastic sealing agent shall be sprayed in accordance with the manufacturer's recommendation.

11.7. Drips

Unless otherwise shown on the Drawings or directed by the S.O., a 15mm wide drip shall be formed along edges of soffits to concrete roof slabs, hoods, undersides of balconies, cantilevered beams and slabs and other parts of building where rainwater is likely to adhere in drops.

11.8. Refuse Chutes

Where shown on the Drawings, all cast-in-situ reinforced concrete refuse chutes shall be constructed without bolt holes made through the chute walls. If such holes are unavoidable then they shall be completely grouted with cement mortar or sealed and waterproofed by other means to prevent leakage to the approval of the S.O. Frames which shall not be of asbestos cement, shall be cast into refuse chute walls for fixing chute hoppers. Such frames shall be obtained from the same supplier of chute hoppers.

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Table D1. Cement and Combination Types[a]

Broad Designation[b]	Composition	Comprises cement and combination types (see Table D2)
CEM I	Portland cement	CEM I
CEM I-SR 0 CEM I-SR 3	Sulphate-resisting Portland cement	CEM I-SR 0 CEM I-SR 3
IIA	Portland cement with 6 % to 20 % fly ash, ground granulated blastfurnace slag, limestone, or 6 % to 10 % silica fume[c]	CEM II/A-L, CIIA-L, CEM II/A-LL, , CIIA-LL, CEM II/A-S, CIIA-S, CEM II/A-V, CIIA-V, CEM II/A-D
IIB-S	Portland cement with 21 % to 35 % ground granulated blastfurnace slag	CEM II/B-S, CIIB-S
IIB-V	Portland cement with 21 % to 35 % fly ash	CEM II/B-V, CIIB-V
IIB+SR	Portland cement with 25 % to 35 % fly ash	CEM II/B-V + SR, CIIB-V + SR
IIIA[d]	Portland cement with 36 % to 65 % ground granulated blastfurnace slag	CEM III/A, CIIIA
IIIA + SR	Portland cement with 36 % to 65 % ground granulated blastfurnace slag with additional requirements that enhance sulphate resistance	CEM III/A + SR[e], CIIIA + SR[e]
IIIB[f]	Portland cement with 66 % to 80 % ground granulated blastfurnace slag	CEM III/B, CIIIB
IIIB+ SR	Portland cement with 66 % to 80 % ground granulated blastfurnace slag with additional requirements that enhance sulphate resistance	CEM III/B + SR[e], CIIIB + SR[e]
IVB-V[g]	Portland cement with 36 % to 55 % fly ash	CEM IV/B-V, CIVB-V

Notes:

[a] There are a number of cements and combinations not listed in this table that may be specified for certain specialist applications. See BRE Special Digest 1 [1] for the sulphate-resisting characteristics of other cements and combinations. See IP 17/05 [5] for the use of high ggbs content cements and combinations in secant piling applications.

[b] The use of these broad designations is sufficient for most applications. Where a more limited range of cement or combinations types is required, select from the notations given in **TABLE D2**.

[c] When IIA or IIA-D is specified, CEM I and silica fume may be combined in the concrete mixer using the *k*-value concept; see MS EN 206:2016, 5.2.5.2.3.

[d] Where IIIA is specified, IIIA+SR may be used.

[e] "+SR" indicates additional restrictions on the chemical composition of cement or ggbs related to sulphate resistance. See **TABLE D2**, footnote d.

[f] Where IIIB is specified, IIIB+SR may be used.

[g] IVA cements and combinations with a siliceous fly ash should be classified as II-V.

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Table D2. General Purpose Cements and Combinations

Type	Notation	Standard	Broad designation	Grouping used in BRE SD1: 2005 [4]
Portland cement	CEM I	MS EN 197-1	CEM I	A
Portland silica fume cement[a]	CEM II/A-D	MS EN 197-1	IIA	A
Portland limestone cement	CEM II/A-L CEM II/A-LL	MS EN 197-1 MS EN 197-1	IIA IIA	B[b] or C[b] B[b] or C[b]
Portland slag cements	CEM II/A-S CEM II/B-S	MS EN 197-1 MS EN 197-1	IIA IIB-S	A A
Portland fly ash cements	CEM II/A-V CEM II/B-V CEM II/B- V+SR[c]	MS EN 197-1 MS EN 197-1 MS EN 197-1	IIA IIB-V IIB+SR	A A D
Blastfurnace cements	CEM III/A CEM III/A+SR[d] CEM III/B CEM III/B+SR[d]	MS EN 197-1 MS EN 197-1	IIIA IIIA+SR IIIB IIIB+SR	A D A F
Pozzolanic cement[e]	CEM IV/B(V)	MS EN 197-1 or BS EN 14216	IVB-V	E
Sulphate-resisting Portland cement	CEM I-SR 0 CEM I-SR 3	MS EN 197-1	CEM I-SR 0 CEM I-SR 3	G
Combinations conforming to Annex B manufactured in the concrete mixer from Portland cement and fly ash, ggbs or limestone fines:				
CEM I cement conforming to MS EN 197-1 with a mass fraction of 6 % to 20 % of combination of fly ash conforming to MS EN 450- 1	CIIA-V	Annex B MS 523-3	IIA	A
CEM I cement conforming to MS EN 197-1 with a mass fraction of 21 % to 35 % of combination of fly ash conforming to MS EN 450- 1	CIIB-V CIIB-V+SR[c]	Annex B MS 523-3	IIB-V IIB+SR	A D
CEM I cement conforming to MS EN 197-1 with a mass fraction of 36 % to 55 % of combination of fly ash conforming to MS EN 450- 1	CIVB-V	Annex B MS 523-3	IVB-V	E
CEM I cement conforming to MS EN 197-1 with a mass fraction of 6 % to 20 % of combination of ggbs conforming to MS EN 15167-1	CIIA-S	Annex B MS 523-3	IIA	A
CEM I cement conforming to MS EN 197-1 with a mass fraction of 21 % to 35 % of combination of ggbs conforming to MS EN 15167-1	CIIB-S	Annex B MS 523-3	IIB-S	A
CEM I cement conforming to MS EN 197-1 with a mass fraction of 36 % to 65 % of combination of ggbs conforming to MS EN 15167-1	CIIIA CIIIA+SR[d]	Annex B MS 523-3	IIIA IIIA+SR	A D

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Table D2. General Purpose Cements and Combinations

(continued)

Type	Notation	Standard	Broad designation	Grouping used in BRE SD1: 2005 [4]
CEM I cement conforming to MS EN 197-1 with a mass fraction of 66 % to 80 % of combination of ggbs conforming to MS EN 15167-1	CIIIB CIIIB+SR[d]	Annex B MS 523-3	IIIB IIIB+SR	A F
CEM I cement conforming to MS EN 197-1 with a mass fraction of 6 % to 20 % of combination of limestone fines conforming to MS 2653	CIIA-L CIIA-LL	Annex B MS 523-3	IIA IIA	B[b] or C[b] B[b] or C[b]

Notes:

[a] When IIA or IIA-D is specified, CEM I and silica fume may be combined in the concrete mixer using the *k*-value concept; see MS EN 206:2016, 5.2.5.2.3

[b] The classification is B if the cement or combination strength is class 42.5 or higher and C if it is class 32.5.

[c] With a minimum proportion of fly ash of 25 %.

[d] Where the alumina content of the slag exceeds 14 %, the tricalcium aluminate content of the Portland cement fraction shall not exceed 10 %.

[e] CEM IV/A cement with siliceous fly ash should be classified as either CEM II/A-V (6 % to 20 % siliceous fly ash) or CEM II/B-V (21 % to 35 % siliceous fly ash).

Table D3. Testing of Aggregates

Properties	Test Methods
Grading	*MS EN 933*
Flakiness Index	*MS EN 933*
Water Absorption	*MS EN 1097*
Shape Index	*MS EN 933*
Percentage of Crushed and Broken Surfaces in Coarse Aggregate Particles	*MS EN 933*
Aggregate Crushing Value	*MS EN 933*
Chloride Content	*BS EN 1744*
Sulphate Content	*BS EN 1744*

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Table D4. General Grading Requirements

Aggregate	Size (mm)	Percentage passing by mass					Category G
		2D[a]	1.4D	D[b]	d	d/2	
Coarse	D > 4 d ≥ 1	100	100	90 to 99	0 to 10	0 to 2	G_C90/10
		100	98 to 100	90 to 99	0 to 15	0 to 5	G_C90/15
		100	98 to 100	85 to 99[c]	0 to 15	0 to 5	G_C85/15
		100	98 to 100	85 to 99[c]	0 to 20	0 to 5	G_C85/20
		100	98 to 100	80 to 99	0 to 20	0 to 5	G_C80/20
		100	98 to 100	85 to 99	0 to 35	0 to 5	G_C85/35
		100	98 to 100	85 to 99[c]	0 to 15	0 to 2	G_{CA}85/15
	d ≥ 1 D ≤ 4	100	95 to 100	85 to 99	0 to 15	-	G_G85/15
		100	98 to 100	85 to 99	0 to 20	0 to 5	G_G85/20
		100	98 to 100	85 to 99	0 to 35	0 to 5	G_G85/35
Natural Graded Aggregates	D = 8 d = 0	100	98 to 100	90 to 99	-	-	G_{NG}90
Fine	D ≤ 4 d = 0	100	95 to 100	85 to 99	-	-	G_F85
All-in	D > 4 d = 0	100	98 to 100	90 to 99	-	-	G_A90
		100	98 to 100	85 to 99	-	-	G_A85
		100	98 to 100	80 to 99	-	-	G_A80
		100	-	75 to 99	-	-	G_A75

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Table D5. Durability Recommendations for Reinforced or Prestressed Elements of Structures with an Intended Working Life of at Least 50 Years

Nominal cover (mm)	Compressive strength class, maximum w/c ratio and minimum cement or combination content for normal-weight concrete with 20 mm maximum aggregate size											Cement/ combination types
	15 +Δc	20 + Δc	25 + Δc	30 + Δc	35 + Δc	40 + Δc	45 + Δc	50 + Δc	60 + Δc	70 + Δc	80 + Δc	
Corrosion induced by carbonation (XC exposure classes)												
XC1	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	All in Table D1
XC2	-	-	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	All in Table D1
XC3/4	-	C40/50 0.45 340	C32/40 0.55 300	C28/35 0.60 280	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	All in Table D1 except IVB-V
	-	-	C40/50 0.45 340	C32/40 0.55 300	C28/35 0.60 280	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	IVB-V
Corrosion induced by chlorides other than seawater (XD exposure classes) adequate for any associated carbonation induced corrosion (XC)												
XD1	-	-	C40/50 0.45 360	C32/40 0.55 320	C28/35 0.60 300	C28/35 0.60 300	C28/35 0.60 300	C28/35 0.60 300	C28/35 0.60 300	C28/35 0.60 300	C28/35 0.60 300	All in Table D1
XD2	-	-	-	C40/50 0.40 380	C32/40 0.50 340	C28/35 0.55 320	C28/35 0.55 320	C28/35 0.55 320	C28/35 0.55 320	C28/35 0.55 320	C28/35 0.55 320	CEM I, IIA, IIB-S, CEM I-SR0, CEM I-SR3
	-	-	-	C35/45 0.40 380	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	IIB-V, IIIA
	-	-	-	C32/40 0.40 380	C25/30 0.50 340	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	IIIB, IVB-V
XD3	-	-	-	-	-	C45/55 0.35 380	C40/50 0.40 380	C35/45 0.45 360	C35/45 0.45 360	C35/45 0.45 360	C35/45 0.45 360	CEM I, IIA, IIB-S CEM I-SR0, CEM I-SR3
	-	-	-	-	-	C35/45 0.40 380	C32/40 0.45 360	C28/35 0.50 340	C28/35 0.50 340	C28/35 0.50 340	C28/35 0.50 340	IIB-V, IIIA
	-	-	-	-	-	C32/40 0.40 380	C28/35 0.45 360	C25/30 0.50 340	C25/30 0.50 340	C25/30 0.50 340	C25/30 0.50 340	IIIB, IVB-V

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Table D5. Durability Recommendations for Reinforced or Prestressed Elements of Structures with an Intended Working Life of at Least 50 Years

(continued)

Nominal cover (mm)	Compressive strength class, maximum w/c ratio and minimum cement or combination content for normal-weight concrete with 20 mm maximum aggregate size											Cement/ Combination types
	30 +Δc	35 +Δc	40 +Δc	45 + Δc	50 +Δc	55 + Δc	60 +Δc	65 + Δc	70 +Δc	75 + Δc	80 +Δc	
Corrosion induced by chlorides from seawater (XS exposure classes) adequate for any associated carbonation induced corrosion (XC)												
XS1	-	-	-	C45/55 0.35 380	C40/50 0.40 380	C35/45 0.45 360	C32/40 0.50 340	C28/35 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	CEM I, IIA, IIB-S
	C40/50 0.35 380	C32/40 0.45 360	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	IIB-V, IIIA
	C35/45 0.40 380	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	IIB-V ≥ 25 % fly ash, IIIA ≥ 46 % ggbs
	C32/40 0.40 380	C25/30 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	IV-B, IIIB
XS2	-	-	-	-	-	-	C45/55 0.35 380	C40/50 0.40 380	C40/50 0.40 380	C35/45 0.45 360	C32/40 0.50 340	CEM I, IIA, IIB-S
	-	-	C35/45 0.35 380	C32/40 0.45 360	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	IIB-V, IIIA
	-	C40/50 0.35 380	C32/40 0.45 360	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	IIB-V ≥ 25 % fly ash, IIIA ≥ 46 % ggbs
	-	C35/45 0.35 380	C28/35 0.45 360	C25/30 0.50 340	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	IV-B, IIIB
XS3	-	-	-	-	-	-	-	-	-	-	C45/50 0.35 380	CEM I, IIA, IIB-S
	-	-	-	-	C40/50 0.35 380	C35/45 0.45 380	C32/40 0.45 360	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	IIB-V, IIIA
	-	-	-	C40/50 0.35 380	C32/40 0.45 360	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C20/25 0.55 320	IIB-V ≥ 25 % fly ash, IIIA ≥ 46 % ggbs
	-	-	-	C35/45 0.35 380	C28/35 0.45 360	C25/30 0.50 340	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	IV-B, IIIB

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Table D6. Durability Recommendations for Reinforced or Prestressed Elements of Structures with an Intended Life of at Least 100 Years

Nominal cover (mm)	Compressive strength class, maximum w/c ratio and minimum cement or combination content for normal-weight concrete with 20 mm maximum aggregate size												Cement/ combination types
	15 + Δc	20 + Δc	25 +Δc	30 +Δc	35 +Δc	40 + Δc	45+ Δc	50 +Δc	55 +Δc	60 +Δc	70 +Δc	80 +Δc	
Corrosion induced by carbonation (XC exposure classes)													
XC1	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	C20/25 0.70 240	All in Table D1
XC2	-	-	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	All in Table D1
XC3/4	-	-	-	C40/50 0.45 340	C35/45 0.50 320	C30/37 0.55 300	C28/35 0.60 280	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	All in Table D1 except IVB-V
	-	-	-	-	C40/50 0.45 340	C35/45 0.50 320	C30/37 0.55 300	C28/35 0.60 280	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	C25/30 0.65 260	IVB-V
Corrosion induced by chlorides other than seawater (XD exposure classes) adequate for associated carbonation induced corrosion (XC)													
XD1	-	-	-	C45/55 0.40 380	C40/50 0.45 360	C35/45 0.50 340	C32/40 0.55 320	C28/35 0.60 300	C28/35 0.60 300	C28/35 0.60 300	C28/35 0.60 300	C28/35 0.60 300	All in Table D1
XD2	-	-	-	-	-	C35/45 0.45 360	C32/40 0.50 340	C28/35 0.55 320	C28/35 0.55 320	C28/35 0.55 320	C28/35 0.55 320	C28/35 0.55 320	CEM I, IIA, IIB-S, CEM I-SR0, CEM I-SR3
	-	-	-	-	-	C32/40 0.45 360	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	IIB-V, IIIA
	-	-	-	-	-	C28/35 0.45 360	C25/30 0.50 340	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	IIIB, IVB-V
XD3	-	-	-	-	-	-	-	-	C45/55 0.35 380	C40/50 0.40 380	C35/45 0.45 360	C35/45 0.45 360	CEM I, IIA, IIB-S CEM I-SR0, CEM I-SR3
	-	-	-	-	-	-	C40/50 0.35 380	C35/45 0.40 380	C32/40 0.45 360	C28/35 0.50 340	C25/30 0.50 320	C25/30 0.50 320	IIB-V, IIIA
	-	-	-	-	-	-	C32/40 0.40 380	C28/35 0.45 360	C25/30 0.50 340	C25/30 0.50 320	C25/30 0.55 320	C25/30 0.55 320	IIIB, IVB-V

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Table 6: Durability Recommendations for Reinforced or Prestressed Elements of Structures with an Intended Life of at Least 100 Years

(continued)

Nominal cover (mm)	Compressive strength class, maximum w/c ratio and minimum cement or combination content for normal-weight concrete with 20 mm maximum aggregate size											Cement/ combination types
	30 +Δc	35 + Δc	40 +Δc	45 +Δc	50 + Δc	55 +Δc	60+Δc	65 +Δc	70 +Δc	75 +Δc	80 +Δc	
Corrosion induced by chlorides from seawater (XS exposure classes) adequate for associated carbonation induced corrosion (XC)												
XS1	-	-	-	-	-	-	-	C45/55 0.35 380	C40/50 0.40 380	C35/45 0.45 360	C32/40 0.50 340	CEM I, IIA, IIB-S
	-	C40/50 0.35 380	C40/50 0.35 380	C35/45 0.45 380	C32/40 0.45 360	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	IIB-V, IIIA
	-	-	C35/45 0.40 380	C32/40 0.45 360	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	IIB-V ≥ 25 % fly ash, IIIA ≥ 46 % ggbs
	-	-	C32/40 0.45 380	C28/35 0.45 360	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	
	-	-	C35/45 0.40 380	C30/37 0.45 360	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	IVB-V
XS2	-	-	-	-	-	-	-	-	-	-	-	CEM I, IIA, IIB-S
	-	-	-		C40/50 0.35 380	C35/45 0.40 380	C32/40 0.45 360	C28/35 0.50 340	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	IIB-V, IIIA
				C40/50 0.35 380	C35/45 0.40 380	C32/40 0.40 360	C28/35 0.50 340	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	C25/30 0.55 320	IIB-V ≥ 25 % fly ash, IIIA ≥ 46 % ggbs
				C35/45 0.35 380	C32/40 0.40 380	C28/35 0.45 360	C25/30 0.50 340	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	C20/25 0.55 320	IVB-V, IIIB
XS3	-	-	-	-	-	-	-	-	-	-	-	CEM I, IIA, IIB-S
	-	-	-	-	-	-	C40/50 0.35 380	C40/50 0.35 380	C35/45 0.40 380	C32/40 0.45 360	C28/35 0.50 340	IIB-V, IIIA
	-	-	-	-	-	-	C40/50 0.35 380	C35/45 0.40 380	C32/40 0.40 360	C25/30 0.55 320	C25/30 0.55 320	IIB-V ≥ 25 % fly ash, IIIA ≥ 46 % ggbs
	-	-	-	-	-	-	C35/45 0.35 380	C32/40 0.40 380	C28/35 0.45 360	C20/25 0.55 320	C20/25 0.55 320	IVB-V, IIIB

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Table D7. Minimum Cement and Combination Contents with Maximum Aggregate Sizes other than 20mm

Limiting values given for 20 mm maximum aggregate size		Maximum aggregate size		
Maximum w/c ratio	Minimum cement or combination content (kg/m^3)	≥ 40 mm	14 mm	10 mm
0.70 0.65	240 260	240 240	260 280	280 300
0.60 0.60	300 280	280 260	320 300	340 320
0.55	300 320	280 300	320 340	340 360
0.50	320 340	300 320	340 360	360 380
0.45	340 360	320 340	360 380	360 380
0.40 0.35	380 380	360 380	380 380	380 380

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Table D8. Exposure Classes

Class designation	Class description	Informative examples applicable in Malaysia
Corrosion induced by carbonation (XC classes) *(where concrete containing reinforcement or other embedded metal is exposed to air and moisture)*		
XC1	Dry or permanently wet	Reinforced and prestressed concrete surfaces inside enclosed structures except voided superstructures and areas of structures with high humidity Reinforced and prestressed concrete surfaces permanently submerged in non-aggressive water
XC2	Wet, rarely dry	Reinforced and prestressed concrete surfaces permanently in contact with soil not containing chlorides
XC3 and XC4 (XC3/4)	Moderate humidity or cyclic wet and dry	External reinforced and prestressed concrete surfaces sheltered from, or exposed to, direct rain Reinforced and prestressed concrete surfaces subject to high humidity (e.g. poorly ventilated bathrooms, kitchens) Reinforced and prestressed concrete surfaces exposed to alternate wetting and drying Interior concrete surfaces of pedestrian subways not subject to de-icing salts, voided superstructures or cellular abutments Reinforced or prestressed concrete surfaces protected by waterproofing
Corrosion induced by chlorides other than from seawater (XD classes) *(where concrete containing reinforcement or other embedded metal is subject to contact with water containing chlorides, including de-icing salts, from sources other than from seawater)*		
XD1	Moderate humidity	Concrete surfaces exposed to airborne chlorides Reinforced and prestressed concrete wall and structure supports more than 10 m horizontally from a carriageway Bridge deck soffits more than 5 m vertically above the carriageway Parts of structures exposed to occasional or slight chloride conditions
XD2	Wet, rarely dry	Reinforced and prestressed concrete surfaces totally immersed in water containing chlorides Buried highway structures more than 1 m below adjacent carriageway
XD3	Cyclic wet and dry	Reinforced and prestressed concrete walls and structure supports within 10 m of a carriageway Bridge parapet edge beams Buried highway structures less than 1 m below carriageway level Reinforced pavements and car park slabs
Corrosion induced by chlorides from seawater (XS classes) *(where concrete containing reinforcement or other embedded metal is subject to contact with Seawater or airborne salt originating from seawater)*		
XS1	Exposed to airborne salt but not in direct contact with seawater	External reinforced and prestressed concrete surfaces in coastal areas
XS2	Permanently submerged	Reinforced and prestressed concrete surfaces completely submerged and remaining saturated, e.g. concrete below mid-tide level
XS3	Tidal, splash and spray zones	Reinforced and prestressed concrete surfaces in the upper tidal zones and the splash and spray zones , including exposed soffits above seawater

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Table D9. Slump Classes

Class	Slump in mm
S1	10 to 40
S2	50 to 90
S3	100 to 150
S4	160 to 210
S5	≥ 220

Table D10. Compaction Classes

Class	Degree Of Compactibility
C0	≥ 1.46
C1	1.45 to 1.26
C2	1.25 to 1.11
C3	1.10 to 1.04

Table D11. Flow Classes

Class	Flow Diameter In mm
F1	≤ 340
F2	350 to 410
F3	420 to 480
F4	490 to 550
F5	560 to 620
F6	≥ 630

Table D12. Slump – flow Classes

Class	Slump-flow[a] tested in accordance with EN 12350-8 mm
SF1	550 to 650
SF2	660 to 750
SF3	760 to 850

[a] The classification is not applicable to concrete with D_{max} exceeding 40 mm

D_{max} = Declared value of D of the coarsest fraction of aggregates actually used in the concrete

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Table D13. Consistence Suitable for Different Uses of In-Situ Concrete

Use of concrete	Form of compaction	Consistence class	
		Normal-weight concrete	Lightweight concrete
Cement-bound for reinstatement or base	Tamping, vibrotamper, vibrating plate or roller, roller-compaction	-	-
Kerb bedding and braking	Tamping	S1	-
Floors and hand placed pavements	Poker or beam vibration	S3	S2
Large or industrial floors		S3	S3
Machine placed pavements	Poker or beam vibration	S3	-
Strip footings	Poker or beam vibration and/or tamping	S4	-
Mass concrete foundations		S3	-
Blinding		S3	-
Normal reinforced concrete in slabs, beams, walls and columns		S3	S3
Sliding formwork construction		S2	S2
Pumped concrete		S3	F5
Vacuum processed concrete		S3	S3
Trench fill	Self-weight compaction	S4	-
In-situ piling		S4	-
Self-compacting concrete for applications such as congested reinforcement or intricate formwork	Self-weight compaction	SF2	SF2

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Table D14. Maximum Total Chloride

Concrete Use	Chloride Content Class[a]	Maximum Cl- Content by Mass of Cement[b] %
Not containing steel reinforcement or other embedded metal with the exception of corrosion-resisting lifting devices	CL 1.00	1.00
Containing steel reinforcement or other embedded metal	CL 0.20	0.20
	CL 0.40[c]	0.40
Containing prestressing steel reinforcement in direct contact with concrete	CL 0.10	0.10
	CL 0.20	0.20

Notes:
[a] For a specific concrete use, the class to be applied depends upon the provisions valid in the place of use of the concrete.
[b] Where additions are used and are taken into account for the cement content, the chloride content is expressed as the percentage chloride ion by mass of cement plus total mass off additions that are taken into account.
[c] Different chloride content classes may be permitted for concrete containing CEM iii-cements according to provisions valid in the place of use.

Table D15. Method for Determining the Chloride Content of Constituent Materials

Constituent	Method specified in
Cement, fly ash, ggbs, limestone fines, metakaolin	*MS EN 196-2*
Aggregate excluding CCA and filler aggregate made from fly ash	*BS EN 1744-1*
Coarse CCA	*BS 1881-124*
Admixture	*BS EN 480-10*
Water[a]	*MS EN 196-2[b] or BS 6068-2.37[b]* (ISO 9297)

[a] Testing is not required if the water is from a potable supply.
[b] MS EN 1008 cites "the relevant clauses of BS EN 196-21" for the determination of chloride ion content. BS EN 196-21 has been superseded by MS EN 196-2. The chemical procedure is the same as that given in BS 6068-2.37 and in this case the starting point is a sample of water. When the chloride ion content is outside the recommended range for the test procedure, dilution and factoring is necessary

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Table D16. Compressive Strength Classes for Designed Concrete Normal Weight and Heavy Weight Concrete

Compressive strength class	Minimum characteristic cylinder strength $f_{ck,cyl}$ N/mm^2	Minimum characteristic cube strength $f_{ck,CUBE}$ N/mm^2
C6/8	6	8
C8/10	8	10
C12/15	12	15
C16/20	16	20
C20/25	20	25
C25/30	25	30
C28/35	28	35
C30/37	30	37
C32/40	32	40
C35/45	35	45
C40/50	40	50
C45/55	45	55
C50/60	50	60
C55/67	55	67
C60/75	60	75
C70/85	70	85
C80/95	80	95
C90/105	90	105
C100/115	100	115

Table D17. Compressive Strength Classes for Light Weight Concrete

Compressive strength class	Minimum characteristic cylinder strength $f_{ck,cyl}$ N/mm^2	Minimum characteristic cube strength $f_{ck,CUBE}$ N/mm^2
LC8/9	8	9
LC12/13	12	13
LC16/18	16	18
LC20/22	20	22
LC25/28	25	28
LC28/31	28	31
LC30/33	30	33
LC32/35	32	35
LC35/38	35	38
LC40/44	40	44
LC45/50	45	50
LC50/55	50	55
LC55/60	55	60
LC60/66	60	66
LC70/77	70	77
LC80/88	80	88

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Table D18. Minimum Rate of Sampling for Assessing Conformity

Production	Minimum rate of sampling for assessing conformity		
	First $50m^3$ of production	Subsequent to first $50m^3$ of production*	
		Concrete with production control certification	Concrete without production control certification
Initial (until at least 35 test results are recorded)	3 samples	1 per $200m^3$ or 1 per 3 production days	1 per $150m^3$ or 1 per production day
Continuous** (when at least 35 test results are recorded)		1 per $400m^3$ or 1 per 5 production days	

Notes:

* Sampling shall be distributed throughout the production and should not be more than 1 sample within each 25 m^3

** Where the standard deviation of the last 15 results exceeds 1.37σ, the sampling rate shall be increased to that required for initial production for the next 35 test results

Table D19. Conformity Criteria for Compressive Strength

Production	Number *n* of test results for compressive strength in the group	Criterion 1	Criterion 2
		Mean of n results (f_{cm}) N/mm^2	Any individual test result (f_{cl}) N/mm^2
Initial	3	$\geq f_{ck}+4$	$\geq f_{ck}-4$
Continuous	15	$\geq f_{ck}+1.48\sigma$	$\geq f_{ck}-4$

Table D20. Values of Verification of Standard Deviation

Number of Test Results	Limits for s_n
15 to 19	$0.63\,\sigma \leq s_n \leq 1.37\,\sigma$
20 to 24	$0.68\,\sigma \leq s_n \leq 1.31\,\sigma$
25 to 29	$0.72\,\sigma \leq s_n \leq 1.28\,\sigma$
30 to 34	$0.74\,\sigma \leq s_n \leq 1.26\,\sigma$
35[a]	$0.76\,\sigma \leq s_n \leq 1.24\,\sigma$

[a] In case of more than 35 test results
Formula (4) applies

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Table D21. The Precision Estimates for Calculated Chloride Content, C_s and Non-Steady State Chloride Diffusion Coefficient, D_{nss}

Parameter	Level	Repeatability conditions [5]		Reproducibility conditions [5]	
		sr	r	sR	R
D_{nss} (E-12) m^2/s	5.09	1.17	3.27	1.54	4.31
C_s m/m (by concrete mass)	0.45	0.20	0.23	0.20	0.24
Precision expressed in terms of coefficient of variation		CVr (%)	r (%)	CVR (%)	R (%)
D_{nss} (E-12) ±		23	65	33	92
C_s % ± (by concrete mass)		13	37	19	54

Note:

These estimates are based on a precision exercise undertaken in 2011-2012 [6]. The results shown have involved 12 laboratories using the same concrete samples (2 per test) made fulfilling EN 206 limiting values for concrete composition with two types of cements and two w/c ratios (four variables). These data were obtained by averaging over four concrete type mixes and three exposure type methods the values of Dnss and of Cs obtained by previously averaging over the laboratories involved in each specific mix/exposure combination. There were insufficient data for two of the exposure methods to determine the precision of each of the methods separately and to determine if there was any significance difference between the methods (the data available indicate no significant difference). The values in the table above apply to the three equivalent test methods described in this standard.

Table D22. Sampling Rate for Identity Testing

Type of Structure	Volume per sample
Prestressed concrete, masts, cantilevers, columns, footings, pile caps, shear wall, retaining wall	10.0 m^3 or every group of 10 batches
Slabs, beams	20.0 m^3 or every group of 20 batches
Raft foundation, mass concrete	50.0 m^3 or every group of 50 batches

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Table D23. Identity Criteria for Compressive Strength of Certified Concrete

Number n of test results for compressive strength from the defined volume of concrete	Criterion 1	Criterion2
	Mean of n results (f_{cm}) N/mm^2	Any individual test result (f_{cl}) N/mm^2
1	Not applicable	$\geq f_{ck} - 4$
2-4	$\geq f_{ck} + 1$	$\geq f_{ck} - 4$
5-6	$\geq f_{ck} + 2$	$\geq f_{ck} - 4$

Note:
The identity criteria give probability that a conforming concrete volume is rejected.

Table D24. Identity Criteria for Compressive Strength of Non-Certified Concrete

Number n of test results for compressive strength from the defined volume of concrete	Criterion 1	Criterion 2
	Mean of n results (f_{cm}) N/mm^2	Any individual test result (f_{cl}) N/mm^2
Consecutive 3	$\geq f_{ck} + 4$	$\geq f_{ck} - 4$

Table D25. Identity Criteria for Slump Specified as a Slump Class

Dimension in millimetres

Specified slump class	Requirement			
	For composite samples taken in accordance with MS 26-1-1		For spot samples taken from initial discharge	
	Not less than	Not more than	Not less than	Not more than
S1	0	50	0	60
S2	40	100	30	110
S3	90	160	80	170
S4	150	220	140	230
S5*	210	-	200	-

Note:
* Due to a lack of sensitivity of the slump test at slump values less than 10 mm or greater than 210 mm, it is recommended to only use the test for slump ≥ 10 mm and ≤ 210 mm.

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Table D26. Recorded Data and Other Documents, Where Relevant

Subject	Recorded data and other documents
Specified requirements	Contract specification or summary of requirements
Constituents	Name of suppliers, sources and declaration of performance
Tests on *mixing* water (not required for potable water)	Date and place of sampling Test results
Tests on constituents	Date and test results
Composition of concrete	Concrete description Record of masses of constituents in batch or load (e.g. cement content) Water/cement ratio Chloride content Code of family member
Tests on fresh concrete	Date and place of sampling Location in structure, if known Consistence (method used and results) Viscosity, if specified Segregation resistance, if specified Passing ability, if specified Density, if specified Fibre content, if specified Concrete temperature, if specified Air content, if specified Volume of concrete batch or load tested Number and codes of specimens to be tested Water/cement ratio, if specified
Tests on hardened concrete	Date of testing Code and ages of specimens Test results for density and strength Special remarks (e. g. unusual failure pattern of specimen)
Evaluation of conformity	Conformity/non-conformity with specifications of concrete
Additionally for ready-mixed concrete	Name of purchaser Location of work, e. g. the construction site Numbers and dates of delivery tickets related to tests Delivery tickets
Additionally for precast concrete	Additional or different data may be required by the relevant product standard

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Table D27. Characteristic Strength of Steel Reinforcement

Type	Nominal Sizes (mm)	Yield Strength, fy (N/mm^2)
Hot rolled grade 500 (MS 146)	All sizes	500
Steel Fabric (MS 145)	All sizes	500
Hard drawn steel wire (MS 144)	Up to and including 12	500
Cold worked (BS 4461)	All sizes	460

Table D28. Distance Between Spacers for Each Structural Component

No.	Structural component	Rebar diameter (mm)	Spacing/ distance (mm)
1.	Slab	6 8 ≥10 Steel fabric	500 600 700 500
2.	Column (Longitudinal direction)	≤10 12 - 20 >20	500 600 - 900 1000
3.	Beam (Longitudinal direction)	≤10 12 - 20 >20	300 400 - 700 800
4.	Footing	Similar to the slab	Similar to the slab.

Table D29. Number of Spacers for Column and Beam in Transverse Direction

No.	Structural component	Width /height in mm.	No. of spacer.
1.	Column	≤100 >100	2 nos. ≥3 nos.
2.	Beam	≤100 >100	2nos. ≥3 nos.

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Table D30. Minimum Periods Between Concreting and Removal of Forms

Vertical faces of beams, wall, columns, piles, foundation plinths and precast components	3 days
Slabs (props left under)	4 days
Removal of props to slab	10 days
Beam soffits (props left under)	8 days
Removal of props to beams	21 days

Note:
This table is applicable only for CEM1 cement. Where other types of cement, admixtures or additional material are to be used, the minimum periods between concreting and removal of forms shall be as approved by the S.O..

Table D31. Recommended Minimum Concrete Strength for Lifting and Handling

Application	Minimum concrete strength $f_{c,cube}$
Lifting which involves significant impact or high acceleration	15 N/mm^2*
All units where concrete strength for lifting is specified in drawing	2/3 of required design concrete strength
Eccentrically pre-stresses elements (tees, deep flooring units)	25 N/mm^2

Notes:
* Dependent on anchor length or as recommended by insert manufacturer or otherwise specified

Special care shall be taken with pre-stressed elements to ensure lifting devices are anchored in compression zones, unless covered by specific design

Table D32. Recommended Corrugated Sleeve Diameter

Corrugated Sleeve Diameter (mm)	Dowel Bar Size (mm)
45	10, 12
55	16, 20, 25
65	25, 32
75	32

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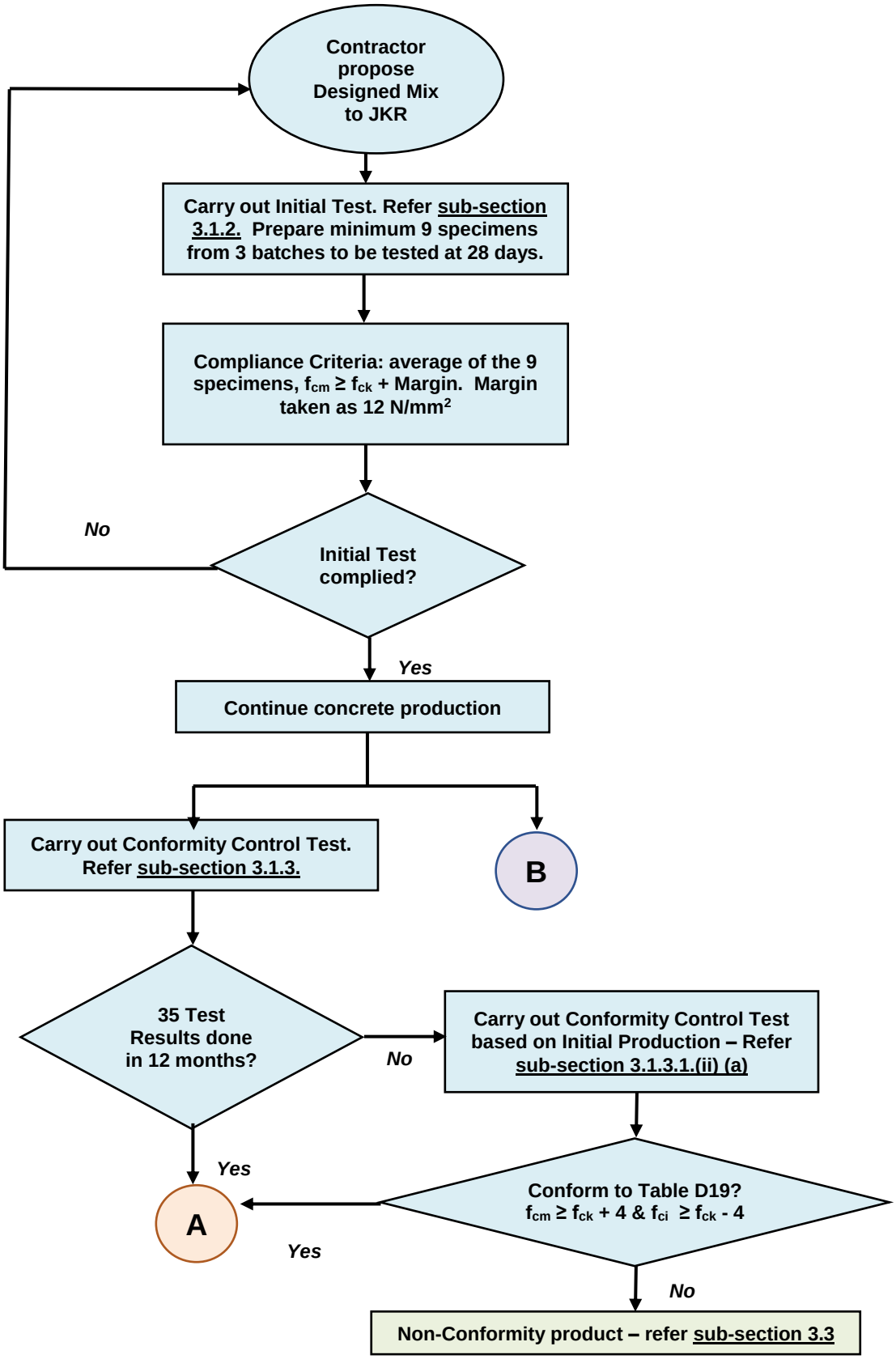
Figure D1a. Concrete Conformity Testing Flow Chart for Designed Concrete

(Non-Certified Concrete)



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(continued)

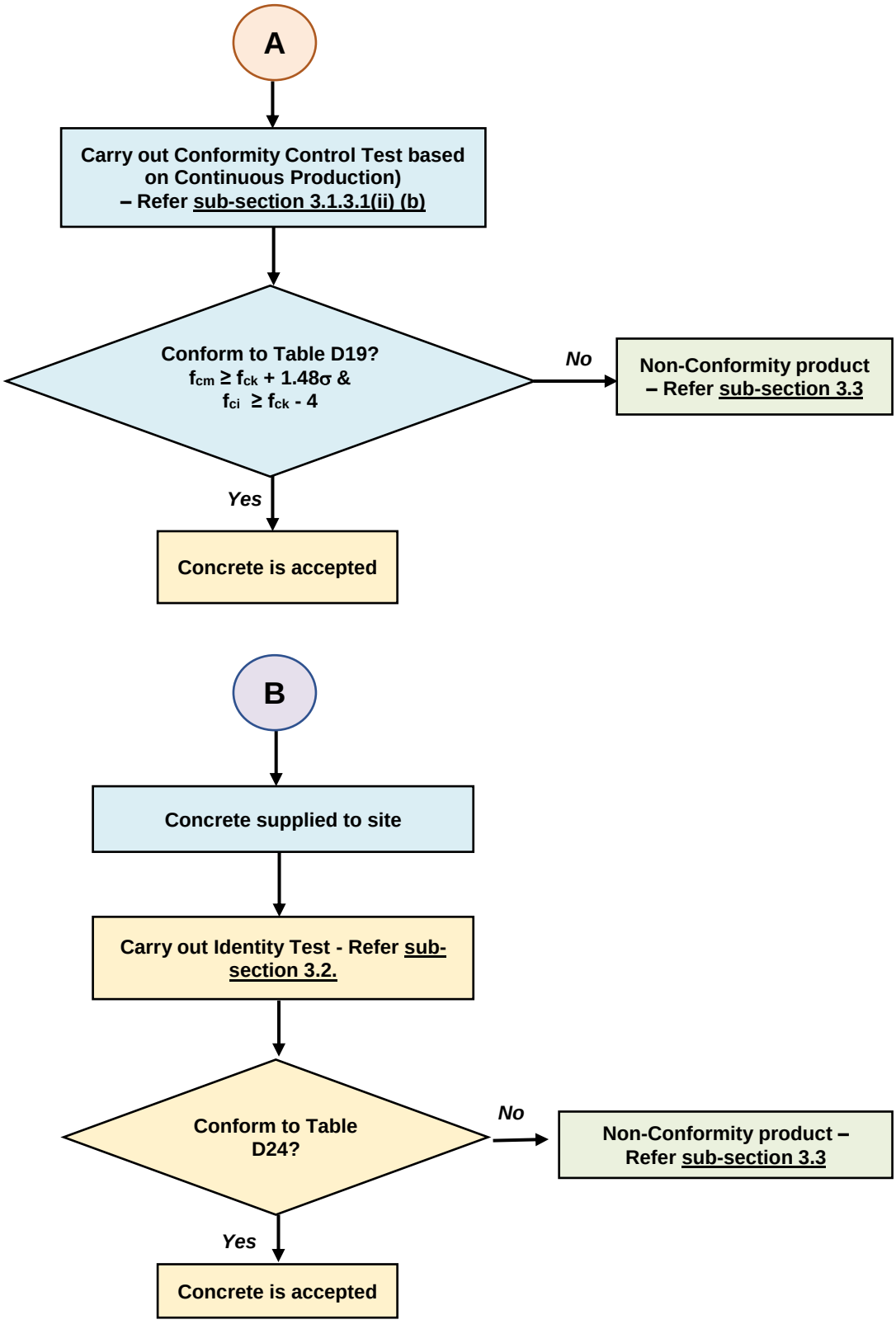

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Figure D1b. Concrete Conformity Testing Flow Chart for Designed Concrete

(Certified Concrete)

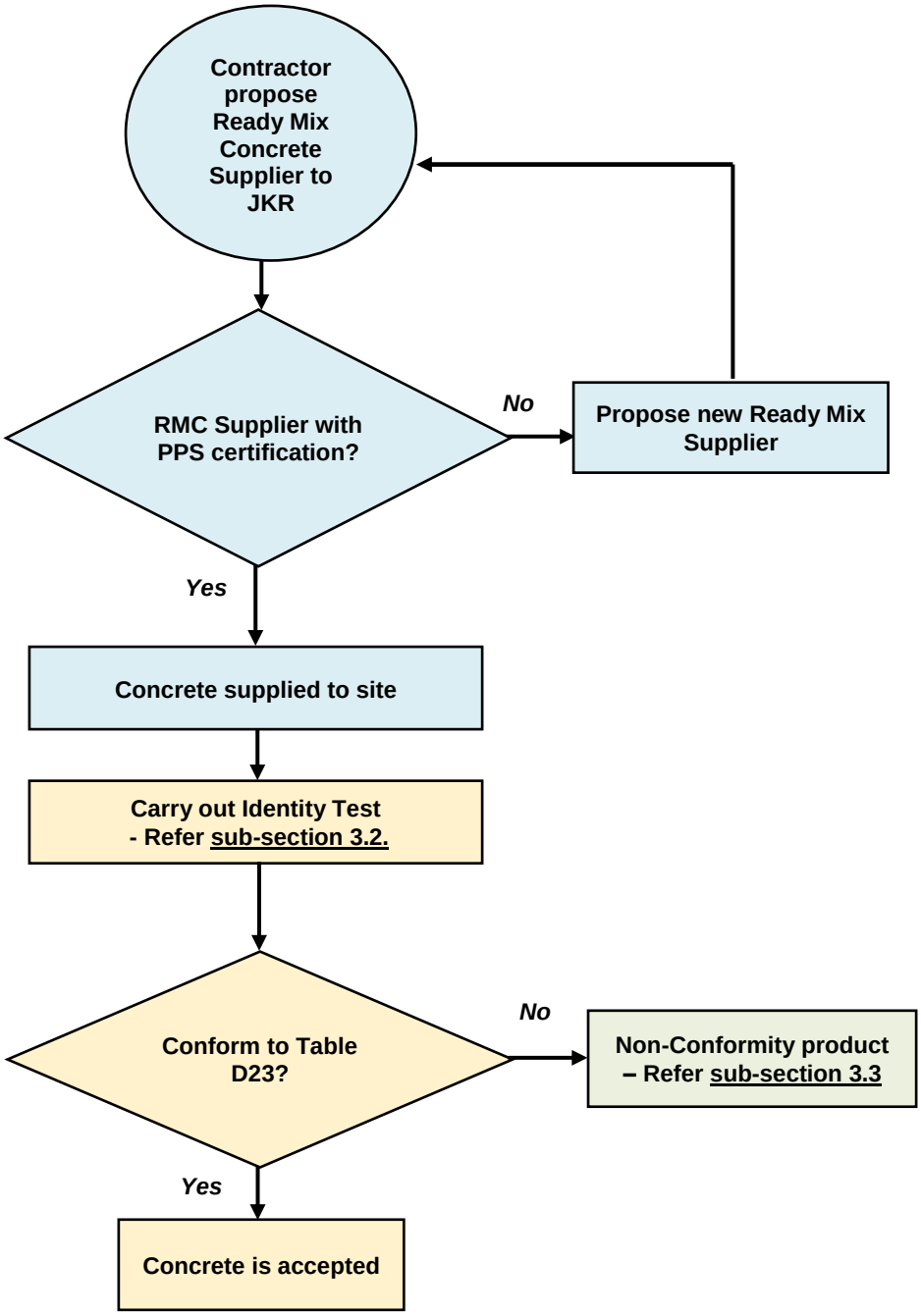

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Figure D2. Slump Test Measurement

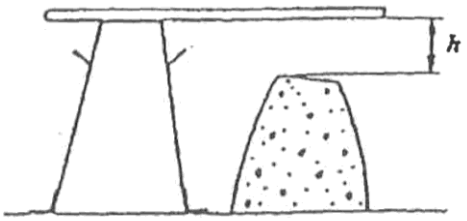

Figure D3. Flow Test Measurement

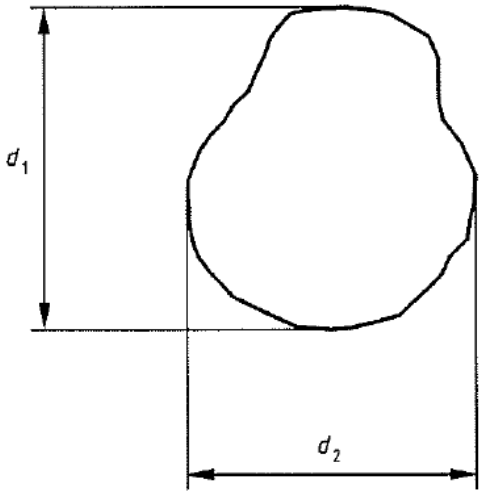

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Figure D4. Lift Shaft Enclosure

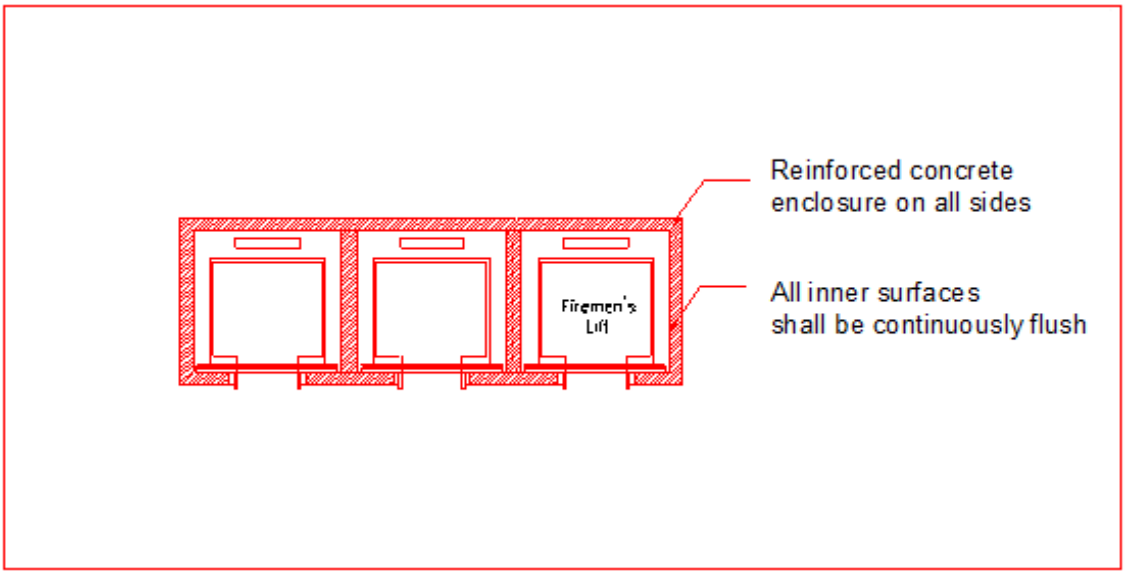

Figure D5. Limit of Accuracy of Shaft Plumb on All Sides of Shaft Enclosure

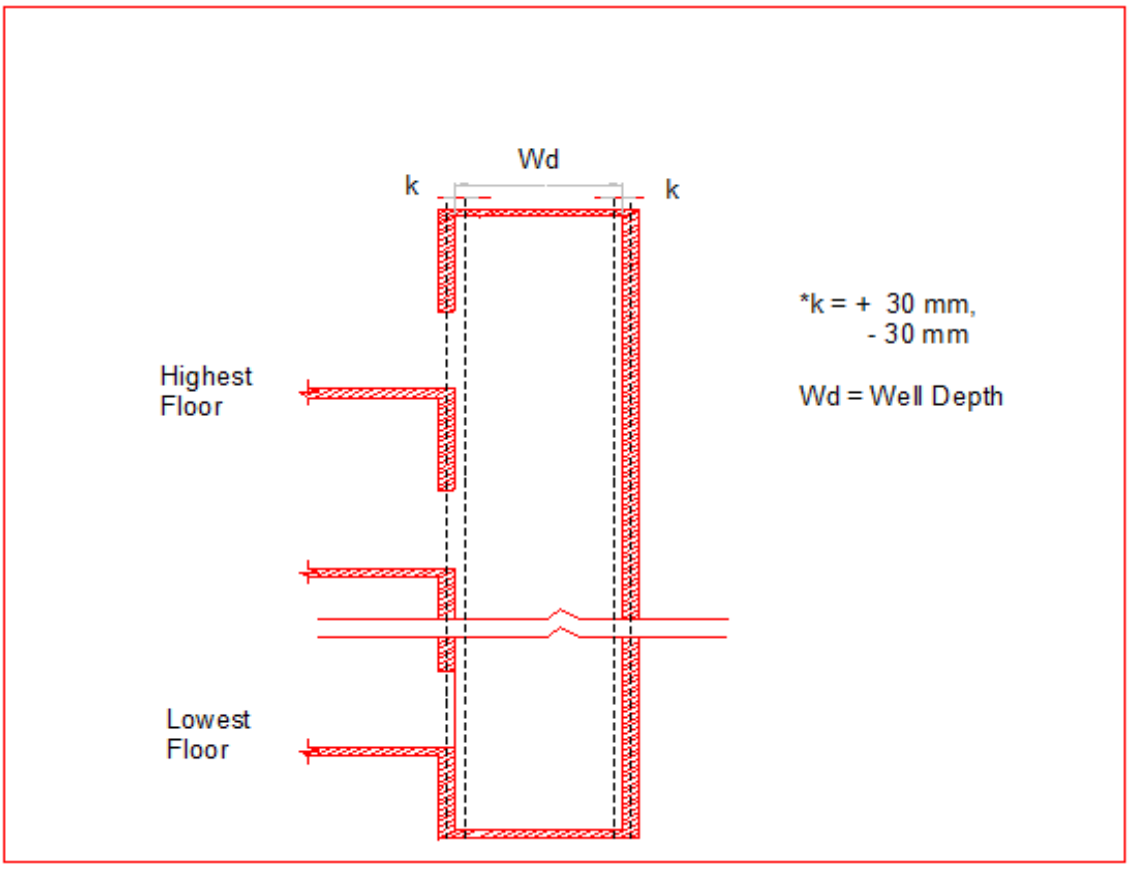

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Figure D6. Accuracy of Structural Opening

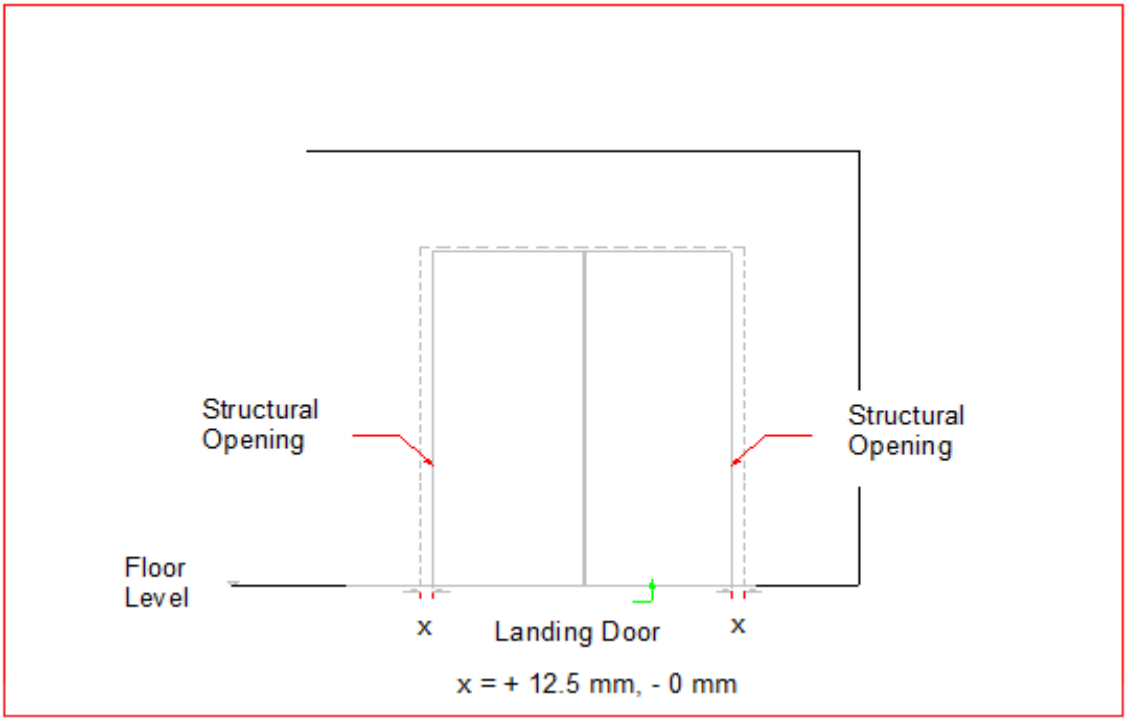

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TABLE OF CONTENTS

SECTION V: GROUND IMPROVEMENT		PAGE
1.	Description	V/1
2.	Removal and Replacement	V/1
3.	Surcharge	V/1
4.	Geosynthetics	V/3
5.	Prefabricated Vertical Drains (PVD)	V/10
6.	Stone Columns	V/16
7.	Deep Soil Mixing	V/25
8.	Dynamic Compaction	V/32
9.	Piled Embankment	V/35
10.	Geotechnical Instrumentation	V/36

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1. Description

This work shall consist of numerous ground improvement technique and instrumentation in regards with general requirement, method of installation and relevant testing to be implemented during construction.

2. Removal and Replacement

2.1. General

This Section shall be read together with SECTION B: EXCAVATION AND EARTHWORKS. Removal and replacement shall be used for ground improvement purposes to increase the bearing capacity of the ground. The work involves removal of unsuitable material and soft soil layer, hence replaced with suitable material as shown in the Drawing. Unsuitable material and suitable material are as defined in SECTION B: EXCAVATION AND EARTHWORKS.

2.2. Determination of Depth of Removal

2.2.1. The depth of removal shall be as shown on the Drawing or as determined by trial pits or JKR/Mackintosh Probe test as approved by the S.O.. The trial pits or probe test shall be carried out at locations as indicated in the Drawing or as instructed by the S.O..

2.2.2. The apparatus used shall be the standard JKR probes or Mackintosh probes. Procedure of works and details of the JKR probes and Mackintosh probes are as per *Standard Specification for Roadworks* "SECTION 17: SITE INVESTIGATION".

2.3. Materials for Replacement

2.3.1. Where geotextile is specified, it shall be laid as shown in the Drawing before commencement of filling works. The specification of geotextile shall be in accordance to sub-section 4.4..

2.3.2. Unless otherwise indicated in the Drawing, suitable materials for fill and method of compaction shall conform to SECTION B: EXCAVATION AND EARTHWORKS.

2.3.3. For replacement of excavated material under standing water, the fill material shall be granular material conforming to SECTION B: EXCAVATION AND EARTHWORKS.

3. Surcharge

3.1. General

3.1.1. The execution of surcharging works shall be in accordance with this Specification and details as shown in the Drawing.

3.1.2. The scope of works shall cover the following:

3.1.2.1. Spread, level and compact surcharging material in accordance with SECTION B: EXCAVATION AND EARTHWORKS and details as shown in the Drawing.

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3.1.2.2. Install geotechnical instrumentation to monitor and validate the performance of the works.

3.1.2.3. Removal and disposal of excess material on completion of specified surcharge period or as shown in Drawing or when directed by the S.O..

3.1.2.4. Removal and disposal of excess material of the embankment to the line, level and grade in accordance to details as shown in the Drawing to complete the works.

3.1.3. The Contractor shall be responsible for the provision of surcharge material and the removal and disposal of excess material on completion of the specified surcharge period or when directed by the S.O..

3.2. Materials

3.2.1. Materials for use in surcharging shall be suitable material conforming to *Standard Specification for Building Works* SECTION B: EXCAVATION AND EARTHWORKS.

3.2.2. The filling material shall be laid in layer and compacted as per SECTION B: EXCAVATION AND EARTHWORKS.

3.3. Surcharge Load and Surcharge Period

The surcharge load shall be applied throughout the surcharge period. The surcharge period specified in the Drawing is subjected to validation from field monitoring results, which may be shortened or lengthened at the discretion of the S.O. based on interpretation of field monitoring results.

3.4. Stability of Embankment

3.4.1. The height of the embankment including the surcharge shall at no time exceed the specified height in the Drawing. The placement of the surcharge materials shall be in uniform layers and care shall be given to ensure stability of the embankment. The Contractor shall check at all times the rate of placement and adjust accordingly in order to avoid instability. Stockpiling of excess earth, machineries or any other materials shall not be permitted on the embankment.

3.4.2. Where counterweight berm is designed to enhance the stability of the embankment including the surcharge, the counterweight berm shall be constructed first prior to placement of surcharge material.

3.4.3. The width, height and slope gradient of the counterweight berms shall be constructed in accordance to details shown in the Drawing. Any remedial works arising from non-compliance of the requirements of this section which leads to embankment failure shall be borne by the Contractor at his own cost and time.

3.5. Drainage Blanket

3.5.1. The drainage blanket layer shall consist of clean sand with less than 10% of fine content passing the 75μm sieve having grading within the respective limits specified in SECTION B: EXCAVATION AND EARTHWORKS, **TABLE B4**.

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3.5.2. The drainage material for depositing in water shall be deposited without the associated use of a compaction plant.

3.5.3. The drainage blanket shall be built up evenly in horizontal layers, each not more than 300mm thick up to the design thickness as specified in the Drawing. Filling shall commence from the lowest level, and each layer shall cover the full area of the intended total fill area at that level before deposition of the subsequent layer commences.

3.5.4. The drainage system shall be regularly maintained throughout the surcharge period to ensure smooth dissipation of water. The outlets of water at the brinks of drainage blanket shall be cleared of any obstruction at all times by way of regular maintenance.

3.6. Instrumentation

3.6.1. Surcharge monitoring shall be carried out to monitor stability, settlement, deflection and pore water pressure of the embankment due to Surcharging. The types and numbers of instruments and frequency of monitoring shall be in accordance to the Drawing or as specified by the S.O.. Specification for Instrumentation shall be in accordance with sub-section 10..

3.6.2. The monitoring results shall be submitted to the S.O. according to the agreed frequency and shall form part of the surcharge control measures. Evaluation and amendments to the surcharging design may be carried out from time to time by the S.O. based on interpretations of the monitoring results.

3.6.3. The Contractor shall be responsible for and shall follow the instructions of the manufacturer in the installation, calibration and testing of all measuring instruments and equipment.

3.7. Removal of Surcharge Materials

3.7.1. Removal of surcharge materials shall only be carried out as instructed by the S.O. upon completion of the specified surcharge period and validated with field monitoring results.

3.7.2. There shall be no unauthorized removal of surcharge materials before the completion of the specified surcharge period and any remedial works arising from such unauthorized removal of surcharge shall be borne by the Contractor at his own cost and time.

3.8. Use of Surcharging in Conjunction with Other Ground Improvement Methods

When surcharging is used in conjunction with other ground improvement methods such as prefabricated vertical drains, the works shall conform to the requirements of the associated ground improvement works.

4. Geosynthetics

4.1. General

4.1.1. Unless otherwise specified elsewhere in the specification or on the Drawing, geosynthetics for use in ground treatment shall conform to requirement as specified herein.

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4.1.2. Geosynthetics used shall be manufactured by manufacturer that is ISO 9001 certified.

4.1.3. Geosynthetics shall be durable and resistant to naturally occurring chemical, fungi and bacteria when in contact with soils or materials to be treated. In addition, geosynthetics used shall be resistant against rotting, mildew, insects, salts, alkali, solvent and other constituents of the ground water.

4.1.4. The contractor shall be responsible for the true and proper setting-out of the areas to which the geosynthetics are to be placed and provide all necessary resources and equipment related to supply and laying of geosynthetics to the correct level and dimension as shown in the Drawing or as instructed by the S.O..

4.2. Packaging, Transportation and Storage

4.2.1. Geosynthetics shall be wrapped in heavy paper or similar heavy-duty protection covering for transportation and storage. If no covered area is available, geosynthetics shall be stored on raised platform and covered with a waterproof canvas. Geosynthetics shall be protected from sunlight, moisture, mud, dirt, dust, debris and other detrimental substances during transportation and storage.

4.2.2. Each roll of geosynthetics delivered to site shall be clearly labelled with the following:

4.2.2.1. Product brand name

4.2.2.2. Product type

4.2.2.3. Product grade

4.2.2.4. Date of manufacture or submission of mill certificate

4.2.2.5. Roll width and length

4.2.2.6. Batch serial number

4.2.3. The Contractor is solely responsible for the good condition of the geosynthetics stored at the worksite and in the event of damages or deterioration of the geosynthetics due to improper storage, the Contractor shall be liable to replace the affected materials at his own cost when directed by the S.O..

4.2.4. All materials which are damaged during transportation, handling or storage and do not meet the minimum requirements of the specification shall be rejected by the S.O. and shall be immediately taken off the site. No payment of any kind shall be made on the rejected product.

4.3. Quality Control and Testing

4.3.1. Submission of Material Test Report (MTR)

4.3.1.1. The contractor shall obtain the S.O.'s approval prior to supplying the geosynthetics to the site. Prior to the procurement of materials, the Contractor shall provide a sample and Material Test Report (MTR) not more than two (2) years old from the *ISO/IEC 17025* accredited laboratory with the scope of

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accreditation referring to geosynthetics, showing full compliance of the proposed geosynthetics to all the specified property values corresponding to their respective test methods for the approval of the S.O.. The *ISO/IEC 17025* accredited laboratory shall be internationally recognized accredited laboratory or higher learning institutions research laboratory.

4.3.1.2. The Contractor shall also submit technical data and samples to verify the physical, mechanical and hydraulic properties of the geosynthetics to be used for S.O.'s approval.

4.3.1.3. All tests shall be carried out in accordance with the Codes of Practices and Test Standards provided within this Specification. All cost associated with the tests and preparation of report shall be borne solely by the Contractor.

4.3.2. Routine Sample Testing

4.3.2.1. Routine sample testing shall be carried out at factory or at an accredited laboratory witnessed by the S.O.'s representative. The Contractor shall submit test report after each routine test showing compliance of the Specification.

4.3.2.2. Prior to installation and at the discretion of the S.O., test samples shall be carried out at the frequency specified in **Table V1** and **Table V2**. Control testing shall be carried out for each batch of geosynthetics in accordance with the provisions of **Table V1** and **Table V2**.

4.3.2.3. Individual sample shall not be less than two (2) meters in length for non-woven geotextile and one (1) meter in length for high strength woven geotextile and geogrid, times the full width of the geosynthetics. Samples submitted for tests shall indicate the linear meters of the geosynthetics and manufacturer's identifications represented by the sample.

4.3.2.4. Should any individual sample selected at random fail to meet the Specification, then that roll shall be rejected, and two additional samples shall be taken at random from two other rolls representing the same batch. If either of these two additional samples fails to comply with the Specification, then the entire batch of geotextile represented by the samples shall be rejected.

4.4. Geotextile

4.4.1. General

Geotextile shall be made of new synthetic polymeric fabric that are stable or stabilized against ultra violet (UV) radiation such that three months exposure to sunlight shall not reduce its specified strength to less than 70%.

4.4.2. Installation

4.4.2.1. Prior to the laying of geotextile, site clearance shall be carried out in accordance with the Specification and Drawing or as directed by the S.O.. All voids shall be filled with suitable material and the area cleared of large stones and exposed tree

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root systems or other such like protrusions. Geotextile fabric shall be installed to the shape and requirements as specified herein and in the Drawing.

4.4.2.2. Geotextile shall be placed just in advance of placement of the specified overlying fill material. Geotextiles laid shall be covered by the fill as soon as possible within seven (7) days of being placed. The counting of this foresaid seven (7) days shall commence immediately upon the geotextile being exposed from its protective wrapping. Installation proposals and trials as deemed required shall be carried out for approval by the S.O. prior to the acceptance of the placement method for the main works.

4.4.2.3. The geotextile shall be unrolled smoothly on the prepared ground. In general, high strength woven geotextile shall be placed transversely, across the direction of the road, or otherwise as approved by the S.O.. The geotextile shall be laid flat on the underlying surface with no wrinkles or folds and shall extend far enough over the edges of the embankment for a wrap-around as shown in the Drawing.

4.4.2.4. Adjacent geotextile rolls shall be overlapped or sewn in accordance with this Specification. Overlapping of geotextile without sewn connections shall only be allowed with the approval of the S.O.. On curves and corners, geotextile may be folded or cut to conform to the direction as approved by the S.O.. The seaming of geotextile is as described in sub-section 4.4.3..

4.4.2.5. The specified overlying fill material properties and method of compaction on the non-woven geotextile fabric shall be in accordance with SECTION B: EXCAVATION AND EARTHWORKS. Fill materials shall be deposited in layers in accordance with SECTION B: EXCAVATION AND EARTHWORKS and shall be spread simultaneously with the dumping in a manner to prevent any localized distress or failure of the ground.

4.4.2.6. No traffic shall travel directly on the non-woven geotextile and there shall be no sudden stops, starts or turns on the fill materials by the construction equipment or other such actions which may cause damage to the geotextile.

4.4.2.7. In water logged or swampy areas, the non-woven geotextiles shall be sunk after jointing by ballasting with sufficient sandbags. To control the location of the mattress, buoys shall be fixed with ropes on the edges of the non-woven geotextile or using other method as approved by the S.O.. The mattress shall be ballasted as soon as possible after positioning.

4.4.2.8. The contractor shall submit a detailed method statement on installation of the non-woven geotextile to the S.O. for approval prior to commencing installation works.

4.4.3. Jointing of Geotextile

4.4.3.1. In general, the joints are allowed for both machine direction (MD) and cross direction (CD) of the non-woven or woven

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geotextile used in separation and filtration application. Jointing of reinforcement geosynthethics such as high strength woven geotextile, geogrid, etc. is only allowed in the CD for reinforced soil structures (reinforced soil wall/soil slope and mechanically stabilized embankment).

4.4.3.2. Methods of Jointing

(i) There are two common methods to connect the geotextile, which are by overlapping or seaming. The decision to use an overlap or seam shall be based on the following: -

a) The weakness of the foundation soil upon which the geotextile is directly placed with respect to the potential for mud waving during the backfill operation;

b) the material and labour costs of deploying individual geotextile panels with extra material required for the overlap versus the material and labour costs of seaming and installing large, fabricated panels; and

c) The feasibility of deploying individual geotextile panels in poor access and/or adverse climatic conditions.

(ii) **Table V3** provides a guide in determining overlap requirements for separation/stabilization applications based on sub grade strength. When the sub grade soils upon which the geotextile is directly placed provides shear strength less than CBR = 0.5, the adjacent geotextile panels shall be seamed.

4.4.3.3. Sewn Seams

(i) The geotextile may be jointed using an approved handheld sewing machine by sewing a double thread ‘lock stitch’ with 'prayer' or ‘J’ or ‘butterfly’ seam (minimum lap of 50mm) as shown in **Figure V1**. Typically, polyester thread is used for seaming geotextiles. Minimum required density of stitches during sewing of the geotextile is 3 stitches per 25mm. The thread shall have a breaking load of not less than 200N.

(ii) The expected seam strength shall be more than 70% of the original strength of the non-woven geotextile. For high strength woven geotextiles, the expected seam strength shall be more than 30% of the original strength. Samples of such sewn seam assembly shall be tested in accordance with *ISO 10321* or *ASTM D4884* as requested by the S.O..

4.4.4. Non-Woven Geotextile

4.4.4.1. Non-woven geotextile described in this specification shall be for separation and filtration application of the ground treatment.

4.4.4.2. Unless otherwise approved by the S.O., non-woven geotextile shall be needle punched fibres of polypropylene or polyester supplied by an approved manufacturer.

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4.4.4.3. The physical, mechanical and hydraulic properties of non-woven geotextile shall meet the minimum requirement as given in **Table V4**. Minimum roll width shall be 4.0 meters.

4.4.4.4. In addition to requirement given in sub-section 4.3., the Contractor shall furnish test certificate from accredited laboratory that includes the following:

(i) Wide width tensile strength

(ii) Elongation

(iii) CBR Puncture Resistance

(iv) Permeability

(v) Effective Opening Size, O_{90} or Apparent Opening Size, O_{95}

4.4.5. High Strength Woven Geotextile

4.4.5.1. High strength woven geotextile described in this specification shall be for basal reinforcement application of the ground treatment.

4.4.5.2. Unless otherwise approved by the S.O., high strength woven geotextile shall comprise of woven yarns of high tenacity polyester filaments with properties that meet the requirement as given in **Table V5**. The edges of fabric shall be selvedge or otherwise finished in such a way to prevent the outer yarn from unravelling.

4.4.5.3. High strength woven geotextile shall be free of any flaws that may have an adverse effect on its physical and mechanical properties. Minimum roll width shall be 5.0 meters.

4.5. Geogrid

4.5.1. General

4.5.1.1. Unless otherwise specified elsewhere in the specification or in the Drawing, geogrid for use as geotechnical reinforcement and in ground treatment shall conform to the requirements as specified herein.

4.5.1.2. Geogrid shall be made of high tenacity polyester coated with PVC that meets the requirements as given **Table V6**. The geogrid shall be formed from cross-laid strips (geo-linear elements) bonded at the cross-over points. The geo-linear elements shall consist of continuous high tenacity polyester fibres coated with PVC.

4.5.1.3. Bonding at the cross-over points shall be such that the properties as required by the Contract are not affected. The strength of the bond shall be such as to ensure the function of the geogrid is achieved.

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4.5.1.4. The polyester fibres shall be:

(i) Coated with PVC to completely prevent ingress of moisture;

(ii) All free ends shall be sealed to completely prevent ingress of moisture;

4.5.1.5. The weft (referring to CD) elements shall be the same quality material as the warp (referring to MD) elements.

4.5.2. Durability of Geogrid

4.5.2.1. Durability of the geogrid shall be such that a design life of 120 years is achieved. The geogrid shall not deteriorate from exposure to sunlight and due to chemical action or biodegradation when buried in wet soil.

4.5.2.2. Information relating to the durability of the geogrid shall be submitted as required by the S.O. for his approval.

4.5.3. Method of Installation

4.5.3.1. Installation of geogrid shall be carried out by qualified and experienced workers under the supervision of a competent person. The geogrid shall be installed in compliance to Manufacturer's instructions utilizing approved plants/equipment. The fill to the lines and levels shall be well-graded granular, dry cohesive soils or other engineered fill as shown in the Drawing.

4.5.3.2. All works related to earthwork shall be referred to SECTION B: EXCAVATION AND EARTHWORKS.

4.5.3.3. Installation of Geogrid for Reinforced Slope

(i) At each level of geogrid reinforcement, backfill shall be roughly levelled before placing the geogrid. Compaction shall be carried out to the requirements of the Specifications. During backfill placement, trucks and heavy vehicles shall be kept back at least 1.0 meter from the face of the Geogrid Reinforced Slope.

(ii) The deposition, spreading, levelling and compaction of the fill shall be carried out generally in a direction parallel to the facing and shall be executed in stages to alternate with the placing and fixing of the reinforcing elements and the facing. The geogrid shall be laid whereby machine direction (MD) is in a direction perpendicular to the face of reinforced wall or slope. The overlapping width of adjacent panels of geogrid shall be minimum 150mm.

(iii) Care shall be taken to ensure that the reinforcing elements and facing are not damaged or displaced during deposition, spreading, levelling and compaction of the fill. The program of filling shall be arranged so that no machines or vehicles run on the reinforcing elements.

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(iv) The fill within 1.0 meter of the face of the Geogrid Reinforced Slope shall be compacted using one of the following:

a) Vibro tamper

b) Vibrating plate compacter having a mass not exceeding 1000kg

c) Vibrating roller having a mass per metre width of not more than 1300kg and a total mass of not more than 1000kg

(v) The rear of the Geogrid Reinforcing Slope shall be adequately supported either by temporary shoring or by phasing the work to ensure the contemporaneous deposition of the retained fill material.

4.5.3.4. Protection of Completed Geogrid Reinforced Slopes from Erosion

The Contractor, as specified in the Drawing or where instructed by the S.O., shall carry out adequate erosion protection measures such as vegetation, etc.

4.5.3.5. Drainage

The Contractor, as specified in the Drawing or where instructed by the S.O., shall carry out adequate water discharge method such as horizontal drain, cascade drain, etc to ensure the drainage of impounding water on the slope and the surface runoff.

5. Prefabricated Vertical Drains (PVD)

5.1. General

5.1.1. This specification covers the technical requirements for the supply and installation of Prefabricated Vertical Drains (PVD) as described herein. All materials used shall meet the requirements of this specification and all works shall be executed in accordance with the details shown in the Drawing and the procedures described herein.

5.1.2. The Contractor shall provide all necessary resources including materials, skilled workers, and plant/equipment to execute and complete the works related to supply and installation of PVD as shown in the Drawing.

5.1.3. All materials and workmanship shall be in accordance with the appropriate British Standards current at the time of tender, including those listed in this Specification, except where the requirements of British Standards conflict with this Specification, the latter shall take precedence unless otherwise approved by the S.O..

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5.1.4. The Contractor shall be responsible for the true and proper setting-out of the areas to which the PVD is to be placed and for the correctness of the lines, widths and levels.

5.2. Soil Investigation Report

A soil investigation report shall be made available at the S.O.'s office for the Contractor's information. The report is intended solely as a preliminary guide and neither the completeness nor the accuracy of the information provided is guaranteed. No responsibility is assumed by the S.O. for any opinion or conclusion given in the soil report. The Contractor shall study the given soil report and make his own interpretation of the information provided and to make due allowance for the effect of site conditions on his construction operations.

5.2.1. Pre-Treatment Soil Investigation

Cone Penetration Test (CPT) may be carried out to verify the thickness of sub-soil to be treated using PVD. CPT may be carried out if necessary. The CPT results shall be submitted to the S.O. for design verification purpose prior to the commencement of work.

5.3. Transportation and Storage

5.3.1. The PVD materials shall be labelled or tagged for sample identification and other quality control purposes. Each pallet shall be identified by the manufacturer's name, lot number, individual roll number, roll length, date of manufacture or mill certificate, manufacturer and product identification of the jacket and core.

5.3.2. During transportation and storage, the PVD shall be wrapped in heavy paper, burlap or similar heavy-duty protection covering. The PVD shall be protected from sunlight, mud, dirt, dust, debris and other detrimental substances during transport and on-site storage.

5.3.3. The Contractor shall ensure that the PVD is in good condition and properly stored in a covered area at the worksite. If no covered area is available, the PVD may be stored on raised platform and covered with a waterproof canvas. In the event of damage or deterioration of the PVD due to improper storage, the Contractor shall be liable to replace the affected materials at his own cost.

5.4. Materials

5.4.1. Prefabricated Vertical Drains (PVD)

5.4.1.1. General Requirements

(i) Prefabricated Vertical Drains (PVD) shall be from an approved manufacturer and consist of a polymer core enclosed within an external non-woven filter jacket and shall comply with the requirements as indicated in **Table V7**. The PVD shall be produced by factory with *ISO 9001* certification. The manufacturing process as well as the relevant tests required shall be accredited. The filter jacket shall be capable of resisting all bending,

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puncturing and tensioning subjected during installation and design life of the drain.

(ii) The core shall be made of continuous plastic material fabricated to facilitate drainage along the axis of the vertical drain.

(iii) The prefabricated vertical drain shall be resistant against rotting, mildew, bacterial action, insect, salts, acids, alkalis, solvent and other constituents in ground water.

5.4.1.2. Quality Control and Testing

(i) Submission of Material Test Report (MTR)

This section shall be in accordance with sub-section 4.3.1..

(ii) Routine Sample Testing

a) This section shall be in accordance with sub-section 4.3.2..

b) Prior to installation and at the discretion of the S.O., individual test sample shall be cut off from at least one roll selected at random to represent each batch or the first 100,000 meters, whichever is lesser. Individual sample shall be not less than 15 meters in length. Samples submitted for tests shall indicate the linear meters of drain and manufacturer's identifications represented by the sample.

5.4.2. Geotextile

This section shall be in accordance with sub-section 4.4..

5.4.3. Drainage Blanket

This section shall be in accordance with sub-section 3.5..

5.5. Installation

Proper method statement for installation shall be prepared and submitted to the S.O. for approval before commencement of works. The method statement shall include the use of all necessary resources such as materials, manpower, machineries and equipments. Also, to include is the sequence of works with diagrammatical illustrations where necessary, workmanship requirements as well as the construction quality controls.

5.5.1. Procedure

The equipment used for the installation of the PVD shall have adequate capacity to install the PVD to the required depth at one go without the need for any withdrawal and re-insertion. The Contractor shall be responsible to ensure that the working platform is stable and safe without risks to workers and nearby buildings or structures.

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5.5.2. Geotextile

The installation of geotextile section shall be carried out in accordance with sub-section 4.4..

5.5.3. Drainage Blanket

This section shall be in accordance with sub-section 3.5..

5.5.4. Prefabricated Vertical Drain (PVD)

5.5.4.1. Equipment

(i) PVD shall be installed with approved equipment of a type which will cause minimum disturbance to the sub-soil during the installation and maintain the mandrel in a vertical position.

(ii) PVD shall be inserted into the soil using a mandrel or sleeve. The mandrel or sleeve shall protect the drain material from tears, cuts and abrasion during installation and shall be retracted after each drain is installed.

(iii) The size and shape of the mandrel or sleeve shall be as close as possible to the size and shape of the drains to minimize disturbance to the soil. The length of the mandrel shall be not less than the maximum length of the drain. The mandrel shall be capable of making a clean puncture through any geotextile if necessary.

(iv) The mandrel or sleeve shall be provided with an anchor plate or similar arrangement at the bottom to prevent the soil from entering the bottom of the mandrel during the installation of the drain and to anchor the drain tip at the required depth at the time of mandrel withdrawal.

(v) The installation equipment of PVD shall come with a data log that shows the details of each PVD installed which includes, among others, the tag number and depth depending on what is required by the S.O.. The data log shall be converted into a file that is accessible and readable to the S.O..

5.5.4.2. Method Statement

(i) Fourteen (14) working days before the commencement of PVD installation, the Contractor shall submit full details of the materials, equipment, sequence and method proposed for PVD installation to the S.O. for review and approval. Approval by the S.O. of installation sequence and methods shall not relieve the Contractor of his responsibility to install drains in accordance with the Drawing and specifications.

(ii) Approval by the S.O. of the method or equipment used to install the drains shall not constitute, necessarily,

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acceptance of the method for the remainder of the project. If, at any time, the S.O. considers that the method of installation does not produce satisfactory quality and productivity as expected, the Contractor shall alter his method and/or equipment as necessary to comply with these specifications.

5.5.4.3. Setting Out

The intended positions of PVD shall be marked, numbered and pegged by the Contractor using a baseline and benchmark indicated by the S.O.. The Contractor shall take all reasonable precautions to preserve the pegs and is responsible for any necessary re-pegging.

5.5.4.4. Depth and Positioning

PVD shall be installed from the working surface to the depth shown in the Drawing, or to such depth as directed by the S.O.. The Contractor shall furnish to the S.O. on the next working day a summary of the PVD installed that day. The summary shall include the PVD type, location and length of PVD installed at each location.

5.5.4.5. Verticality

Equipment for installation PVD shall be plumbed prior to installing each PVD and shall not deviate from the vertical more than 1 in 50 during installing of any PVD.

5.5.4.6. Tolerances

The positions of installed PVD shall not vary by more than 150mm from the positions indicated in the Drawing. PVD installed which deviated more than 150mm from design plan positions or are damaged or improperly installed shall be rejected and abandoned in place and replaced accordingly.

5.5.4.7. Installation

(i) PVD shall be installed using a continuous push using static weight or vibration. Installation techniques using driving will not be permitted.

(ii) The installation shall be performed, without any damage to the PVD during advancement or retraction of the mandrel. In no case will alternate raising or lowering of the mandrel during advancement be permitted. Raising of the mandrel will only be permitted after completion of an installation.

(iii) The completed PVD shall be cut off neatly 150mm above the working grade, or as otherwise specified in the contract Drawing.

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5.5.4.8. Instrumentation Damage

The Contractor shall observe precautions necessary for protection of any field instrumentation devices. The Contractor shall replace, at his own expense, any instrumentation or equipment that has been damaged or become unreliable as a result of his operations prior to continuing with PVD installation or other construction activities.

5.5.4.9. Pre-Augering

(i) The Contractor shall be responsible for penetrating overlying fill material as necessary to satisfactorily install the PVD. Satisfactory installation may require clearing obstructions defined as any man-made or natural object or strata that prevents the proper insertion of the mandrel and installation of the PVD.

(ii) Where obstructions are encountered below the working surface which cannot be penetrated by the installation equipment, the Contractor shall complete the drain from the elevation of the working surface to the obstruction and notify the S.O. prior to installing any more PVD.

(iii) At the direction of the S.O. and under his review, the Contractor shall attempt to install a new PVD within 600mm horizontally from the obstructed PVD. A maximum of two attempts shall be made as directed by the S.O.. If the PVD still cannot be installed to the design tip elevation, the PVD location shall be abandoned and the installation equipment shall be moved to the next location, or other action shall be taken as directed by the S.O..

(iv) The Contractor may use augering, spudding, or other approved methods to loosen the soil and any obstructive material prior to the installation of PVD. The obstruction clearance procedure is subjected to the approval of the S.O.; however, such, approval shall not relieve the Contractor of his responsibility to clear obstructions in accordance with the specification.

(v) If augering is the selected method, the augers shall have a minimum outside diameter equal to the largest horizontal dimension of the mandrel, shoe or anchor, whichever is greater.

5.5.4.10. Splicing

Splicing of PVD material shall be done by stapling in a workmanlike manner and so as to ensure structural and hydraulic continuity of the drain. At the splice, the minimum overlap shall be 150mm and the lower portion of the jacket shall be external to the upper portion. A maximum of 1 splice per PVD installed will be permitted.

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5.5.5. Surcharge

This section shall be in accordance with sub-section 3..

5.6. As-Built Records

The Contractor shall submit to S.O. the daily installation record verified by S.O. representative, specialist contractor and main contractor on the next working day. The contractor shall submit as-built PVD treatment area plan certified by a Licensed Surveyor within fourteen (14) working days of completion of the last PVD. The as-built Drawing and records shall include the as-built position and depth of each PVD point noting any deviation outside specified tolerances.

6. Stone Columns

6.1. General

The work shall consist of the supply of equipment, labour and materials for the execution of stone column works for ground improvement. The stone column described in this Specification shall be carried out by deep vibratory compaction incorporating stone columns formed with imported granular backfill complying with the requirements of the latest version of *BS EN 14731*. This section shall be also in accordance with sub-section 5.1..

6.2. Soil investigation report

This section shall be in accordance with sub-section 5.2..

6.2.1. Pre-Treatment Soil Investigation

This section shall be in accordance with sub-section 5.2.1..

6.3. Method Statement for Construction Operations

6.3.1. Two (2) weeks before the commencement of the works, the Contractor shall submit to the S.O. a detailed method statement for the works. The method statement shall contain the following:

6.3.1.1. A detailed construction sequence;

6.3.1.2. Shop drawing showing details of all special requirements for the construction activities;

6.3.1.3. Design calculation of key temporary works endorsed by a P.E.;

6.3.1.4. Materials, plant and labour requirement at each construction stage;

6.3.1.5. Rate of production output based on resources allocated;

6.3.1.6. Environmental Management Plan in related with the works;

6.3.1.7. Other information relevant to the works.

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6.3.2. If requested by the S.O., the Contractor shall submit additional information pertaining to the method of construction.

6.3.3. The Contractor shall not change the methods which have been approved by the S.O.'s Approval. of the Contractor's proposed methods of construction shall not in any way relieve the Contractor of any of his duties or responsibilities under the contract.

6.4. Unexpected Ground Conditions

The Contractor shall report immediately to the S.O. any circumstances which, in the Contractor's opinion, indicate ground conditions that may differ from those expected by him from interpretation of the soil investigation report. The Contractor's report shall be in the form of written notice of which shall be given to the S.O. at the earliest possible time after encountering such conditions and obstructions. The report shall be accompanied by all information available to the Contractor which will materially assist the S.O. in verifying the conditions reported.

6.5. Adjacent Structures

6.5.1. The Contractor shall pay very careful attention to the construction constraints imposed by adjacent structures. The Contractor shall exercise extra care and implement adequate monitoring measures when carrying out the works so as not to disturb or damage the existing adjacent properties and foundations. The Contractor shall provide a proposal for monitoring adjacent properties for any detrimental effects arising out in execution of the works, so that appropriate and timely preventive action can be taken to minimise damage. The Contractor's proposal and monitoring program shall be certified by his Professional Engineer and approved by S.O..

6.5.2. The Contractor shall also carry out a condition survey of adjacent properties to establish the condition of the existing structures and facilities prior to commencement of work. Condition Survey shall be conducted by competent personnel and the result of the survey shall be submitted to the S.O. for record.

6.5.3. The Contractor shall be responsible for and shall bear the cost of such works and any claims of damage to adjacent structure and facilities arising from his execution of the works.

6.6. Existing Services

Prior to commencement of works, services in the ground and overhead shall be identified and clearly marked. The Contractor shall give all required notices to the appropriate utility authorities before commencement of works. The Contractor shall also locate existing services by piloting, protect existing services, rectify any damage or interference to them and provide temporary support while repairs are being carried out if so required.

6.7. Workmanship

6.7.1. The Contractor shall satisfy the S.O. regarding the suitability, efficiency and adequacy of the equipment to be employed. The Contractor shall state the type and number of rigs he intends to use.

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6.7.2. On completion of each area of stone column the Contractor shall grade debris and surplus material arising from the stone column to leave a reasonable firm and level working surface. On completion of the stone columns to the satisfaction of the S.O., the Contractor shall remove from the site all plant and unwanted material.

6.7.3. Installation of the stone columns shall be carried out by experienced Specialist Contractor approved by S.O.. The Specialist Contractor shall have the following experience and personnel: -

6.7.3.1. The Specialist Contractor shall employ personnel experienced in the construction of stone columns for this part of the Works.

6.7.4. For both dry and wet methods, the depth vibrator shall be sufficiently powerful to ensure:

6.7.4.1. The depth indicated in the Drawing may be reached; and

6.7.4.2. Adequate compaction of the stones can be achieved

6.7.5. For the avoidance of doubt, any equipment other than a depth vibrator as specified in the latest version of *BS EN 14731*, is non-complying and precluded.

6.8. Setting Out

Setting out shall be carried out by the Contractor from grid lines provided and maintained by the Contractor. Immediately before installation, the column position shall be marked with suitable identifiable pins, pegs or markers at least 300mm length. The pins, pegs or markers should be driven to ground level and the location marked with contrasting material.

6.9. Materials

6.9.1. Material used for forming stone columns shall consist of hard and durable stone so as to remain stable during column construction and the working life of stone columns. The material may be natural or crushed stones or recycled material based on availability at site, and shall conform to the following requirements:

6.9.1.1. The Aggregate Crushing Value (ACV) shall be not more than 30% (tested in accordance with latest version of *MS 30* or equivalent);

6.9.1.2. The Flakiness Index shall be not more than 30% (tested in accordance with latest version of *MS 30* or equivalent);

6.9.1.3. The average loss of weight in the sodium sulphate soundness test (5 cycles), shall not be more than 10% (tested in accordance with *AASHTO Test Method T104* or equivalent);

(i) The gradation shall comply with **Table V8** as appropriate.

The above tests shall be carried out on each of every source of material supplied to site.

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6.9.2. Material shall be used with a grading appropriate for compaction to form a dense column fully interlocking with surrounding ground. Material shall be compatible with the vibro plant used and flow freely within bottom and through feed delivery systems without arching, which may block these systems.

6.9.3. Material with particle size falling in the range of 20-40mm size (dry method) and 50-75mm size (wet method), its appropriate grading limit are as per **Table V8**. Quarry dust and other fine stone chippings shall be limited to not more than 5%. The material shall also be free of unsuitable material.

6.9.4. Prior to commencement of the works, the Specialist Contractor shall submit samples of the stone backfill from proposed source of supply to the S.O. for his approval.

6.9.5. Throughout the period of the works, when directed by the S.O., the Specialist Contractor shall be required to substantiate that the output from the approved sources of stone consistently conforms to the requirement of the Specifications and any conditions stipulated during the initial approval.

6.10. Stone Column Construction

6.10.1. The construction method may either be the wet or dry process. Generally, the wet process is suited for sites underlain by very soft to firm soils and a high ground water table. For dry process, it is suitable for soils with undrained shear strength of about 40-60kN/m^2 with relatively low ground water table. If the dry process is used it shall be demonstrated on site that the hole made by the machine will remain open to enable the stone to be placed cleanly to the bottom of the hole to form a continuous column to the surface.

6.10.2. Working platforms shall be designed, prepared and maintained by the Contractor in a manner suitable for the safe movement and working of the vibro plant. Material used to provide working platforms shall be granular, suitable for the ground conditions on which it is placed and shall not prevent poker penetration. Minimum thickness of the working platforms shall be at least 1000mm to ensure that stone compaction is effectively carried out to the ground surface.

6.10.3. Site working levels for the stone column shall be maintained throughout the duration of the Works. Where near surface obstructions occur, they shall be broken out prior to the commencement of the vibro works and the resulting voids shall be filled with granular material that can be penetrated and compacted by the vibrating poker.

6.10.4. The stone column shall be formed to the working surface without inclusion of clay or other unsuitable material preventing intergranular contact between stone particles.

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6.10.5. When the dry top-feed process is being used, the vibrator may be removed completely from the hole to allow access for the stone. Where the dry bottom-feed process is used, the depth vibrator shall not be removed from the ground during column construction. When the wet process is being used, the vibrator shall be kept in the hole at all times in order to maintain stability of the sides and to ensure that the stone shall reach the required depth via the annular space around the vibrator.

6.10.6. The Contractor shall provide a supply of water if the wet process is selected. The Contractor shall indicate the rate of water supply required and be responsible for checking that this is available. The Contractor shall be responsible for supplying any extra storage tanks and pumping as required.

6.10.7. Any unnecessary excavation on the stone column construction shall be avoided. Where this is not possible, excavation of the constructed stone columns shall be carried out with prior approval from the S.O. and under his strict supervision to minimize the disturbance on the constructed stone columns. Compaction by rolling or tamping rammer shall be carried out before foundation construction.

6.10.8. The Contractor shall be responsible for disposal of effluent from the works and complying with the Environmental Law and Regulations. The Contractor shall provide countermeasures as required by the Environmental Management Plan (EMP) and maintain silt traps required. On completion of the stone column the Contractor shall remove all such equipment and backfill any pits.

6.10.9. In ground conditions where pre-boring is deemed necessary, it shall be carried out by a method and to a sequence agreed by the S.O.. Pre-boring shall be carried out immediately before, or as near as practicable, to stone column construction to mitigate any safety issues associated with open excavations and prevent unnecessary deterioration of the underlying ground, for example due to water ingress.

6.10.10. Verticality

The maximum permitted deviation of the stone column from the vertical is 1 in 20.

6.10.11. Depth and Spacing

The depth and spacing of the stone columns shall be as shown in the Drawing and neither the depth nor spacing shall be varied without the prior agreement of the S.O.. Any variations in depth of stone columns due to site conditions not anticipated in the design shall be reported immediately to the S.O. who shall advise on any action to be taken.

6.10.12. Tolerances

All stone columns shall be located to within 150mm of the plan positions shown on the stone column layout Drawing.

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6.11. Construction Records

6.11.1. The Contractor shall keep records each of the stone column carried out as required by the S.O. and shall submit two signed copies of these records to the S.O. not later than at noon of the next working day after the stone column is completed. The duly signed records shall form part of the records for the works. Any unexpected conditions shall be noted in the records.

6.11.2. The Contractor shall ensure that the equipment to be used shall be instrumented with sensors and the data processed by a micro-processing unit to enable continuous monitoring and data capture of the following parameters during the construction of each stone column:

6.11.2.1. The depth of vibrator and vibrator movements (depth of penetration); and

6.11.2.2. Power consumption (compaction effort)

6.11.3. Data captured shall be continuously displayed on an LCD unit and graphical output (plots of depths versus time and power consumption) generated by an automated computerised recording device throughout the process of the stone column installation. This shall be done for each point and records shall be submitted to the S.O. by the next working day.

6.11.4. The records of each completed stone column shall contain but not limited to the following information where applicable: -

6.11.4.1. Identification number and location of stone column point

6.11.4.2. Date and time

6.11.4.3. Method of treatment

6.11.4.4. Equipment and personnel in-charge

6.11.4.5. Depth of penetration

6.11.4.6. Time required to reach maximum depth and withdrawal

6.11.4.7. Vibrator power consumption during penetration and compaction

6.11.4.8. Material consumption

6.11.5. Any observed ground heave or settlement during construction shall also be recorded and reported to the S.O..

6.12. Preliminary Stone Columns

Prior to commencement of actual stone column works, the Contractor shall carry out preliminary stone column as shown in the Drawing to establish the installation criteria for the subsequent stone column and for confirming the adequacy of the design, dimensions and working load through load test. The Contractor shall give at least three (3) days' notice of the commencement of construction of any preliminary stone column.

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6.13. Testing of Stone Column Works

6.13.1. To verify the design assumptions and working load, The Contractor shall carry out load test on stone column as shown in the Drawing or as instructed by S.O.. The testing procedures shall be submitted two (2) weeks before the commencement of load test for S.O. approval. Loading of a stone column shall not commence until seven (7) days have elapsed after completion of its installation.

6.13.2. Load testing for stone column can be carried using plate test or zone test as shown in the Drawing or as instructed by the S.O.

6.13.2.1. Plate test: A plate test is a loading test carried out using a plate on treated ground essentially used as a control of workmanship. It can be a single column plate load test or a group of four columns plate load test.

6.13.2.2. Zone test: A zone test is a loading test carried out over a large treated area, intended to test stone columns' performance over a wider and deeper zone than in the plate bearing test. A zone test is usually carried out by placing earth fill to simulate widespread loads, and the fill height will be determined to meet the required test pressures.

6.13.3. During the progress of a test, the testing equipment and all records of the test shall be available for inspection by the S.O..

6.13.4. Load Test Procedures

The plate load test shall be carried out in accordance with the latest version of *MS 2038*.

6.13.5. Submission of Results

6.13.5.1. Full test data and results shall be jointly signed in duplicate by the S.O.'s representative witnessing the test and the Contractor's authorized personnel immediately upon completion of the test. A copy of this records shall be kept by the S.O..

6.13.5.2. Within seven (7) days of the completion of the test, a complete test report inclusive of all necessary analysis shall be submitted to the S.O. This shall be as specified below for a plate bearing test or a zone test as appropriate.

6.13.5.3. Information on Tested Ground from Plate Tests

(i) The Contractor shall provide information about the tested ground in accordance with the following schedule where applicable:

a) General

i. Contract identification
ii. Date of test

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b) Test area Details

i. Identification of area relative to site layout drawing
ii. Brief description of position in structure
iii. Ground level at test position
iv. Excavated test level

c) Treatment Details

i. Date and time of treatment
ii. Unexpected circumstances or difficulties

d) Stone Columns

i. Identification numbers of stone columns
ii. Diameter and depth of stone columns exposed
iii. Spacing of adjacent columns
iv. Depth
v. Stone consumption

e) Test Procedure

i. Approximate weight of kentledge
ii. Date and times of load application

f) Test Results

i. Load and settlement with time reported in tabular form, and in graphical form, load and settlement being plotted against time, and load against settlement.

6.13.5.4. Information on Tested Ground from Zone Tests

The Contractor shall provide information about the tested ground in accordance with the following schedule where applicable:

(i) General

a) Contract identification
b) Date Of tests

(ii) Test Area Details

a) Identification of area relative to site layout drawing
b) Size and position of area
c) Ground level at test position
d) Excavated test level

(iii) Treatment Details

a) Date and time of treatment
b) Unexpected circumstances or difficulties
c) Identification number of stone columns
d) Depth of treatment
e) Stone consumption

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(iv) Test Details

a) Plan showing position and extent of zone test fill in reference to the stone columns and instrumentation layout

b) Method of load-measurement, if any (e.g. pressure cells, or earth fill field density tests)

c) Fill height measurements versus time (e.g. rod settlement gauges)

d) Dates and times of fill application, duration of instrumentation

e) Other instrumentation measurements over time (e.g. inclinometers, settlement markers)

(v) Test Results

a) Load and settlement with time reported in tabular form, and in graphical form, load and settlement being plotted against time, and load against settlement

6.13.6. Completion of a Test

Upon completion of a test, all temporary structures used in the testing (concrete slab or ground anchor etc.) shall be dismantled and removed from site. The ground shall be made good to the original commencing surface level.

6.14. As-Built Records

6.14.1. The Contractor shall submit an as-built stone column location plan certified by a Licensed Surveyor to the S.O. within fourteen (14) working days after the completion of the works. Partial as-built plan may be submitted throughout construction of the works for verification by the S.O..

6.14.2. The as-built Drawing shall include the following information:

6.14.2.1. The stone column identification number and corresponding as-built depth of each point;

6.14.2.2. Spatial coordinates of reference points delineating the treatment; and where stone columns positions were deviated on site due to obstructions or other reasons with the knowledge of the S.O., the new position coordinates shall be included.

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7. Deep Soil Mixing

7.1. General

The work shall consist of the supply of equipment, labour and materials for the execution of deep soil mixing (DSM) works. Deep soil mixing method shall comply to *BS EN 14679*. This section shall also be in accordance with sub-section 5.1..

7.2. Soil Investigation Report

This section shall be in accordance with sub-section 5.2..

7.2.1. Pre-Treatment Soil Investigations

7.2.1.1. This section shall be in accordance with sub-section 5.2.1..

7.2.1.2. The Contractor shall carry out chemical test to determine the types of chemical present in the soil for effective deep soil mixing. The Contractor shall provide Material Safety Data Sheet (MSDS) produced by the Manufacturer for the handling and storage of chemicals used. The use of chemicals shall be in accordance with *Standard Specification for Roadworks* "SECTION 18: SOIL STABILISATION".

7.3. Method Statement for Construction Operations

7.3.1. This section shall be in accordance with sub-section 6.3.. The method statement shall also include precautions against heave and settlement.

7.4. Unexpected Ground Conditions

This section shall be in accordance with sub-section 6.4..

7.5. Adjacent Structures

This section shall be in accordance with sub-section 6.5..

7.6. Existing Services

This section shall be in accordance with sub-section 6.6..

7.7. Specialist Contractors and Personnel

DSM works shall be carried out by experienced Specialist Contractor approved by the S.O.. The Specialist Contractor shall have the following experience and personnel:

7.7.1. Personnel experienced in the design, supervision and construction of DSM columns

7.8. Setting Out

This section shall be in accordance with sub-section 6.8..

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7.9. Material

7.9.1. Binder

7.9.1.1. Cementitious binders to be used shall be an approved variant of Portland cement, complying with *Standard Specification for Building Works* SECTION D: CONCRETING or as per *BS EN 197-1*. The cement shall be adequately protected from moisture and contamination in storage on the job site. Reclaimed cement containing lumps or deleterious matter shall not be used. Other binders shall be acceptable if the project requirements can be met with their use. Laboratory tests shall be required to verify the suitability and dosage of the other binder variants.

7.9.1.2. If other chemicals are proposed, the material shall be in accordance with *Standard Specification for Roadworks* "SECTION 18: SOIL STABILISATION".

7.9.2. Water

Freshwater, free of an excessive amount of deleterious substances that adversely affect the properties of the binder shall be used. It is the responsibility of the Contractor that the grout resulting from the water shall always meet the requirements of this specification.

7.9.3. Grout suspension

Grout suspension shall be prepared on site using binder(s) as described in sub-section 7.9.1. and other additives, wherever required, in water. The grout shall be pumpable and workable with the DSM injection equipment.

7.9.4. Additives

7.9.4.1. Admixtures may be used to enhance the workability or final properties of the treated soil. Conventional additives include bentonite, fly ash, lime, sodium silicate, a set retarder, alkali activator, etc. Additives may be added to the water or the grout. Notwithstanding, the use of additives is subjected to the approval of the S.O..

7.9.4.2. The Contractor shall provide Material Safety Data Sheet (MSDS) produced by the Manufacturer on the use of chemical additives to ensure the safety of the material used. The Contractor shall be made liable for any discrepancies that occur during the application of chemical additives in the absence of MSDS.

7.9.5. Soil Mixing Material

Soil-mixing material, resulting from the in-site mixing of soil with grout suspension (mainly for a wet method of mixing), should have a compressive strength as specified in the drawing. The factor of safety concerning the maximum characteristic stress acting on a single column shall be not less than 2.0.

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7.9.6. Steel Reinforcement

Steel reinforcement, if specified in the drawing shall comply with SECTION D: CONCRETING, relevant specifications and Malaysian Standards.

7.10. DSM Column Installation

7.10.1. General

The Contractor shall satisfy the S.O. regarding the suitability, efficiency and adequacy of the equipment to be employed based on soil conditions and the requirements defined herein and in the design. The equipment chosen for the installation of works shall be in full compliance with the provision of the *BS EN 14679*.

7.10.2. Drilling Equipment

7.10.2.1. Deep soil mixing equipment shall be capable of rotating down to the required depth or stiff layer through the weak soil and withdrawing the mixing tool by simultaneous rotation and mixing of the binder with in-situ soil.

7.10.2.2. Deep soil mixing machine shall have a single or multiple shaft(s) with cutting/mixing blades at the lower end.

7.10.2.3. Deep soil mixing machine shall be able to operate at different rotation and withdrawal rates within the required range as in the design to complete the work and produce the required cement columns, and as required by *BS EN 14679*.

7.10.2.4. The cutting/mixing blades shall have the minimum diameter as per design. The size of the mixing tool shall define the column diameter.

7.10.2.5. The mixing tools shall consist of a minimum of one nozzle for the binder delivery but shall be demonstrated that it is adequately sized to meet the binder dosage as required by design.

7.10.2.6. Real-time measuring and recording devices shall be provided throughout the mixing operation, to capture data e.g. column number, time, depth, pressure, feed rates, rotation speed, injection rate, injection volume, binder consumption, etc.

7.10.3. Binder Delivery Station

7.10.3.1. Dry Method

In the dry method, the deep soil mixing process shall be carried out by mixing the binder in powder form. The medium of transportation of binder is typically compressed air unless otherwise approved by the S.O.. Binder storage tank(s)/ silo(s) is generally on-board with the DSM machine or on a separate self-propelled chassis connected to the DSM machine.

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7.10.3.2. Wet Method

In the wet method, the deep soil mixing process shall be carried out by mixing the binder in slurry form. The medium of transportation of binder usually is water unless otherwise approved. The binder is generally prepared at the separate mixing and holding tanks and pumping station shall be required to deliver the binder to the DSM machine. The mixing and pumping station shall be able to produce enough volume of slurry required and enable continuous supply and controlled delivery of slurry.

7.10.4. Working Platform Preparation

Working platforms shall be designed, prepared and maintained by the Contractor in a manner suitable for the safe movement and working of the deep soil mixing equipment. The material used to provide working platforms shall be suitable for the ground conditions on which it is placed and shall not be detrimental to the drilling operation. Site working levels for the treatment shall be provided and maintained by the Contractor throughout the deep soil mixing works.

7.10.5. Soil Mixing Work

7.10.5.1. Unless otherwise specified, pressure feed of the binder shall be terminated approximately 0.5m to 1.0m below the working platform. Satisfactory quality shall not be relied on in the design over a depth of 1.0m below the working level, i.e. within the working platform material. If the deep soil mixing operation is interrupted for any reason, re-mixing or repositioning may be required upon confirmation from the S.O. on site.

7.10.5.2. The mixing tool rotation speed shall be adjusted to accommodate a constant rate of mixing as given in the design. The penetration/withdrawal rate of the mixing tool shall be maintained such that the proper amount of binder is added and the proper amount of mixing time is allowed as per design. Both the rotation speed for mixing tool and penetration/withdrawal rate can be adjusted according to drilling difficulty, upon confirmation from the S.O. on site.

7.10.5.3. The injection rate per vertical meter of column shall be predefined by the Contractor. The injection rate shall be adjusted accordingly, if necessary, with the working parameters in the paragraph above herein, throughout the work to achieve the requirement for the DSM columns. The injection rate of the binder shall be measurable and monitored with the appropriate device as proposed by the Contractor.

7.10.5.4. After completion, the DSM columns shall be left undisturbed for at least 14 days. The area of DSM columns shall not be driven over with heavy equipment.

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7.10.6. Obstruction

In the event of obstructions preventing the drilling and installation of DSM columns, the S.O. shall be informed immediately. Remedial options subject to approval from the S.O. shall include:

7.10.6.1. Reposition the column a short distance from the original position.

7.10.6.2. Additional DSM column(s) around the obstruction, if necessary.

7.10.6.3. Excavate, remove the obstruction, backfill and compact to the requirements of *Standard Specification for Building Works* SECTION B: EXCAVATION AND EARTHWORKS and reinstall the DSM column.

7.10.7. Verticality

The maximum permitted inclination of the DSM columns is 1 in 75.

7.10.8. Length, diameter and spacing

The length, diameter and spacing of the DSM columns shown in the Drawing shall be adjusted to suit site conditions when deemed necessary as instructed by the S.O..

7.10.9. Tolerances

The maximum permitted deviation of the centre of the DSM column from the centre point shown on the setting out drawing shall be 150 mm in any direction.

7.11. Construction Records

7.11.1. On the same day, a daily record shall be submitted to the S.O. summarizing the points done and depths of DSM column installed. Two (2) copies of signed records for each soil mixing element shall be submitted to the S.O. on the next working day.

7.11.2. The record shall include the following information, but not limited to: -

7.11.2.1. Column ID or reference number;

7.11.2.2. Depth of installation;

7.11.2.3. Column top and toe level;

7.11.2.4. Binder type and composition, injection rate and total injection volume;

7.11.2.5. Time for mixing during penetration and withdrawal;

7.11.2.6. Rotation of mixing tool versus depth and blade rotations by numbers;

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7.11.2.7. Weather report;

7.11.2.8. Any other information as may be required by the S.O..

7.12. Preliminary DSM Column(s)

7.12.1. Before commencement of the DSM works, the Contractor shall carry out field trial as shown in the Drawing. A total number of minimum four (4) numbers of preliminary columns shall be constructed to verify the deep soil mixing methodology, suitability of the mixing tool and the design parameters. The quality of DSM columns shall conform to the design requirements and shall be verified using the appropriate testing method, e.g. by the mean of the load test. Loading on the DSM column shall not commence until fourteen (14) days have elapsed after completion of its installation.

7.12.2. Where excavation is possible, assessment of the geometric and mechanical characteristics of the DSM column should be made by visual inspection. Coring can be made on the completed columns. Unconfined Compressive Strength Testing (UCS) on samples recovered by coring or excavation can be made to verify the soil-mixing material compressive strength as specified in the design. At least one (1) of the trial columns shall be sampled and UCS testing shall be carried out on three samples. The sampling and testing frequency may be varied based on project requirements or at the instruction of the S.O..

7.13. Quality Control and Quality Assurance

7.13.1. Quality Control

7.13.1.1. Before the commencement of all works, procedures for verification, control and acceptance shall be established in the method statement with reference to the drawing and specification.

7.13.1.2. Blade rotation number of soil mixing shall be used as a guide to verify the consistency of mixing and forming homogenous columns. Minimum blade rotation number in cohesionless soils shall be at least 300, whereas for cohesive soils it shall not be less than 400. For peaty and organic soils, the blade rotation number shall be at least 600. These requirements shall be followed unless otherwise stated in the project requirement or instructed by the S.O..

7.13.1.3. The construction process shall be controlled and monitored automatically, with the aid of a computerised system. The construction parameters and information as detailed in **Table V9** shall be monitored continuously during execution.

7.13.2. Sampling

7.13.2.1. The sampling of soil mixing improved ground shall be done by conventional vertical coring. Double tube sampling shall also be acceptable provided the Contractor can demonstrate that good sample recovery can be obtained. Wet grab sampling shall also be permitted, and samples shall be prepared from wet grabs at

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the instruction of the S.O.. The S.O. shall also instruct at what depth the sampling needs to be taken. Sampling shall ensure that the recovery ratio is at least 80% or otherwise instructed by the S.O..

7.13.2.2. At least 1% of the installed columns shall be sampled by coring, double tube or wet grabbing, unless otherwise stated in the drawing. Minimum three (3) samples from each sampled column shall be tested for UCS. The sampling and testing frequency may be varied based on project requirements or at the instruction of the S.O..

7.13.3. Unconfined Compression Test

7.13.3.1. Where necessary, the improvement from the treatment shall be tested by Unconfined Compression Test (UCT) of samples. The Unconfined Compressive Strength (UCS) of samples shall meet the requirements of the design, where the characteristic strength of samples shall be more than the project requirements.

7.13.3.2. UCT testing shall be done on cylindrical or cube samples having a minimum dimension of 50 mm diameter. Corrections to readings and reporting of values shall be as per *BS EN 12504-1*.

7.13.3.3. Where required the S.O. may specify additional tests to determine other engineering properties of the improved ground.

7.13.4. Load Test

This section shall be in accordance with sub-section 6.13..

7.13.5. Submission of Test Results

This section shall be in accordance with sub-section 6.13.5..

7.14. As-Built Drawing

7.14.1. The Contractor shall submit an as-built DSM columns location plan certified by a Licensed Surveyor to the S.O. within fourteen (14) working days after the completion of the works. Partial as-built plan may be submitted throughout construction of the works for verification by the S.O..

7.14.2. The as-built Drawing shall include the following information:

7.14.2.1. The DSM column identification number and corresponding as-built depth of each point;

7.14.2.2. Spatial coordinates of reference points delineating the treatment; and where DSM columns positions were deviated on site due to obstructions or other reasons with the knowledge of the S.O., the new position coordinates shall be included.

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8. Dynamic Compaction

8.1. General

The works shall consist of the supply of plant, equipment and specialist personnel for the execution of dynamic compaction (DC) works for ground improvement. This section shall also be in accordance with sub-section 5.1..

8.2. Specialist Contractor

DC works shall be carried out by experienced Specialist Contractor approved by the S.O.. The Specialist Contractor shall have the following experience and the personnel:

8.2.1. The Specialist Contractor shall employ competent and experienced geotechnical engineer who is capable of analyzing existing soil data, obtaining and interpreting additional data as required, performing field testing prior to, during and after DC works.

8.3. Soil Investigation Report

This section shall be in accordance with sub-section 5.2..

8.4. Method Statement for Construction Operations

This section shall be in accordance with sub-section 6.3..

8.5. Unexpected Ground Conditions

This section shall be in accordance with sub-section 6.4..

8.6. Adjacent Structures

8.6.1. This section shall be in accordance with sub-section 6.5..

8.6.2. At locations where acceptable peak particle velocity or acceleration are likely to be exceeded, cut off trenches or other protective measure shall be taken. Contractor shall demonstrate to the satisfaction of the S.O., by trials, that his proposal will reduce the maximum peak particle velocity or acceleration to acceptable values.

8.7. Existing Services

This section shall be in accordance with sub-section 6.6..

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8.8. Workmanship

8.8.1. Contractor shall satisfy the S.O. on the suitability and efficiency of the equipment to be employed.

8.8.2. The dynamic compaction (DC) works shall be performed by a qualified Contractor. The DC works shall be carried out up to the designed depth/compaction energy required to make sure the design criteria are achievable.

8.9. Setting Out

Contractor shall perform setting out from the temporary bench mark (TBM) provided and shall be maintained by the Contractor. The approximate limits of work shall be shown in the DC shop Drawing and the exact limit shall be determined by the Contractor upon completion of the pre-treatment testing. DC points shall be marked with suitable and identifiable markers.

8.10. Working Platform

The working platform shall be prepared and maintained by the Contractor and suitable for safe movement and working for the DC plant and equipment. The working platform shall be made of granular material and at least 1000 mm above the ground water level.

8.11. Spacing

The spacing of the DC point shall be shown in the construction drawing. This shall be confirmed by field calibration or field trial conducted as approved by S.O..

8.12. DC Field Trial Area

The Contractor shall perform at least one (1) DC field calibration or trial area prior to commencement of the full production DC works. Minimum trial area shall be 20m x 20m. The objective of the field trial is to determine the optimum compaction energy to be applied to the DC point and to confirm the technical data obtained is as per design.

8.13. Site Records

The Contractor shall keep and submit to the S.O. the following records:

8.13.1. Number of blows for each DC point for each phase of DC works.

8.13.2. DC pounder free fall height for each blow for each phase of DC works.

8.13.3. Ground level before and after DC works.

8.13.4. Any other record as required by the S.O..

8.14. Testing

8.14.1. Pre-Treatment Testing

8.14.1.1. The Contractor shall undertake soil testing prior to commencement of DC works to provide data for the purpose of

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refining the preliminary design to comply with the acceptance criteria as specified. The field testing shall include the following:

(i) Pressuremeter Tests (PMT) shall be performed at every meter vertical interval and at changes in strata in accordance with the method outlined in ASTM D4719 or the latest version of BS EN ISO 22476-4.

(ii) Cone Penetration Tests (CPT) shall be performed in accordance with ASTM D5778 or the latest version of BS EN ISO 22476-1.

8.14.1.2. The Contractor shall determine the total number of locations of pre-engineering tests necessary to analyse the soil conditions and to delineate the areas requiring DC works. Pre-engineering testing shall include the following as a minimum:

(i) A minimum of one PMT for every 2000m² of area marked for improvement in the Drawing.

(ii) A minimum of one CPT for every 2000m² of area marked for improvement in the Drawing.

8.14.1.3. The Contractor shall determine locations of any additional testing that may be required if conflicting test results are indicated by two adjacent tests or to delineate areas for ground improvement.

8.14.2. Final Acceptance Testing

8.14.2.1. The Contractor shall verify the ground improvements works for compliance with the acceptance criteria by in-situ tests of the improved soils and by analysis of the test results. The final testing shall be conducted at a minimum of one week after completion of the ground improvement works.

8.14.2.2. The final tests shall generally be at the locations of the pre-engineering test locations and shall include the following field tests:

(i) PMT shall be performed at every meter vertical interval and at changes in strata in accordance with the method outlined in *ASTM D4719* or the latest version of *BS EN ISO 22476-4.*

(ii) Cone Penetration Tests (CPT) shall be performed in accordance with ASTM D5778 or the latest version of BS EN ISO 22476-1.

8.14.2.3. Final testing shall include the following as a minimum:

(i) A minimum of one PMT for every 2000m² of area marked for improvement in the Drawing.

(ii) A minimum of one CPT for every 2000m² of area marked for improvement in the Drawing.

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8.14.2.4. Areas in which the specified criteria are not met shall be reworked by the Contractor until the specified requirements are met. The S.O., at his/her discretion, may check the Contractor's test results by conducting additional and independent testing.

8.14.2.5. If necessary, correlation between the CPT results with PMT results can be conducted to obtain the limit pressure and pressure meter modulus required for the engineering calculations.

8.15. Documents Submission

8.15.1. The contractor shall submit to S.O. documents regarding the DC works as follows:

8.15.1.1. Pre-treatment testing proposal – this document is a plan and schedule for pre-treatment testing and shall be submitted at least seven (7) days before the pre-treatment testing is scheduled to begin.

8.15.1.2. Pre-treatment testing report – this document shall be submitted not later than fourteen (14) days after completion of pre-treatment testing.

8.15.1.3. Interim progress report – this document stated the DC works operations, including pre-treatment testing, final acceptance testing, elevation measurements, quantities completed during month, cumulative quantities to date and a forecast of remaining work.

8.15.1.4. Final technical report – this document shall be submitted at the completion of the DC works. The report shall contain graphical presentation of all parameters used by the Contractor to accomplish the acceptance criteria including all pre-treatment testing and final testing results together with as built Drawing. The report shall be submitted in five copies duly endorsed by a Professional Engineer.

9. Piled Embankment

9.1. General

9.1.1. The works shall consist of all labour, materials, tools, transportation, instrumentation, etc. necessary to construct piled embankment in accordance to the Drawing and SECTION C: FOUNDATION WORKS AND WORKS BELOW LOWEST FLOOR LEVEL.

9.1.2. The works shall cover the following:

9.1.2.1. Mobilization and demobilization of all labour, plants, piling and drilling equipment on site.

9.1.2.2. Supply, handling, pitching and installation of piles to the pile lengths as specified in the Drawing.

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9.1.2.3. Lengthening of piles by jointing to detail.

9.1.2.4. Strip pile to cut-off level and check pile eccentricity.

9.1.2.5. Construct reinforced concrete slab as per the details in the Drawing.

9.1.2.6. Carry out pile testing in accordance to SECTION C: FOUNDATION WORKS AND WORKS BELOW LOWEST FLOOR LEVEL on working piles as specified.

10. Geotechnical Instrumentation

10.1. General

10.1.1. Instrumentation shall be installed to measure horizontal and vertical displacement of the subsoil or structures supported by the subsoil and water pressures within the works and shall remain operational both during and after the construction period specified in the contract.

10.1.2. The Contractor shall be responsible for and shall follow the instruction of the manufacturer and the requirements of this specification in the installation, calibration and testing of all measuring instruments and equipment, which shall be carried out under the direct supervision of the S.O.. The Contractor shall inform the S.O. at least 2 days prior to undertaking installation of the equipment. The Contractor shall make due allowances in his construction programme for any delays which may arise on account of the installation of the instruments.

10.1.3. Protection and Maintenance of Instruments

The Contractor shall take all necessary precautions to protect the instruments and maintain the instruments in good working order after commissioning. For all instruments which project through and above the fill, special precautions shall be taken to provide protection from vehicles and plant including substantial and readily visible barriers at a radius of 750mm around each instrument. Heavy compaction equipment shall not approach within 1.0m of projecting instruments. Damaged instruments shall be replaced or repaired by the Contractor at his own expense within seven days.

10.1.4. Stabilising Electronic Readout Devices

All electronic readout devices and transducers shall be shaded from direct sunlight during use. Probes which are used inside access tubes shall be placed inside the tube and allowed to come to a stable temperature for at least 10 minutes before use. Zero or starting values shall only be taken once temperature stabilization is complete. All readout units shall be calibrated at least once a year and the calibration certificates submitted to the S.O..

10.1.5. Personnel

10.1.5.1. The Contractor shall submit names and curricular vitae of personnel including instrumentation engineer and

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instrumentation technician to carry out the instrumentation and monitoring and a programme of their attendance for the approval of the S.O.. Deviation from the approved programme of attendance or the requirements given in this clause shall only be permitted with the approval of the S.O..

10.1.5.2. The instrumentation engineer shall be responsible for the overall planning, implementation and monitoring of the instruments. He shall be on site throughout installation, commissioning and initial monitoring. He shall be on site for the remaining monitoring on a basis to be agreed with the S.O..

10.1.5.3. All instrumentation and monitoring works shall be carried out by an experienced instrumentation technician. Instrument data obtained shall be verified by an instrumentation engineer.

10.1.6. Boreholes for Instruments

10.1.6.1. Boreholes for instruments may be drilled by any method provided that it results in a clean and stable hole of the required diameter to the correct depth. The method of forming boreholes, including the procedure for advancing casing, shall be submitted to the S.O. for approval before commencement of the works.

10.1.6.2. Boreholes shall be cased to their full depth unless strata are sufficiently competent for the hole to stay open under dry conditions. If boreholes are drilled using water as a flushing medium, clean water shall be used. Drilling mud or polymer additives shall only be used with the approval of the S.O.. In the case of installation of piezometers, drilling mud or polymer additives shall not be permitted.

10.1.6.3. During drilling care shall be taken to ensure that minimum material is lost from outside the casing. Surging of the casing shall not be allowed and flushing of drilling water outside the annulus of the casing shall be minimized.

10.1.7. Grouting of Boreholes

For all instruments placed in boreholes, grouting is required for part or the entire borehole during installation. The grout shall be a bentonite: cement mixture with sufficient water to achieve a pumpable mix. The proportions of the mix shall be such as to imitate as closely as possible the strength or consistency of the natural soils present. Unless otherwise stated in the Drawing, the Contractor shall propose the suitable bentonite: cement mixture to S.O.'s approval. Grout shall be pumped into boreholes using a tremie pipe.

10.1.8. Labelling and Marking of Instruments

All instruments shall be labelled with their reference numbers at the location where readings or measurements are taken. The labelling shall be permanent using a method or material to be agreed with the S.O..

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10.1.9. Survey Equipment and Survey Reference Station

10.1.9.1. The Contractor shall be responsible for establishing survey reference station at locations selected by the S.O. to monitor settlement markers, settlement plates, displacement markers and other instruments deemed necessary.

10.1.9.2. All survey equipment used in conjunction with the monitoring of instrumentation, including measuring tapes, levels and total stations shall be maintained and calibrated as required by the manufacturers and good surveying practice.

10.1.9.3. The survey reference station provides a reference for levelling or horizontal measurement to other points. The location of the survey reference station, shall be agreed by the S.O.. The coordinates and elevation of the survey reference station shall be surveyed in and submitted to the S.O..

10.1.9.4. The survey reference station shall be established on undisturbed ground clear of the embankment. The survey reference station shall be located on stable ground not affected by the Works, preferably away from the construction activities. The survey reference station is to be located on structures free of settlement and lateral movement or as agreed by the S.O..

10.1.9.5. The survey reference station may comprise of a steel rod of 20mm diameter, which shall be driven vertically into the undisturbed ground for a minimum distance of 1.0m and shall project approximately 75mm above ground surface. The rod shall be surrounded by not less than 0.03m^3 of concrete at surface level, and the top of the rod shall be carefully centre-punched.

10.1.9.6. The survey reference station shall be checked at intervals to be established by the S.O. to ensure that it is stable during the course of the monitoring works.

10.1.10. Deep Levelling Datum

10.1.10.1. A deep datum is required to provide a reference for measurement of ground levels in areas of soft ground.

10.1.10.2. The Contractor shall propose the location and depth of the deep levelling datum for the approval of the S.O..

10.1.10.3. The datum itself shall be fixed into hard ground with Standard Penetration Test (SPT) value more than 50 or rock and isolated from soft and compressible overlying strata. If the SPT value of more than 50 is not achievable at great depths, the contractor and the S.O. shall mutually agree on the termination depth.

10.1.10.4. A deep levelling datum shall consist of a 25mm galvanized iron (GI) pipe fixed into hard ground with cement grout. The datum pipe shall be isolated from the overlying soft ground by a 75mm GI pipe bedded into the top of the cement grout. The upper part of the 75mm pipe shall be surrounded by a square concrete

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plinth of not less than 0.03m^3 of concrete. The details of the deep levelling datum including its protective measures are as shown in the Drawing. The concrete shall be scored with the reference number of the datum.

10.1.10.5. The level of a deep levelling datum shall be established by standard levelling techniques from agreed bench mark in the vicinity. Levelling shall be closed back to the bench marks to check for accuracy. The level shall be measured three times soon after installation of the datum and shall be checked at intervals to be agreed by the S.O..

10.1.11. Instrumentation Equipment References

Details of equipment shall be submitted to the S.O. for approval. If the S.O. considers it necessary, demonstrations shall be arranged by the Contractor. Any supplier of geotechnical instrumentation shall demonstrate that the manufacturer operates an adequate system of product quality assurance.

10.2. Displacement Marker/Settlement Marker

10.2.1. Displacement marker/Settlement marker is required to monitor the horizontal and vertical movement of the ground or embankment surface. The Contractor shall be responsible for establishing settlement markers at locations as shown in the Drawing or as determined by the S.O..

10.2.2. The marker shall comprise of a steel rod of minimum 20mm diameter which shall be driven vertically into the embankment or undisturbed ground for a minimum depth of 1.0m and shall project approximately 75mm above the ground surface. The rod shall be surrounded by not less than 0.03m^3 of concrete at ground level, and the top shall be domed and centre-punched. The details of the installation are shown in the Drawing. The concrete shall be scored with the reference number of the marker.

10.2.3. For the settlement marker~~s~~, the level of the top of the rod shall be measured using standard precise levelling techniques, referencing and closing back to the survey reference station with instrument to a minimum of +1mm accuracy.

10.2.4. For the displacement marker~~s~~, the lateral movement shall be measured using a total station or other survey techniques agreed by the S.O..

10.3. Building Settlement Marker

10.3.1. Vertical deformation of adjacent structures shall be determined by means of precision devices to an accuracy of + 1.0mm. The Contractor shall install building settlement points at location as specified by the S.O..

10.3.2. The precise levels shall have robust tripods. Levelling studs are to be provided for the purpose of precise levelling. Levelling studs shall be: -

10.3.2.1. Manufactured from stainless steel.

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10.3.2.2. Fixed to the building lining in the same manner and standard.

10.3.2.3. Designed such that their use in conjunction with the appropriate precise instruments allow precision levelling to an accuracy of + 1.0mm.

10.3.2.4. Designed such that the heads of the levelling studs on the walls can be easily levelled without the studs being vulnerable to damage.

10.3.2.5. Designed such that the studs are safe from any hazards and to human life.

10.4. Rod Settlement Gauge

10.4.1. Rod settlement gauge is required to measure settlement beneath the embankment. The Contractor shall provide and install rod settlement gauge at location and level as shown in the Drawing or as specified by the S.O..

10.4.2. The details of the rod settlement gauge shall be as shown in the Drawing and the Contractor shall be responsible for the installation of all the gauges as work proceeds. The base plate and first length of the rod shall be placed as early as possible during earthworks, preferably before any significant filling has been placed. Extension lengths shall be installed when the level of compacted embankment is 250mm below the top of the preceding lengths.

10.4.3. Should a rod settlement gauge be damaged, or should the Contractor fail to extend the gauge when required, the Contractor shall stop all filling activities in the vicinity of the gauge until the necessary remedial works have been carried out. The Contractor shall be liable for any delay in his programme, or any additional works that need to be done as result of such damage.

10.4.4. Should any rod settlement gauge be damaged in such a way as to make it useless for its purpose and unable for S.O. to assess the settlement, the contractor shall engage a third-party specialist at his own cost to assess the settlement for measurement purposes and shall be agreeable and approved by S.O. as the final decision.

10.4.5. Rod settlement plates shall be monitored by standard precise levelling techniques, referencing and closing back to the survey reference station with instrument to a minimum of +1mm accuracy. Levels shall be taken at the top of rod itself and the fill adjacent to the gauge on each occasion. When rods are extended, levels shall be measured immediately before and immediately after adding the extension.

10.5. Inclinometer

10.5.1. Inclinometer provides a method of measuring a continuous profile of horizontal deflection both at the surface of and within a mass of soil. The Contractor shall install Inclinometer at locations and depths as specified by the S.O.. The details of the Inclinometer shall be as shown in the Drawing.

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10.5.2. Inclinometer access tube shall consist of broached polyvinyl chloride (PVC) tubing with four keyways set at right angles to each other and with couplings and end caps where necessary. The S.O. may instruct the Contractor to obtain spiral metric measurements of the keyways in the inclinometer tubing after installation. After that, assembly joints and rivets shall be wrapped in sealing tape. The tube shall be coated with thick grease over its upper part when it passes through compressible subsoils.

10.5.3. The assembled tube shall be lowered into borehole backfilled with a suitable bentonite: cement grout mix. Alternatively, the tube may be placed in an open borehole and grout placed afterwards. In granular material, the backfill may be sand or pea gravel. The keyways shall be orientated such that movements are measured parallel to and at right angles to the embankment axis.

10.5.4. Angular movements shall be measured by an inclinometer probe (torpedo) which shall be a biaxial type and the system shall be capable of measuring lateral deformation to an accuracy of ± 6mm over a depth of 25m.

10.5.5. The inclinometer data logger unit shall display the readings from the inclinometer torpedo on an alphanumeric display. The following facilities are also, required within the readout unit:

10.5.5.1. Scan stored data.

10.5.5.2. Display of face errors as readings are being obtained.

10.5.5.3. Display of mean deviation and cumulative deviation of anyone set of readings.

10.5.5.4. Backlit LCD display.

10.5.6. The readings shall be read at every 0.5m and stored in the data logger.

10.5.7. The level of the top of the access tube shall be measured by standard precise levelling techniques as and when necessary.

10.6. Horizontal Inclinometer

10.6.1. The horizontal inclinometer provides a method of measuring vertical displacement beneath an embankment. Readings are taken at regular intervals across the entire width of the embankment. The contractor shall install the horizontal inclinometer across the full width of the embankment at locations and with details as shown in the drawing.

10.6.2. The horizontal inclinometer shall be installed before earthworks commence as shown in the Drawing and shall consist of 70mm or 85mm inclinometer casing installed in a trench. The trench shall be filled with sand or the excavated material provided it is suitable fill and stone free, and approval is given by the S.O.. Each end of the inclinometer casing shall have an end cap and shall have an eye for retention of the instrument draw cord. Each end of the inclinometer casing shall also pass freely through a plastic protective cover set into a concrete pad. The concrete pads shall have minimum dimensions of 1.5m x 1.5m x 0.3m. They shall be located beyond the influence of the area causing

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settlement. At each concrete pad, a survey pin shall be cast into the concrete.

10.6.3. Sufficient inclinometer casing shall be installed to accommodate large relative movement of the ground.

10.6.4. The horizontal inclinometer readout unit shall have a resolution of ±0.02mm or better and a sensor accuracy of ±0.1mm or better.

10.6.5. Immediately before taking a set of readings, levels shall be taken of the two survey pins set into the concrete pads.

10.7. Hydrostatic Profile Gauges

10.7.1. The hydrostatic profile gauge provides a method of measuring vertical displacement beneath an embankment. Readings are taken at regular intervals across the full width of the embankment and provide a continuous profile of settlement. The Contractor shall install hydrostatic profile gauges at locations and with details as shown in the Drawing.

10.7.2. The hydrostatic profile gauge shall be installed before earthwork commences as shown in the Drawing and shall consist of semi rigid or high-density polyethylene (HDPE) profile tube with minimum outer diameter of 50mm installed in a trench. The trench shall be filled with sand or the excavated material provided it is suitable fill and stone-free, and approval is given by the S.O.. Each end of the access tube shall pass freely through a protective cover fabricated in plastic complete with solid PVC taper-threaded plug. The plug shall have an eye for retention of the instrument drawcord.

10.7.3. Each protective cover shall be set into a concrete pad. If the expected settlement is large such that the protective cover may not be long enough to accommodate the relative movement of the access tube, then the protective cover shall be extended using a suitable piece of plastic pipe. The concrete pads shall have minimum dimensions of 1.5m x 1.5m x 0.3m at both ends of the HDPE tube. The concrete pads shall be located beyond the influence of the located area causing settlement. A survey pin shall be cast into each of the concrete pad. Both ends of the access tube shall be covered with a suitable end cap at all times.

10.7.4. The readout device system shall be capable of measuring elevation with reference to the survey pin to an accuracy of ±1.0mm. Immediately before taking a set of readings with the hydrostatic profile gauge, levels shall be measured of the two survey pins set into the concrete pads.

10.8. Magnetic Extensometer

10.8.1. Magnetic extensometer provides a method of measuring settlement at a point or a series of points below the ground surface. The Contractor shall install magnetic extensometer at locations and as specified by the S.O.. The details of the magnetic extensometer shall be as shown in the Drawing.

10.8.2. The magnetic extensometer shall consist of an access tube and a series of magnetic targets which are free to slide down the tube, together with a datum magnet which is fixed to the tube near its base. The access tube

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shall be a rigid PVC tube with minimum 33mm outer diameter and 24mm inner diameter. External coupling shall be used to connect the access tube and this compression/extension coupling shall allow axial movement of access tubes to minimize distortion due to vertical strain. A rigid PVC endcap shall be fixed to the lower end of the series of tubes.

10.8.3. A datum ring magnet shall be fixed approximately 1m above the lower end of the tube. Spider magnets shall be used within the subsoil and plate magnets within fill.

10.8.4. The tubes and spider magnets shall be assembled prior to installation in such a way that the magnets remain in the correct position in relation to the tube.

10.8.5. It shall then be lowered together with all magnets and necessary accessories fixed in position into a 100mm diameter borehole backfilled with a suitable bentonite: cement grout mix. Once in position the spider magnets shall be released.

10.8.6. Where the access tube passes through fill which is being placed, the access tube and outer sleeve shall be extended as filling progresses. The top of the access tube, and the larger diameter sleeve where present, shall be protected with a suitable cover.

10.8.7. Magnetic extensometer shall be monitored by passing the probe down to the base of the access tube. The probe shall then be pulled upwards measuring the position of each magnet from the top of the tube. The position of each magnet shall be measured, once with the probe moving upwards from the base. Immediately before or after taking a series of readings, the level of the top of the access tube shall be measured by standard levelling techniques.

10.9. Combined Magnetic Extensometer and Inclinometers

10.9.1. Combined magnetic extensometer and inclinometer provide a method of measuring both vertical settlement and horizontal displacement at a series of points below the ground surface. The Contractor shall install combined magnetic extensometer and inclinometer at locations, and with depths and details as specified by the S.O or as shown in the Drawing or as specified by the S.O..

10.9.2. The specification for magnetic extensometer shall be referred to sub-section 10.8. and the specification for Inclinometer shall be referred to sub-section 10.5..

10.9.3. The magnets shall be positioned in relation to sleeved joints such that they can move downwards without obstruction sufficiently to monitor the expected settlement.

10.9.4. The borehole shall be 150mm diameter.

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10.10. Standpipe

10.10.1. Standpipe provides a method of monitoring the water table or ground water level. The Contractor shall install standpipe at locations and with depths and details as specified in the Drawing or S.O..

10.10.2. The standpipe shall be slotted unplasticised polyvinyl chloride (UPVC) tubing of nominal size 50mm diameter. The perforated part shall be wrapped with filter fabric as indicated in the Drawing.

10.10.3. The UPVC tubing shall be installed in not less than 3m lengths, except for one shorter length as required to suit the total standpipe dimensions. The concrete upper end of the tube shall be set in concrete.

10.10.4. The standpipe shall be placed in a 100mm diameter borehole backfilled with a graded filter sand (600 to 1200microns) to the depth indicated. The top of the hole shall be sealed with bentonite pellets, and with a concrete plug. A protective cover shall be set into the concrete with caps and air vents.

10.10.5. Depth to water in the standpipe shall be measured using a dipmeter.

10.11. Piezometers

10.11.1. Standpipe Piezometers

10.11.1.1. Standpipe piezometers give a measurement of piezometric level at a specific depth within a soil profile. They are generally used in soils of medium to high permeability. The Contractor shall install standpipe piezometer at locations, and with depth and details as shown in the Drawing or as directed by the S.O..

10.11.1.2. Standpipe piezometer shall be installed in boreholes at locations as shown in the Drawing or as instructed by the S.O.. The piezometer tip shall consist of a porous ceramic, plastic element or other suitable element not less than 150 mm long with minimum diameter of 25mm and shall be protected at each end by UPVC fittings. The filter element shall have a pore diameter of not more than 60 microns and a permeability of not higher than 3×10^{-4} m/s. The tubes shall be jointed together and to the porous element with threaded coupling or other approved coupling, tape and glue in such a manner that the joints remain leak proof under the anticipated head of water.

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10.11.1.3. The standpipe piezometer shall be installed in a borehole of minimum 76mm diameter. The sand filter surrounding the porous element shall be clean and fall wholly between the limits of grading 600 and 1200 microns. The contractor shall ensure that no sand adheres to the soil in the sides of the borehole. Where there is water in the borehole the contractor shall allow sufficient time for all sand to settle. The final level of the top of this sand shall be recorded. The porous element shall be placed in the hole and the remaining sand filter shall then be added as described above.

10.11.1.4. Seals consisting of bentonite pellets shall be placed above, and if necessary, below a sand filter. The remainder of the hole shall be filled with a bentonite: cement grout, and the top part with concrete with caps and air vents as indicated in the drawing. Before taking initial readings, the contractor shall carry out simple falling head test by raising the water level 1.5m above the static level, using an extension pipe if necessary.

10.11.1.5. The depth to water in the standpipe piezometer shall be measured using a dip meter.

10.11.2. Pneumatic Piezometers

10.11.2.1. Pneumatic piezometer is used to measure pore water pressures at specific depths within a soil profile. They can be used in a wide variety of soil types. The Contractor shall install pneumatic piezometers at locations, and with depths and details as shown in the Drawing or as directed by the S.O..

10.11.2.2. Pneumatic piezometer tips shall be of high air entry ceramic type with an average pore diameter of 1 micron using stainless steel. The piezometer system shall be capable of measuring water pressures to an accuracy of 0.2m head of water in the range 0-35m head of water.

10.11.2.3. The piezometers shall be connected to twin tubing with suitable brass couplings. Joints in the tubing other than at the piezometer tip or at the terminal point shall not be permitted. The tubing shall be connected either to suitable quick release couplings or a terminal point which shall be protected at all times. Where tubing is laid in trenches the backfill shall either be sand or excavated material provided it is suitable fill and stone-free. The tubing shall be laid with sufficient slack to take up any lateral movements that are expected to occur due to settlement of embankments or structures.

10.11.2.4. Before installation and taking initial readings, the Contractor shall conduct a pressure test on the pneumatic piezometer tip in a container of water after connection to the tubing to check for leaks or poor connections. The ceramic element shall be workable under vacuum and precautions shall be taken to ensure that it remains saturated during installation. During

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installation, readings shall be taken when the piezometer tip is lowered down the borehole, when it is pushed in or placed in the sand pocket and at various times after installation to check the response of the piezometer and help find the static pressure value before the initial base readings are taken.

10.11.2.5. Readings shall be taken by and stored on the readout device. Care shall be taken to ensure that the flow and return leads are connected correctly.

10.11.3. Vibrating Wire Piezometer (VWP)

10.11.3.1. The Vibrating Wire Piezometer is used to measure water pressure at specific depths in variety of soil types. The Contractor shall install vibrating wire piezometer at location, and with depths and details as specified by the S.O.. Prior to the installation of the VWP, the Contractor shall submit all required technical specifications, including a calibration certificate for S.O.'s approval.

10.11.3.2. VWP is used to monitor pore water pressures in soils. The VWP converts water pressure signal via components of VWP, include a porous tip containing a pressure-sensitive diaphragm; a pre-tensioned steel wire; and an electro-magnetic coil, one end of which is connected to the diaphragm, and the other to the body of the piezometer.

10.11.3.3. The VWP tip shall be of high air entry ceramic type with an average pore diameter of 50 micron using a stainless steel body. The piezometer system shall have a pressure range with an accuracy of 0.1% of full scale.

10.11.3.4. The cable shall be laid with sufficient slack to take up any lateral movements that are expected to occur due to settlement of embankments or structures.

10.11.3.5. During installation, readings shall be taken when the piezometer tip is lowered down the borehole, when it is pushed in or placed in the sand pocket and at various times after installation to check the response of the piezometer and help find the static pressure value before the initial base readings are taken.

10.11.3.6. Readings shall be taken by connecting the signal cable to the readout unit and the data shall be stored in the readout unit.

10.11.4. Installation of Piezometer (All Types)

10.11.4.1. The piezometer shall be installed in a borehole of not less than 76mm diameter. The drilling medium shall be water and extra care and attention shall be given during boring to ensure that the borehole is as vertical as possible to the required depth. Steel casing shall be used to prevent the collapse of the borehole. The borehole shall be flushed clean with water prior to installation.

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10.11.4.2. Before installation the piezometer element shall be immersed in de-aired water for at least 24 hours to saturate the element. De-aired water shall be prepared by boiling, and subsequently allowing the water to cool before use.

10.11.4.3. The piezometer tip shall be installed in a borehole backfilled with graded sand filter to the depth indicated. The sand filter surround to the porous element shall be clean and fall wholly between the limits of grading 600 and 1200 microns. The contractor shall ensure that no sand adheres to the soil in the sides of the borehole. The Contractor shall allow sufficient time for all sand to settle. The final level of the top of the sand shall be recorded. The porous element shall be placed in the hole and the remaining sand filter shall then be added as described above.

10.11.4.4. Seals consisting of bentonite pellets shall be placed above, and if necessary, below the sand filter. The remainder of the hole shall be filled with a bentonite: cement grout, and the top part with a concrete plug. The bentonite: cement grout mix shall be designed to mimic the surrounding soil or as shown in the Drawing. A protective cover shall be set into the concrete with caps and air vents as indicated in the Drawing.

10.12. Commissioning and Base Readings

10.12.1. After installation the functioning of each instrument shall be demonstrated to the S.O. including the recording of measured values using the appropriate readout device. As part of the commissioning three sets of readings shall be taken and compared. This three sets of readings shall be taken immediately after installation of the instruments. If there are significant differences or anomalies, further readings shall be taken. Once three sets of comparable readings have been taken, these shall be averaged to form the base readings.

10.12.2. In cases where instruments are installed during earthworks, three sets of readings shall be taken in quick succession and the results compared. These results shall be used to provide base readings in a manner to be agreed with the S.O..

10.13. Readings

10.13.1. The measured values shall be recorded on a record sheet. for readings that are recorded on data loggers, a record sheet shall be required giving references to the data stored. The format of plotted results shall be submitted to the S.O. for approval. Details of information and values to be stored on each record sheet in addition to the general information required but not limited to the details in **Table V10**.

10.13.2. The Contractor shall submit to the S.O. the specified number of copies of each record sheet with necessary raw data within one working day of taking the readings.

10.13.3. If any anomalous readings are detected and verified to be correct, the S.O. shall be informed immediately.

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10.13.4. Frequency of Readings

Each instrument shall be read immediately before and after each change in loading (i.e. each layer of embankment or structural fill, etc.) unless otherwise shown in the Drawing or as directed by the S.O. Any instruments found to be faulty shall be promptly brought to the S.O.'s attention so that remedial measures can be implemented.

10.13.5. Anomalous Readings

Whenever sets of data are measured, they shall be compared to previous sets of data. If anomalous readings are present which differ from the expected values or trends, then further readings shall be taken immediately and the S.O. shall be informed. If the anomalous values persist, then the S.O. shall be informed and an investigation shall be carried out to find the reason(s) for the anomalous readings.

10.14. Report

10.14.1. General Information on All Records

All records of instrumentation including installation, readings or monthly summaries, shall contain the following information:

(i) Project name

(ii) Contract name and number

(iii) Instrument reference number and type

(iv) Dates and times of installation and completion,

(v) Summary of reading

(vi) Chainage and offset / coordinates in WGS 84

(vii) Personnel names, roles and responsibilities

(viii) Relevant comments or remarks

10.14.2. Installation Records and Reports

The Contractor shall prepare an installation record sheet for each instrument to be installed and submit to the S.O. for approval at least two weeks before installation commences.

10.14.3. Monthly Monitoring Reports

10.14.3.1. A sample of the format of the report shall be submitted to the S. O. including all graphical presentations for approval at least one month before submission of the first monthly report unless specified by S.O. Each monthly report shall include:

(i) A description/scope of monitoring works

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(ii) Information on reading anomalies or corrections, if any, and factors which may influence measured data

(iii) Observations or remarks

(iv) A Drawing showing installed locations of instrumentation

(v) Data tabulations or plots of instrument readings include but not limited to the details in **Table V11**

10.14.3.2. The Contractor shall submit four sets of report (hardcopy and softcopy) within 7 days after the end of each calendar month of monitoring.

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Table V1. Sampling Frequency and Testing Requirements for Geotextile

Area of Geotextile (m^2)	Number of Rolls to be Sampled Representing the Area of Geotextile	Testing by the Contractor	
		Non-Woven Geotextile	High Strength Woven Geotextile
Initial 10,000 or part thereof	1	Tensile strength, Elongation, CBR puncture, Permeability, Effective Opening Size (O_{90}) or Apparent Opening Size (O_{95})	Tensile strength, Elongation
Each subsequent 100,000 or part thereof	1		

Table V2. Sampling Frequency and Testing Requirements for Geogrid

Area of Geogrid (m^2)	Number of Rolls to be Sampled Representing the Area of Geogrid	Testing by the Contractor
		Geogrid
Initial 10,000 or part thereof	1	Tensile strength, Elongation
Each subsequent 100,000 or part thereof	1	

Table V3. Guidelines for Geotextile Overlap Requirements as a Function of (Foundation Soil) Strength

Soil CBR	Minimum Overlaps
>3	0.3 – 0.45 meter
1 – 3	0.6 – 1 meter
0.5 – 1	1 meter or sewn
< 0.5	sewn

(Source: AASHTO M288-06,2007)

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Table V4. Properties of Non-woven Geotextile

Item	Properties	Test Standard	Unit	Types of Non-Woven (NW) Geotextile			
				NW 9	NW 13	NW 19	NW 24
1.	Wide width tensile strength	ISO 10319 or ASTM D4595	kN/m	≥ 9	≥ 13	≥ 19	≥ 24
2.	Wide width elongation at break	ISO 10319 or ASTM D4595	%	≥ 35			
3.	CBR puncture resistance	ISO 12236 or ASTM D6241	N	≥ 1500	≥ 2100	≥ 2850	≥ 3850
4.	Cone drop	ISO 13433	mm	≤ 40	≤ 25	≤ 20	≤ 15
5.	Permeability at 50mm head	ISO 11058 or ASTM D4491	$l/m^2/s$	≥ 90	≥ 70	≥ 55	≥ 45
6.	Effective opening size, $O_{90,}$	ISO 12956	µm	≤ 120	≤ 100	≤ 90	≤ 90
	or						
	Apparent Opening Size, O_{95}	ASTM D4751	µm	≤ 270	≤ 240	≤ 190	≤ 180
7.	UV resistance	EN 12224	% retained after 430 hours	≥ 70			
		or					
		ASTM D4355	% retained after 500 hours				

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Table V5. Properties of High Strength Woven Geotextile

Item	Properties	Test Standard	Unit	Types of High Strength (HS) Woven Geotextile*					
				HS 100/50	HS 200/50	HS 300/50	HS 400/50	HS 600/50	HS 800/50
1.	Characteristics Short Term Strength – MD**	ISO 10319 or ASTM D4595	kN/m	≥ 100	≥ 200	≥ 300	≥ 400	≥ 600	≥ 800
2.	Characteristics Short Term Strength at 5% elongation – MD**	ISO 10319 or ASTM D4595	kN/m	≥ 45	≥ 90	≥ 135	≥ 180	≥ 270	≥ 360
3.	Characteristics Short Term Strength – CD***	ISO 10319 or ASTM D4595	kN/m	≥ 50					
4.	Elongation at Characteristics Short Term Strength – MD**	ISO 10319 or ASTM D4595	%	≤ 10					
5.	Long Term Design Strength at 120 years design life****	BS 8006	kN/m	≥ 55	≥ 110	≥ 170	≥ 220	≥ 355	≥ 475

* For high strength woven geotextile with required strength more than 800 kN/m, special design and specification shall be discussed with the designer

** MD: Machine Direction

*** CD: Cross Direction

****The long-term design strength assessment should take into consideration of reduction factors for creep, installation damage, environmental effects and extrapolation of data

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Table V6. Properties of Geogrid

Item	Properties	Test Standard	Unit	Types of Geogrid (GD)*						
				GD 40	GD 60	GD 80	GD 100	GD 130	GD 150	GD 200
1.	Characteristics Short Term Strength – MD**	ISO 10319 or ASTM D4595	kN/m	≥ 40	≥ 60	≥ 80	≥ 100	≥ 130	≥ 150	≥ 200
2.	Characteristics Short Term Strength at 5% elongation – MD**	ISO 10319 or ASTM D4595	kN/m	≥ 20	≥ 30	≥ 40	≥ 50	≥ 65	≥ 75	≥ 100
3.	Characteristics Short Term Strength – CD***	ISO 10319 or ASTM D4595	kN/m	≥ 30						
4.	Elongation at Characteristics Short Term Strength – MD**	ISO 10319 or ASTM D4595	%	≤ 10						
5.	Long Term Design Strength at 120 years design life ****	BS 8006	kN/m	≥ 20	≥ 30	≥ 40	≥ 50	≥ 75	≥ 80	≥ 105

* For geogrid with required strength more than 800 kN/m, special design and specification shall be discussed with The designer

** MD: Machine Direction

*** CD: Cross Direction

****The long-term design strength assessment should take into consideration of reduction factors for creep, installation damage, environmental effects and extrapolation of data

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Table V7. Properties of Prefabricated Vertical Drain

Item	Properties		Test Standard	Unit	Types of PVD	
					Type A*	Type B**
	Material	Core Filter			Continuous plastic drain core wrapped in non-woven geotextile material	
1.	Dimension of drain	Width		mm	100 ± 3	
		Thickness		mm	4 to 5	
2.	Coefficient of permeability of drain filter		ASTM D 4491	m/s	≥ 1 x 10^{-4}	
3.	Discharge Capacity at Pressure, P=240kN/m^2 and Hydraulic Gradient, i=1		ASTM D 4716	m^3/s	≥ 25 x 10^{-6}	≥ 100 x 10^{-6}
4.	Apparent Opening Size, O_{95}		ASTM D 4751	μm	≤ 90	≤ 90
5.	Tensile strength of entire drain		ASTM D 4595	N	≥ 2500	≥ 2800
6.	Tensile strength of filter		ASTM D 4595	N/m	≥ 3000	≥ 6000
7.	Tensile elongation of entire drain at 1000N		ASTM D 4595	%	≤10	≤ 10

* PVD Type A: For common application where soft soil depth is generally <25m and less compressible soil [Vertical strain (Settlement) < 15%].
** PVD Type B: For more critical application such as when soft soil depth is generally ≥25m, highly compressible soil like peat or gyttja [Vertical strain (Settlement) ≥ 15%], PVD associated with vacum preloading method or other special considerations based on engineering judgement of the designer.

Table V8. Typical Gradings Used with the Different Processes for Stone Column

Process	Grading in mm
Dry top-feed process	40 to 75
Wet process	25 to 75
Dry bottom-feed process	8 to 50

Table V9. Construction Parameters to be monitored during DSM Installation

Dry Method	Wet Method
• Air tank pressure • Time vs depth (penetration and retrieval rate) • Rotation speed (revs/min during penetration and retrieval) • The quantity of binder per meter of depth during penetration and retrieval	• Slurry pressure; air pressure (if any) • Time vs depth (penetration and retrieval rate) • Rotation speed (revs/min during penetration and retrieval) • The quantity of slurry per meter of depth during penetration and retrieval

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Table V10. Data Required for Each Instrument

Instrument	Data Required
Displacement marker	- distance from fixed point (m) (details to be given) including base reading - change in distance from fixed point relative to base readings (mm)
Settlement marker	- reduced level of top of rod (mRL) including base reading - change in reduced level of top of rod relative to base readings and previous reading (mm)
Building Settlement Marker	- reduced level of stud (mRL) including base reading - change in reduced level of stud relative to base readings and previous reading (mm)
Survey reference station	- chainage, offset, coordinates (in WGS 84) and reduced level of top of rod (m)
Deep levelling datum	- reduced level of datum (mRL)
Rod settlement gauge	- reduced level of top of rod (mRL) including base reading - original ground level at gauge location (mRL) - reduced level of ground adjacent to gauge (mRL) - record of fill placed (m) - total thickness of fill (m) - record of extensions (m) - settlement of plate relative to base readings and previous reading (mm)
Hydrostatic profile gauge	- reduced levels of survey pins (mRL) - original ground level every 10.0m along line of gauge (mRL) - level of fill every 10.0m along line of gauge (mRL) - thickness of fill along the line of the - gauge (m) - distance from end of access tube to point used as reference for longitudinal measurement (m) - listing of elevation of access tube relative to survey pin at 1.0m intervals (mRL) - graph of settlement of access tube relative to base readings and thickness of fill against distance along the tube - maximum settlement relative to base readings and previous reading and its location (mm)
Horizontal Inclinometer	- reduced levels of survey pins (mRL) - original ground level every 10.0m along line of gauge (mRL) - level of fill every 10.0m along line of gauge (mRL) - thickness of fill a long line of gauge (m) - distance from end of access tube to point used as reference for longitudinal measurement (m) - listing of elevation of access tube relative to survey pin at 0.5m intervals (mRL) - graph of settlement of access tube relative to base readings and thickness of fill against distance along the tube - maximum settlement relative to base readings and previous reading and its location (mm)

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Instrument	Data Required
Magnetic extensometer	- reduced level of top of access tube (mRL) - reduced level of ground adjacent to access tube (mRL) -distance of each magnet from top of tube (m) - reduced level of each magnet (mRL) - settlement of each magnet relative to base readings (mm)
Inclinometers	- reduced level of top of access tube (mRL) - reduced level of ground adjacent to access tube (mRL) - graph and listing of horizontal movement of access tube relative to base readings against depth
Combined magnetic extensometer and inclinometer	- reduced level of top of access tube (mRL) including base reading - reduced level of ground adjacent to access tube (mRL) -distance of each magnet from top of tube (m) - reduced level of each magnet (mRL) - settlement of each magnet relative to base readings (mm) - graph and listing of horizontal movement of access tube relative to base readings against depth depth to water from top of tube (m)
Standpipe piezometers	- depth to water from top of tube (mRL) including base reading - reduced level of top of tube (mRL) - reduced level of ground adjacent to standpipe (mRL) - water head (mRL) - change in water head relative to base readings (m)
Pneumatic piezometers	- water pressure reading (m water) including base reading - reduced level of piezometer tip as installed (mRL) - water head (mRL) - change in water head relative to base readings (m)
Vibrating wire piezometer	- water pressure reading (m water) including base reading - reduced level of piezometer tip as installed (mRL) - water head (mRL) - change in water head relative to base readings (m)

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Table V11. Data Required for Each Instrument

Instrument	Data Required Plots and Summaries Required
Displacement marker	- deflection vs. time indicating direction of movement (tabulation and plot)
Settlement marker	- settlement vs. time (tabulation and plot)
Building settlement marker	- settlement vs. time (tabulation and plot)
Survey reference station	- chainage, offset coordinates and reduced level (tabulation)
Deep levelling datum	- reduced level (tabulation)
Rod settlement gauge	- thickness of fill and settlement of plate vs. time (tabulation and plot)
Hydrostatic profile gauge	- latest graph of settlement of access tube relative to base readings and fill thickness against distance along the tube - maximum gauge settlement and corresponding fill thickness vs. time (tabulation and plot)
Horizontal inclinometer	- latest graph of settlement of access tube relative to base readings and fill thickness against distance along the tube maximum gauge settlement and corresponding fill thickness vs. time (tabulation and plot)
Magnetic extensometer	- settlement of each magnet vs. time (tabulation and plot) - settlement of each magnet vs. depth for latest set of readings (plot)
Inclinometer	- latest graph of horizontal movement of access tube relative to base readings against depth - Maximum horizontal movement relative to base readings vs. time (tabulation and plot)
Combined Magnetic Extensometer Inclinometer	- as per magnetic extensometer and inclinometer described above
Standpipe piezometer /Pneumatic piezometer/ Vibrating wire piezometer	- water head vs. time (tabulation and plot) - excess water head vs. time (tabulation and plot) - all instruments in a profile plotted on the same graph

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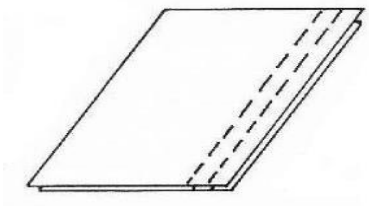
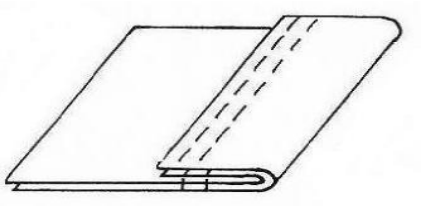
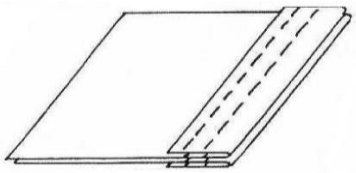


(i) Prayer Seam



(ii) J Seam



(iii) Butterfly Seam

Figure V1. Types of Seam with Double Thread Lock Stitch

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TABLE OF CONTENTS

SECTION X: INTERNAL COLD WATER AND SANITARY PLUMBING SYSTEM		PAGE
1.	Scope of Work	X/1
2.	Internal Cold Water Plumbing System	X/2
3.	Sanitary Plumbing System	X/14
4.	Testing, Adjusting, Balancing and Commissioning (TABC)	X/23
5.	Comprehensive Service and Maintenance for Internal Cold Water and Sanitary Plumbing System	X/27

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1. Scope of Work

1.1. The work to be performed under this contract shall comprise, but not limited to the supply, delivery, installation, testing, adjusting, balancing, commissioning and maintenance of the following principal services and the associated works and items:

1.2. Internal Cold Water Plumbing System

1.2.1. Internal Piping system complete with all bends, tees, sockets, valves, plugs, reducers, brackets, supports and other necessary accessories to complete the installation.

1.2.2. Water Tank (Suction and Storage Tank)

1.3. Internal Sanitary Plumbing System

1.3.1. Internal piping complete with all necessary bends, tees, sockets, branches, offsets, and other necessary accessories to complete the installation.

1.3.2. Internal inspection chamber, gully trap and grease trap.

1.4. The contractor shall at his own cost be responsible to appoint Suruhanjaya Perkhidmatan Air Negara (SPAN) certified personnel for the submission, supervision, construction, testing and certification of the completed works.

1.5. The Contractor shall prepare and submit working drawings to the Superintending Officer (S.O.) for approval within thirty (30) days from the date of acceptance of tender. In preparing these working drawings, the Contractor shall coordinate with the building layout and constructional details of the architectural, structural and electrical drawings.

1.6. The drawing shall be fully dimensioned and show all the precise locations, arrangement and loading of the equipment. The drawings shall also indicate location and details of all foundation, supports, chases, core holes, opening in partition wall, floors and roof and any other information required for works or services to be provided by others.

1.7. The drawings submitted shall be modified as necessary and, if requested by S.O., re-submitted for final approval. Six (6) sets of drawings shall then be submitted for distribution to all parties concerned.

1.8. The contractor shall submit method statement (upon S.O. request), samples of materials or execute samples of workmanship (mock-up) for S.O. approval, and for further samples as required until the samples submitted or executed are, in accordance with this specification.

1.9. Samples, after approval, shall indicate the standard of materials and workmanship to be maintained in the execution of the works.

1.10. After connection work is done, the Contractor shall ensure that all system to be operational as required.

1.11. The Contractor shall service and maintain the above-mentioned cold water and sanitary plumbing system during Defect Liability Period (DLP) from the date of Certificate of Practical Completion (CPC) in good operating condition until Certificate of Making Good Defect (CMGD).

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1.12. The Contractor shall submit the as-built drawing, Operation and Maintenance Manual (OMM) complete with Schedule of Maintenance before handing over subject to S.O. approval.

2. Internal Cold Water Plumbing System

2.1. General

All water supply plumbing and installation shall be executed in accordance with the latest edition of the following:

2.1.1 *Act 655 - Water Services Industry Act 2006*

2.1.2. *Water Services Industry (Water Reticulation and Plumbing) Rules 2014*

2.1.3. *BS 8558 – Guide to the design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages – Complementary guidance to BS EN 806.*

The Contractor shall submit method statement of installation if required by the S.O..

2.2 Pipework (Material Pipes Standards)

2.2.1 General

Pipework for water supply plumbing shall be to the dimensions shown in the drawings or as specified hereinafter and shall be complete with all bends, tees, sockets, plugs, reducers, brackets, supports and other accessories to complete the installation.

2.2.2 Standards

2.2.2.1. All pipes, fittings and equipment used for water supply plumbing and installation shall be of the type and make approved by SPAN and as mentioned in the drawings.

2.2.2.2. The standards stated in this specification shall comply with their latest edition issued or relevant standards approved by SPAN.

The details of the internal piping shall be referred to **Table X1.**

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Table X1. List of Internal Piping

Type of pipe	Minimum wall thickness & pressure rating	Standard	Fitting
High Density Polyethylene (HDPE)	PN 12.5 at 20°C (equivalent to 10 bar derated working pressure at 30°C)	MS 1058 or BS EN 12201 and marked with SIRIM certification numbers	Moulded integrally dezincified brass with BSP threads of BS EN 12420:2014 or BS EN 12165:2016. Nickel and Chromium plated to BS 1224 service condition NO. 2.
Acrylonitrile Butadiene Styrene (ABS)	PN 12 to MS 1419: Part 1: 2007	MS 1419: Part 1: 2007	MS 1419: Part 2: 2007 - Fitting MS 1419: Part 3: 2007 - Solvent cement. All ABS pipes, fittings and solvent cement shall be supplied by the same manufacturers.
Polybutylene (PB)	PN 15 at 20°C (equivalent to 15 bar derated working pressure at 30°C)	MS ISO 15876 or AS/NZS 2642	Moulded integrally dezincified brass with BSP threads of BS EN 12420:2014 or BS EN 12165:2016. Nickel and Chromium plated to BS 1224 service condition NO. 2.
Polypropylene random co-polymer (PP-R)	PN 14 at 70°C	MS 2286 or BS EN ISO 15874	Moulded integrally dezincified brass with BSP threads of BS EN 12420:2014 or BS EN 12165:2016. Nickel and Chromium plated to BS 1224 service condition NO. 2.
Stainless Steel (SS)	BS EN 10312: <Ø 12mm → Series 1 ≥Ø 12mm → Series 1 or Series 2 or ASTM A312/A312M: Ø ½'' – Ø 2'' → Schedule 40S (Threaded) Ø 2½'' – Ø 8'' → Schedule 10S (Welded)	MS 1841: 2010, BS EN 10312 ASTM A312/A312M or JIS G 3448	Stainless steel compression fittings to BS 4368 or SAS 322: 2003 Ø ½'' – Ø 2'' → (Schedule 40S) Threaded & screw fittings according to ISO 4144:2003 Ø 2½'' – Ø 8'' → (Schedule 10S) Butt weld fittings according to ASTM A 403 / A 403M
Copper Tubing	Type K	BS EN 1057 BS 2871	Brazing according to BS EN 1254: Part 1 or Compression joint according to BS EN 1254: Part 2 or Accelerated 'push fit' according to BS EN 1254: Part 2
Crosslinked Polyethylene (PE-X)	PN 12 at 70°C	MS 1736: Part 2	MS 1736: Part 3 - Fitting Moulded integrally dezincified brass with BSP threads of BS EN 12420:2014 or BS EN 12165:2016. Nickel and Chromium plated to BS 1224 service condition NO. 2.

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2.3 Pipe Installation

2.3.1. Pipes and fittings shall be cleaned and free from manufacturing burrs and site debris.

2.3.2. The pipes shall be adequately protected against damage during transit. Each delivery of pipes shall be accompanied by the manufacturer's testing certificate.

2.3.3. Internal Piping

2.3.3.1. All installation shall be done according to the approved drawings and pipe manufacturer's recommendation. Plumber shall be competent in various types of installation. Special care shall be taken in the arrangement of piping to ensure a neat finishing and alignment.

2.3.3.2. Services pipes and distribution pipes except those buried under ground level shall be concealed in wall, ceilings, boxed up or laid within the common trench, services shaft, etc provided where possible. All work shall be executed in such a manner to avoid cutting into finished work in walls, aprons, beam, etc. where practicable as the work proceeds. Pipe work to be buried or concealed shall not be covered or plastered before they are examined, tested and approved by the S.O..

2.3.3.3. Installation of valves and fittings shall be grouped where this will not affect their operation, to reduce the number of joints to a minimum.

2.3.3.4. All necessary isolating valves, check valves and other fittings as required are as shown in the approved drawings. Every section of major branch supply piping shall be installed a gate valve at the point of connection to the supply.

2.3.3.5. Minimum diameter for internal cold water plumbing system shall be 20mm (3/4") except for flush valve system where minimum diameter shall be 25mm (1"). Final branches to fittings shall be 20mm diameters and the sizes of feeders from which these branches are taken shall be as in **Table X2**:

TABLE X2. Diameter of Feeders to Number of Fitting Served

No of Fittings Served	Diameter of Feeders
1	20mm
2	20mm
3, 4	25mm
5, 6 ,7	32mm
8, 9, 10, 11, 12	40mm
13, 14, 15, 16, 17, 18	50mm

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2.3.4. Threaded Joints

2.3.4.1. Threaded end connections for plastic (ABS/PE/PB) pipes shall have tapered thread forms complying with **AS ISO 7.1-2008 and AS ISO 7.2-2008** or equivalent approved standard in accordance with manufacturer's instruction.

2.3.4.2. Where threaded joint is to be made between plastic (ABS/PE/PB) pipes and metal, the plastic (ABS/PE/PB) pipes should be the male component of the joint.

2.3.4.3. All screwed joints shall be made by using Teflon tape or approved jointing compound.

2.3.5. Flanged Joints

Flanged joints or other suitable methods can be used for pipe more than 50mm and working pressure more than 10 bar (PN10).

2.3.6. Bends

Bends of all piping shall have a radius of not less than 5 times the diameter and shall be of standard type.

2.4. Pipe Supports

2.4.1. Pipe supports, hangers, anchors, guides etc. shall be supplied and installed for proper support.

2.4.2. Vertical riser shall be supported at each floor with galvanized iron (G.I) riser clamps or other material subject to S.O.'s approval.

2.4.3. Horizontal pipe runs shall be supported on hangers of split ring adjustable type or clevis type. Where pipelines run along walls, columns or ceilings, brackets or clamps may be used.

2.4.4. Piping at all equipment, valve positions and at main junctions, shall be adequately supported to prevent any distortion or transmission of strain to connect equipment or valves.

2.4.5. Where pipe lines run in a common group, they shall be supported from a common hanger bar as indicated in the approved drawings.

2.4.6. Pipe supports and hangers shall be spaced at intervals as shown in **Table X3** and **Table X4**:

TABLE X3. Recommended Maximum Spacing of Support for Horizontal Cold Water Pipe

Pipe Size (mm)	Recommended Maximum Spacing of Support (m)	
	Non-metal	Metal
20	0.8	1.5
25	0.85	1.8
32	1.0	2.4
40	1.1	2.4
50	1.25	2.4

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80	1.65	3.0
100	1.9	3.0

Source: *British Standards Institute. (2010). BS EN 806-4: Specifications for installations inside buildings conveying water for human consumption. Installation*

TABLE X4. Recommended Maximum Spacing of Support for Vertical Cold Water Pipe

Pipe Size (mm)	Recommended Maximum Spacing of Support (m)	
	Non-metal	Metal
20	1.0	2.4
25	1.1	2.4
32	1.3	3.0
40	1.3	3.0
50	1.6	3.6
80	2.1	3.6
100	2.5	3.6

Source: *British Standards Institute. (2010). BS EN 806-4: Specifications for installations inside buildings conveying water for human consumption. Installation*

2.4.7. Vertical pipes shall be supported at least at the top and bottom of each riser, at each floor level, and at each isolating valve. In addition, a further support shall be provided between floor levels for pipes smaller than 32mm.

2.5. Pipe Sleeve and Cover Plate

2.5.1. Where pipes are required to be laid through structural beams or slabs, G.I/ uPVC pipe sleeves shall be provided. All pipes shall be properly secured in place with brackets.

2.5.2. All exposed piping within occupied rooms shall be boxed up to S.O.'s approval.

2.5.3. Where pipe past through fire break walls or other partitions, clearance between pipes and sleeves shall be tightly pegged with suitable fire rated material to form a sound and fire barrier.

2.6. Valves and Fitting

2.6.1. All valves shall be of SPAN approved, manufactured and generally constructed in accordance with relevant standard. All valves shall be suitable for system operating pressure.

2.6.2. All valves and fittings necessary for the correct control, operation and maintenance of all services shall be provided and installed to the satisfaction of the S.O.. Samples shall be submitted for S.O.'s approval before installation. Valves shall be installed where they are easily accessible for maintenance and operating purposes.

2.6.3. Each valve shall be of the same nominal size as the pipeline in which it is installed, except for control, pressure reducing and similar valves which shall be correctly sized as per specific duty and functionality.

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Connection between each valve and adjacent piping or equipment shall be made either flange or threaded joints may be applicable.

2.6.4. Before installation, every valve shall be blown out with air to remove any foreign matter lodged in the valve.

2.6.5. Stop Valves / Gate Valves

2.6.5.1. Stop valves / gate valves are generally used as isolation valves.

2.6.5.2. Full bore copper alloy screw-down stop valves / gate valves of the same diameter as the pipe shall be provided and fixed for control in the following positions:

(i) On the service pipe before it enters the building.

(ii) On each branch of the service pipe.

(iii) On the inlet to each storage or feed cistern.

(iv) On the inlet to each flushing cistern.

(v) On the outlet of each storage tank or feeder cistern.

(vi) In other position on the pipe as shown or indicated, other than on overflow/warning pipe.

(vii) For system with pressure reducing valve (PRV), location of the gate valves shall be as indicated in the approved drawings.

2.6.5.3. Stop valve of 50mm and below shall be complied with *MS 1022* and stop valve of 50mm and above shall be complied with *BS EN 1213*.

2.6.5.4. Gate valve of various sizes shall be complied with *BS EN 12288* (copper alloy valves) and *BS EN 1171* (cast iron valves) (PN12 above).

2.6.5.5. Gate valve sized from 65mm to 100mm shall be either screwed or flanged end complied with above mentioned standards.

2.6.5.6. Valves with reduced flow areas shall not be used for water closet flush valves and flushing cistern.

2.6.5.7. All valves shall have hand-wheel with externally screwed bronze or stainless steel spindle.

2.6.6. Pressure Gauges

2.6.6.1. Dial type with 3-way gauge cock shall be supplied and installed where indicated in the approved drawings.

2.6.6.2. A pressure gauge shall be installed at every suction pipe, every delivery pipe and at the common header pipe.

2.6.6.3. Pressure gauges shall be minimum 100mm diameter dial face type and having ranges suitable for the service pressure

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encountered. The measuring range of the gauge should be 125% of the maximum pressure.

2.6.6.4. The gauges shall be industrial type shock proof, liquid filled, stainless steel casing and IP 65 Ingress Protection Rating.

2.6.6.5. The construction of pressure gauges shall comply with *BS EN 837-1*.

2.6.7. Pressure Reducing Valve (PRV)

2.6.7.1. Air vent and pressure reducing valve shall be installed at 30 meter intervals along downpipes to restrict the pressure sustained by the fittings to prevent water hammer and other effect.

2.6.8. Check Valves

2.6.8.1. Where shown in the drawings, non-slam-type check valves shall be supplied and fitted.

2.6.8.2. Valves shall be selected in relation to the velocity of the water in the pipe. In all cases, the valve is required to operate silently on reversal of water flow and if necessary, valves of the double or articulated clack type or the spring assisted type shall be fitted.

2.6.9. Water Meter

2.6.9.1. Suitable water meter approved by SPAN shall be supplied and installed as required.

2.7. Water Tank

2.7.1. Water Tank Material

2.7.1.1. All water tanks for water supply shall be of the type and capacity shown or stated in the drawings. The water tanks shall be watertight and properly supported.

2.7.2. Fibreglass Reinforced Plastic (FRP) Water Tank

2.7.2.1. The tanks shall be scribbled down and flushed out with clean water and sterilized with chemical containing chlorine before being put into use.

2.7.2.2. Water tank design shall comply with the following standards:

(i) MS 1241 - FRP Water Tank

(ii) MS 1390 – FRP Sectional Water Tank

(iii) Any other standards approved by SPAN

2.7.2.3. Materials for the construction of panels shall conform to MS 1241. The surface of FRP panels shall be manufactured with built-in stabilizer against embrittlement due to ultra-violet radiation.

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2.7.2.4. The panel shall be of hot press moulded and fabricated from fiberglass reinforced plastic (FRP) of dimension 1meter x 1meter square with maximum tolerance of 1.5mm. Each FRP panel will be manufactured with flanges at a right angle of 90° to all sides of each panel. The thickness of the flange for the side wall and base plates will not be less than 10mm and the landed width of each flange will not be less than 70mm for base and side panels.

2.7.2.5. Water storage tank of 10,000 litres or more shall have internal compartments to facilitate maintenance of the water tank. Alternatively, multiple tank may be employed. An equalizing pipe shall be provided between each compartment or between each separate storage tank supplying water to the same distribution pipe.

2.7.2.6. Physical Properties of the FRP Panel is as shown in **Table X5**:

TABLE X5. Physical Properties of FRP Panel

Parameter	Results
Tensile strength	>70 MN/m²
Bending strength	>100 MN/m²
Elastic modulus in bend	>6,000 MN/m²
Hardness	30% or 90% of the resin manufacturer specification whichever is higher
Glass content	>25%
Water absorption	1.0%

Source: *Malaysian Standard. (2010). MS 1390: Glass-Fibre Reinforced Polyester Panels and Panel Water Tanks – Specification (First Revision)*

2.7.2.7. Jointing Material

(i) The jointing material shall be synthetic rubber as sealant with stainless steel washer, nuts and bolts.

(ii) The holes for the bolts will be 12mm $\pm$ 1.5 to 2.0mm in diameter, suitable for M12 bolts and nuts.

2.7.2.8. Connections

(i) All holes and pipe connection made in wall, top and bottom of tanks shall be factory fabricated before delivery of tank to site. The positions and type pipe connections shall be carried out strictly in accordance with the manufacturer's recommendations.

2.7.2.9. Painting

(i) The internal face of the water tank shall be given two coats of non-toxic, non-corrosive paint and external one coat primer and two coats of non-corrosive paint to S.O. approval.

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2.7.3. High Density Polyethylene (HDPE) Tank

2.7.3.1. The HDPE tanks shall be constructed of physiologically safe, non-toxic, inert, visor-elastic, UV-resistant high density polyethylene of one-piece moulded seamless construction to *BS 4213* or *MS 1225* and *SIRIM* certified without welding or joint. The tanks shall be manufactured from 100% virgin food grade resins without the additional recycled or reworked material. The resin used must be certified by the resin manufacturer to be food grade compliance and suited for the potable water.

2.7.3.2. The tanks and all piping connections shall be installed strictly in accordance to manufacturer's instructions and specification and the installation shall be supervised and verified by the manufacturer.

2.7.3.3. The tanks shall come with a minimum 10 years warranty against defect in materials, manufacture and workmanship by the tank manufacturer. The warranty certificate shall be submitted to S.O. before handing over.

2.7.4. Stainless Steel Tank

2.7.4.1. Stainless steel tank design shall comply with the following standards shown in **Table X6**:

TABLE X6. Standard for The Respective Steel Tank

Type of water tank	Standard
Stainless steel storage tank	JKR 20200-0041-99
Pressed steel sectional rectangular tank panel	BS 1564

2.7.5. Stainless Steel Storage Tank

2.7.5.1. Material used in the fabrication of this tank shall be of Grade 304 stainless steel ASTM Designation: A240/A240M-94a or equivalent standards and supported by the respective mill certificates.

2.7.5.2. The finished surface of the materials used shall be of bright annealed (BA) and/or non-shining (2B) finished.

2.7.5.3. The tank shall be manufactured inclusive of the following components:

(i) Top cap

(ii) Top cover

(iii) Tank body

(iv) Bottom cover

(v) Stand (for round bottom & spherical types only)

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2.7.5.4. The stands (except for flat bottom type), fittings and accessories such as internal and external ladder, tank cover, screw nut, etc. of the tank shall be made of similar stainless steel materials of the above grade.

2.7.5.5. Each tank shall be marked / labeled on the external upper part of the tank body according to the following information:

(i) Manufacturer's name and/or trade mark

(ii) Date of manufacture

(iii) Serial number and model

(iv) Capacity

2.7.6. Pressed Steel Sectional Rectangular Tank Panel Water Tank

2.7.6.1. Material for the pressed steel sectional water tank shall be manufactured from 0.8mm thickness Grade 304 stainless steel plate inner surface composite with minimum of 5mm external surface of mild steel plate.

2.7.6.2. The reinforcement for pressed steel sectional water tank shall be reinforced using suitable support. Detail calculation for internal / external reinforcement design shall be submitted to S.O. for record.

2.7.6.3. All bolts, nuts and washers in contact with water shall be of stainless steel Grade 304. All external bolts, nuts and washers in contact with water shall be of hot dipped galvanized mild steel.

2.7.6.4. The cover for pressed steel sectional water tank shall be constructed 1.2m x 1.2m / 1m x 1m from 1.2mm thickness Grade 316 stainless steel plate.

2.7.6.5. Non-toxic PVC foam shall be used for jointing between flanges.

2.7.7. Tank Components and Accessories

2.7.7.1. The installation of storage / domestic tanks shall include but not limited to the following accessories and fitting to the tanks:

(i) Overflow / warning pipe, outlet tapping and scour pipes shall discharge outside the building or to a point shown or stated in the approved drawing.

(ii) Access manholes with cover, the number, locations and details of which shall be approved by S.O..

(iii) Mosquito-proof air vents to the tank cover at the positions and as per details approved by S.O..

(iv) Water tanks of two (2) metres depth or more shall be provided with internal and external ladders. The internal ladder and external ladder shall be made of stainless steel grade 304 unless otherwise specified. The ladder width shall not be less than 300mm and the length shall

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be suitable for the tank specified. The maximum height from floor finish level to the first ladder step shall be 300mm.

(v) Water level indicators and scales graduated in meters to suit the depth of the tank as shown in the approved drawings.

(vi) Float Operated / Ball Valves

a) Float operated valve shall comply with BS 1212. The combination of body pattern, seat number and size of float to suit the required pressure zone shall be as per standard.

b) All ball valves shall be supplied and fitted complete with back nuts, ball float, arm, etc. Ball floats may be of soldered copper or brass or alternatively polyethylene and PVC.

(vii) Pilot Operated Valve

a) Pilot-operated valve shall comply with AWWA C530-07. The configuration and material of main valve, vertical float rod and float shall be as per standard and specification.

(viii) Drain Cocks

a) Gunmetal drain cocks shall be provided as necessary to ensure that all sections of the pipework and plant can be effectively drained. The sizes of drain cocks shall be as follows: -

i. Tanks, plant and pipes above 6” diameter - ≥ 1” diameter

ii. Pipes 3” to 5” diameter - 0.75” diameter

iii. Pipes up to 2.5” diameter - 0.5” diameter

2.7.8. Water Tank Foundation

2.7.8.1. Panel Tank

(i) Unless otherwise shown in the approved drawings, the foundations shall be constructed to provide continuous support to all base panel joints in one direction at 1000mm nominal centres according to panel sizes. The concrete foundation shall have a width of at least 300mm and height of at least 600mm. All foundations shall be constructed according to JKR standard specifications.

(ii) If concrete slab is used, dwarf walls or steel beams shall be placed between the tank and the base level to allow a minimum clearance of 500mm to enable ease of tank

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installation and subsequent bolts tighten and adjustments after installation.

(iii) Whenever recommended by the tank manufacturer, the steel skid base shall be designed and constructed in accordance with manufacturer's instructions, and details. In such cases, the continuous support can be spaced at greater than 1000mm nominal centers as recommended by the manufacturer.

2.7.8.2. Round Tank

(i) The concrete plinth shall have minimum of 100mm height complete with 5mm mild steel base plate as per tank size.

2.7.9. Flange Joint (Nozzle)

2.7.9.1. Flange joint used for the inlet, outlet and scour of storage tanks shall be made of stainless steel grade 304 externally and internally. Joint gaskets shall be of 5mm thick, medium rubber reinforced with two-ply flexible fabric and complying with BS 6956, or approved silica sealant used in the FRP tanks. All bolts, nuts and washer used for flange nozzles shall be made of stainless steel grade 304.

2.8. Cleaning, Painting and Identification

2.8.1. Cleaning of Pipework

2.8.1.1. All pipes, fittings, etc., shall be kept closed against moisture and foreign matters when stored on site.

2.8.1.2. All pipes, fittings, valves and accessories shall be thoroughly cleaned internally and externally before their installation and again where necessary before closing up.

2.8.1.3. After installation and before putting into service, all pipework including fittings, valves shall be thoroughly cleaned internally.

2.8.2. Painting and Identification

2.8.2.1. All pumping equipment shall be factory painted according to the manufacturer's recommendations.

2.8.2.2. All thermoplastic pipes, fittings, valves, etc., exposed directly to sunlight shall be painted with water based exterior-grade latex paint.

2.8.2.3. All surfaces to be painted shall be first thoroughly cleaned to remove dirt, scales, grease spots etc. Surface shall be completely dry before painting.

2.8.2.4. All surfaces shall have minimum one coat primer and two coats finish subject to S.O.'s approval.

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2.8.3. Pipework Identification

2.8.3.1. All pipes installed shall be identified in accordance with their relevant standards.

2.8.3.2. Directional arrows shall be painted on the pipework in the plant rooms, tank room and vertical risers. Lettering and the direction of flow must be indicated by painting a black / white arrow on to the pipelines at appropriate intervals. These arrows shall be 3" long on pipes up to 50mm (2") diameter, 150mm (6") long for pipes over 50mm (2") diameter.

2.8.4. Labels for Valves and Controls

2.8.4.1. All control valves, relays, switches and instrumentation shall be identified by black or white engraved laminated plastic labels, securely attached to the item by means of non-corrodible screws or rivet or any other method approved by the S.O., or when such item is installed on or within panels or cubicle, the labels shall be located immediately below the item.

3. Sanitary Plumbing System

3.1. Rules and Regulation By Law

3.1.1. All the workmanship and material for the supply, installation, testing, adjusting, balancing & commissioning of all system and accessories shall comply with the following rules and regulation requirements:

3.1.1.1. Drainage, Sanitation and Sanitary Plumbing By-Laws of the Street, Drainage and Building Act. 1974;

3.1.1.2. Gravity Drainage Systems Inside Buildings - Sanitary Pipework, Layout and Calculation, BS EN 12056 Part 1, Part 2 & Part 5;

3.1.1.3. Code of Practice for Sanitary System in Buildings, MS 1402:2006;

3.1.1.4. Local Authority By-Laws in force at time of installation; and

3.1.1.5. Other relevant rules and regulations.

3.2. Material Standard

3.2.1. Pipework for sanitary plumbing shall be to the dimensions shown in the drawings or as specified hereinafter and shall be complete with all fittings, brackets, supports and other accessories to complete the installation.

3.2.2. All pipes, fittings and equipment used for sanitary plumbing and installation shall be of the type and make approved by SPAN and as mentioned in the drawings.

3.2.3. The standards stated in this specification shall comply with their latest edition issued or relevant standards approved by SIRIM.

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3.2.4. The following standards in their latest edition as shown in **Table X7** shall apply:

TABLE X7. Standard for Different Types of Sanitary Pipe

Item	Standard
Unplasticized polyvinyl chloride (uPVC)	MS 1063, BS EN 1329-1, BS 4514, MS 628, BS EN ISO 1452-2:2009
Unplasticized polyvinyl chloride (uPVC) (Underground)	MS 979: Part 1 (∅100mm & ∅155mm) MS 979: Part 2 (∅200mm and above) or BS EN 1401-1, MS 1085
Poly propylene (PP)	MS ISO 7671:2012
Cast Iron Pipes	BS 416 for heavy grade pipes BS 437 for spigot / socket drain
Galvanized Iron	BS EN 10255 “Heavy”

3.3. Definition of Sanitary Pipe

3.3.1. Soil (Black Water) Pipe

3.3.1.1. Pipes attached to a building and designed to convey sewage or waste matter from any water closet (W.C) or urinal.

3.3.2. Waste (Grey Water) Pipe

3.3.2.1. A separate waste pipe shall be provided for the following:

(i) Dirty water from baths, basins, wash troughs, ablution, floor trap and other waste containing a small proportion of soap and /or dirt; and

(ii) Greasy water from kitchen sinks and equipment where grease traps or interceptors are required.

3.4. Sanitary Discharge System

3.4.1. All main stacks shall be minimum 100mm diameter or subject to S.O.’s approval.

3.4.2. The discharge system can be classified as follows:

3.4.2.1. Single Stack System

(i) In this system, all appliances discharge separately into a single discharge stack. All traps are unventilated and those on pipes 50mm and below must have 75mm water seals (trap). The stack is directly connected to the manhole.

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3.4.2.2. Fully Ventilated System

(i) All appliances are directly discharged to a common stack and essential features of this system are the provision of 75mm deep seal traps on baths, basins and sinks as well as the provision of a ventilating pipe to which every appliance connected.

3.4.2.3. The Modified Single Stack System

(i) The modified single stack system basically similar to the single stack system, with the exception that the W.C.'s only are ventilated direct to the main ventilating pipe.

(ii) The depth of the water seal to all appliances, except W.C.'s shall 75mm.

(iii) The depth of the water seal to W.C.'s shall be 50mm to the main discharge stack.

3.4.2.4. Ventilated System

(i) The discharge from W.C.'s, urinal and other soil appliances are conveyed via a main discharge soil (soil pipe) and finally to the sewer line.

(ii) A separate waste pipe conveys the discharge from waste basins, baths, sinks to the waste water drain through a trapped gully.

3.5. Pipework Material

3.5.1. UPVC Soil, Waste and Vent Pipes

3.5.1.1. All pipes shall run in accordance with layout sizes shown in the approved drawings. The pipes shall be provided, fixed and connected to fittings and sanitary installation complete with all necessary bends, tees, sockets, branches, offsets, inspection pieces, etc. Pipes shall be joined with approved solvent in accordance with the manufacturer's instructions.

3.5.1.2. Pipes, fittings and the system of unplasticized polyvinyl chloride (uPVC) in the field of soil, ventilation and waste discharge (low and high temperature) inside buildings, for soil and waste discharge systems buried in ground within the building structure and for soil, ventilation and waste discharge for both inside buildings and buried in building structure shall complied to MS 1063 or BS EN 1329 Part 1 or BS 4514 (size ∅82mm only).

3.5.1.3. Pipes, fittings and the system of unplasticized polyvinyl chloride (uPVC) piping systems shall comply to MS 1063; or BS EN 1329: Part 1; or BS 4514 (size ∅82mm only)

(i) For soil, ventilation and waste discharge (low and high temperature) inside buildings (marked with "B").

(ii) For soil and waste discharge systems buried in ground within the building structure (marked with "D").

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(iii) For soil, ventilation and waste discharge for both inside buildings and buried in building structure (marked with "BD").

3.5.1.4. The pipes and the fittings shall be coloured through the wall. The colour of pipes and fittings shall be as follows:

(i) "B" code – white

(ii) "D" code – brown

(iii) "BD" code - white

3.5.1.5. All underground sewerage pipe and fittings of ∅ 4" (100mm) diameter and ∅ 6" (150mm) diameter shall be of uPVC Brown complied to MS 979: Part 1; and for size ∅ 200mm and above complied to MS 979: Part 2 or BS EN 1401 Part 1 or BS 4660 (fitting of nominal size 110mm and 160mm only).

3.5.1.6. Main soil, waste and vent pipes shall be carried up to the roof level and protected by vent cowl and weather apron as per approved drawing.

3.5.1.7. All pipes shall be fixed in straight runs and all horizontal runs shall be laid to gradients in accordance with BS EN 12056 Part 2 and in any event not less than 18mm/m unless otherwise instructed.

3.5.1.8. UPVC Waste, Vent and Soil System (Inside building, buried in building structure and buried in ground within building structure)

(i) The uPVC pipes, fittings and system shall comply in all respects with the requirements of MS 1063 or other relevant standard certified by SIRIM / SPAN.

(ii) Pipes shall be supplied in plain-ended lengths and the minimum acceptable with thickness of pipe and fittings as shown in **Table X8**:

TABLE X8. Minimum Acceptable Thickness of UPVC Waste Pipe and Fittings

Nominal Sizes (mm)	Wall Thickness (mm)		
	Pipes (mm)	Fittings (mm)	Sockets (mm)
32	3.0	3.0	2.0
40	3.0	3.0	2.0
50	3.0	3.0	2.0
63	3.0	3.0	2.0
75	3.0	3.0	2.0
80	3.0	3.0	2.3
82	3.0	3.0	2.3
90	3.0	3.0	2.3
100	3.0	3.0	2.3
110	3.2	3.2	2.4
125	3.2	3.2	2.4
140	3.2	3.2 / 3.5*	2.4 / 2.6*

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160	3.2	3.2 / 4.0*	2.4 / 3.0*
180	3.6 / 4.4*	3.6 / 4.4*	2.7 / 3.3*
200	3.9 / 4.9*	3.9 / 4.9*	2.9 / 3.7*
250	4.9 / 6.2*	4.9 / 6.2*	3.7 / 4.7*
315	6.2 / 7.7*	6.2 / 7.7*	4.7 / 5.8*

Note * For soil and waste discharge systems buried in ground within the building structure and for soil, ventilation and waste discharge for both inside buildings and buried in building structure.

(iii) The method of jointing to be employed shall be that solvent welding using the manufacturer's approved cement. Seal ring fittings shall be used where necessary to accommodate thermal movement or the sockets of standard fittings shall be converted to seal ring adaptor.

(iv) Access shall be provided where necessary either by means of an integrally moulded door in an access fitting with an externally fitted rubber seal and secured with two-piece clamp type door fitted into the pipe run.

3.5.1.9. Underground uPVC Sewerage Pipes and Fittings

(i) The underground uPVC sewerage pipes and fittings shall comply in all respects with the requirement of MS 979: Part 1 (∅100mm and ∅155mm) and MS 979: Part 2 (∅200mm and above) or other relevant standard certified by SIRIM / SPAN.

(ii) Pipes shall be supplied in plain-ended lengths.

(iii) The minimum acceptable wall thickness of pipes and fittings shall be as shown in **Table X9**:

TABLE X9. Minimum Acceptable Thickness of Underground UPVC Pipe and Fittings

Nominal Sizes (mm)	Wall Thickness (mm)		
	Pipes	Fittings	Junctions
100	3.2	3.4	3.4
155	4.1	4.1	4.1
200	4.9	4.9	4.9
250	6.1	6.1	6.1

(iv) The method of jointing to be employed shall be strictly to manufacturer's recommendation.

3.5.1.10. Expansion Joints (Expansion Coupling for uPVC Pipes)

(i) Where pipework is constructed using solvent welded joints, expansion joints for uPVC pipes shall be carried out in accordance with the manufacturer's recommendations.

(ii) Expansion joints shall be provided at a maximum of 4 meter centre for soil, 2 meter centre for waste and between fixed points over 1 meter centre.

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3.5.1.11. Cast Iron/Galvanized Iron Pipe

(i) Where shown or stated in the drawing, 100mm diameter cast iron soil and vent pipes internally coated with anti-corrosive bituminous coating shall be provided, fixed and connected to the fittings and sanitary system.

(ii) All main and branch soil pipe and fittings shall be cast iron to BS 416 Heavy grade coated with an approved tar-based composition.

(iii) Main and branch vent pipe and fittings shall be cast iron to BS 416 Heavy grade factory coated with an approved certificate tar-based composition.

(iv) Branch vent pipe of 2" (50mm) diameter and below shall be galvanized to BS 10255: Heavy grade.

(v) Cast iron pipes shall be jointed with an approved certificate resin with molten lead and well-sealed. All necessary bends, tees, sockets, branches, offsets, inspection pieces, shall be provided where necessary.

3.5.1.12. Other Material

(i) All material not specifically mentioned above shall conform to the latest edition of their respective British Standard and/or Malaysian Standard or equivalent specification and shall be to the approval of SIRIM / SPAN.

3.6. Workmanship & Pipe Support

3.6.1. The installation, method of jointing and fixing shall comply in all respects to the manufacturer's recommendation and comply with latest relevant standards.

3.6.2. All soil, waste and vent pipes, pipe hooks clamps and clips shall be placed tight up against the head or underside of the collar. Extension clips shall be used where it is necessary to run the pipe clear of the wall.

3.6.3. Use only fixings that are compatible with the materials and system of pipework. Do not exceed the maximum spacing between fixings for sanitary pipes given below.

3.6.4. Maximum intervals between pipe supports shall be:

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3.6.4.1. Horizontal Position

TABLE X10. Recommended Maximum Spacing of Support for Horizontal Sanitary Pipe

Pipe Size (mm)	Recommended Maximum Spacing of Support (m)	
	Non-metal	Metal
32	0.5	2.1
40	0.5	2.4
50	0.6	2.7
80	1.0	3.0
100	1.0	3.0
150	1.2	NA

Source: British Standards Institute. (2000). BS EN 12056-2: Gravity drainage systems inside buildings. Sanitary pipework, layout and calculation

3.6.4.2. Vertical Position

TABLE X11. Recommended Maximum Spacing of Support for Vertical Sanitary Pipe

Pipe Size (mm)	Recommended Maximum Spacing of Support (m)	
	Non-metal	Metal
32	1.2	3.7
40	1.2	3.7
50	1.2	4.6
80	2.0	4.6
100	2.0	5.5
150	2.0	NA

Source: British Standards Institute. (2000). BS EN 12056-2: Gravity drainage systems inside buildings. Sanitary pipework, layout and calculation

3.6.5. The work shall be inspected and tested during installation at agreed stages as determined by the S.O..

3.6.6. All work, which will be concealed, shall be tested before it is finally enclosed.

3.6.7. A final test shall be made upon completion for soundness and performance in accordance with BS EN 12056-2: Gravity Drainage Systems Inside Buildings: Sanitary Pipework, Layout and Calculation or MS 1402 – Code of Practice for Sanitary System in Buildings.

3.7. Ventilating Pipe

3.7.1. Main ventilating stack pipe shall be discharge to the open air or connected to the discharge stack above the spillover level of the highest

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appliance on the stack. (Soil pipe or single stack system shall in all cases be vented by upward extension of the soil or combined pipe).

3.7.2. The upward vent pipe shall be straight and free from any bends or angles except where unavoidable. It shall be extended through the roof to the required height with the open end protected by means of copper wire globe or approved cowl. The distance of outlet is not less than 900mm above the head of any window or other opening into a building and within a horizontal distance of 3m.

3.7.3. All vent and branch vent pipes shall be graded 18mm/m (minimum 1°) to drip back to the soil or waste pipe by gravity. A branch vent must rise vertically or at an angle of not more than 45˚ from the vertical to a point 150mm above the fixture it is venting before running horizontally.

3.7.4. Main ventilating pipe shall not be less than 50mm dia. or 2/3 of the diameter of the main soil/waste pipe whichever the larger diameter is.

3.8. Anti-Syphonage

3.8.1. An anti-syphonage pipe shall be carried up from each fixture to the branch or main vent pipe above the level of the fixture to prevent the loss of the water seal in traps.

3.8.2. No fixture shall be connected to the soil, waste or combined pipe at any point between the trap and the anti-syphonage pipe, which it serves.

3.8.3. In special cases, anti-syphonage vent pipe could be connected to the waste, combined pipe or soil pipe on the opposite side of the water seal to the fixture at a point, which should be between 75mm to 300mm from the crown of the trap. In the case of bath and closet pan, the vent pipe shall not exceed 1.2m from the crown of the trap.

3.8.4. Before connecting to the main vent pipe all anti-syphonage pipework shall rise above the floor level of the sanitary appliances.

3.8.5. Anti-syphonage pipework shall not be less than 32mm diameter.

3.9. Traps

3.9.1. Each sanitary appliance shall be fitted with a trap either as an integral part of the appliance or attached to and immediately beneath its outlet. All traps shall be accessible and provided with adequate facility for cleaning. The internal surface of the trap shall be smooth throughout. Generally, the trap shall be of the same material as the soil/waste pipe.

3.10. Floor Traps

3.10.1. Floor trap in all areas, unless otherwise specified, shall be 100mm diameter similar materials to the pipe traps complete with grating and self-tapping screw.

3.11. Testing Tees

3.11.1. Testing tees shall be located on the vertical stacks between floors to enable each floor to be tested independently as specified hereafter. Upon completion of testing, the tees shall be sealed up with lead joint or solvent joint where uPVC pipe is specified.

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3.12. Grease Interceptors/Waste Drain Trap (Where Specified)

3.12.1. The body of the interceptor and baffles shall be made of Stainless Steel Grade 316. The baffles shall be of removable type.

3.12.2. Grease interceptors shall be certified by relevant authority. It shall be of floor mounted or fully recessed manual type complete with extension collar or extension piece to suit the structural requirement where required.

3.13. Reducing Fitting

3.13.1. Wherever reduction in pipe sizes takes place, reducing fitting shall be used.

3.14. Cleaning Eyes and Inspection Opening

3.14.1. To provide access for the proper inspection, cleaning and testing of the entire length of pipe, inspection openings and cleaning eyes shall be provided on all soil, waste and combined pipes at:

3.14.1.1. Each change of direction of piping; and

3.14.1.2. Based on each soil, waste or vent stack.

3.15. Temporary Closing of Pipeworks (Ingress of Contaminants)

3.15.1. As soon as pipes have been installed, all openings shall be capped or plugged to prevent the entrance of materials that would obstruct or choke the pipes. It is the responsibility of the Contractor to ensure that caps and plugs are left in place until removal is necessary for completion of installation.

3.16. Inspection Chamber / Gully Trap

3.16.1. The works shall include the construction of all inspection chambers / gully trap generally as shown in the civil/tender/working drawings and specification. Inspection chamber and gully trap shall not be located in clinical areas, clean areas or any other areas that will affect the cleanliness, functionality and operability of the spaces.

3.17. Underground/Buried Pipe (For Sanitary)

3.17.1. All underground/buried pipes shall be carefully laid on beddings free from rocks, stones and other broken materials. Unless otherwise stated, all direct buried pipework shall be installed in open trench.

3.17.2. Excavation and Trenching for Piping

3.17.2.1. The Contractor shall perform all excavation to the depths indicated in the drawings or as specified in conformance with local authority requirements.

3.17.2.2. All excess excavation materials shall be removed from the site. The contractor shall prevent surface water from flowing into trenches or the excavations by using sheeting and shoring method thus ensuring the safety of personnel. Any water accumulating therein shall be removed.

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3.17.3. Trench Excavation

3.17.3.1. Trenches shall be of necessary width for the proper laying of the pipe, and the banks shall be as nearly vertical as practicable. The bottoms of the trenches shall be accurately graded to provide uniform bearing and supports for each section of the pipe on undisturbed soil at every point along its entire length, or may be over excavated 100mm below depth indicated and filled with well tamped salt free coarse sand or other approved materials. Layers or brick, concrete base and angle blocks shall be used support for the laying of piping.

TABLE X12. Trenches Width for Different Pipe Diameter

Pipe Diameter Inches	Trenches Width Inches
3 and under	15 - 24
4 - 6	18 - 28
8	20- 30

3.17.4. Depth of Trench's Cover

3.17.4.1. The minimum depth of trenches covered with concrete slab shall be 450mm from top of pipe to finished ground level and trenches without concrete slab shall be 750mm.

3.17.5. Protection of Existing Utilities

3.17.5.1. Existing utility lines or other completed utility lines if damaged by the Contractor shall be repaired at his own expense.

3.17.5.2. When connecting to existing utility lines, no section of the existing piping shall be abandoned unless it is specifically indicated on the drawings.

3.17.6. Backfilling of Trenches

3.17.6.1. Trenches shall not be backfilled until all required pressure and other tests have been performed. Backfill and compaction shall comply to Civil & Structural Engineer's requirements.

4. Testing, Adjusting, Balancing and Commissioning (TABC)

4.1. General

4.1.1. All work to be performed shall be in accordance with this specification and the commercial practice.

4.2. Internal Cold Water Plumbing System

4.2.1. The Contractor shall allow for the cost of all tests to the plumbing system to the satisfaction of the S.O.. The completed plumbing system shall be tested for hydraulic performance.

4.2.2. The cost for providing all testing, adjusting, balancing and commissioning as well as calibrated measuring equipment, all materials and consumables such as fuel, electricity, water etc. shall be borne by the Contractor.

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4.2.3. All pipework which is to be encased or concealed shall be tested, approved and recorded before it is finally enclosed.

4.2.4. The Contractor shall give the S.O. a minimum of full seven (7) days notice of his readiness to carry out acceptance tests, completed testing sheet and schedule for S.O.'s approval.

4.2.5. Before the commencement of acceptance tests, the Contractor shall have completed all of his preliminary testing and adjusted the equipment to its proper running order.

4.2.6. During the testing period, no modification, adjustment or other work on the installation shall be carried out without the permission of the S.O.. Should there be any contravention of this requirement, the results of all tests completed may be rejected and a retest shall be carried out.

4.2.7. No acceptance test shall be carried out except in the presence of the S.O., the State Water Authority's representative (if required) and the Contractor or their respective representative appointed for the purpose.

4.2.8. If the installation fails to perform during testing in accordance with the requirements of the Specification or acceptance criteria, the S.O. may reject the whole or any part of it. The Contractor shall bear all costs and expenses for all retests and remedial works.

4.2.9. Testing of Internal Pipework

4.2.9.1. Pressure Test

(i) Internal reticulation and main distribution pipes shall be slowly and carefully charged with water in order that all air is expelled from the system. The system shall be allowed to stand full for 24 hours. An air relief valve should be provided at the highest point in the system to bleed off any air that is present.

(ii) A test pressure of 1.5 times the maximum working pressure shall be applied for 24 hours.

(iii) No pipework shall be covered or concealed until it has been tested to the satisfaction of the S.O. or his representatives. Where arrangement of work makes necessary, the piping system shall be tested by sections to prove joints between sections.

(iv) The completed system shall be inspected for leaks during the test. Should any signs of leakage occur in the tanks or pipework, their positions shall be marked and the Contractor shall carry out remedial measures. The pressure tests procedure shall be repeated until the whole water system passes. The pipe installation is considered to have passed the pressure test if no visible leak and no drop in the pressure reading are observed during the test.

(v) All equipment not designed to withstand test pressure shall be disconnected during test, but shall be reconnected and tested under actual working pressure.

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(vi) The permanently installed pumps shall not be used for pressure testing of the water system.

4.2.9.2. Flow Test

(i) During the flow test, all pumps shall be run with all valves fully open and the following data shall be recorded:

a) Flow at pump outlet into storage tank

b) Head at pump discharge outlet

c) Current consumed

d) Voltage

4.2.9.3. Flushing of Cold Water System

(i) After completion of the pressure tests to the satisfaction of the S.O., the whole piping and water storage system shall be thoroughly flushed with potable water before they are put into use.

(ii) The Contractor shall ensure the system is fit for purpose and the water in the pipeline is safe for consumption after flushing.

(iii) The Contractor, at his own expense, shall use water supply for cleaning and flushing out of all the plumbing system that he had installed as per Contract.

(iv) Control valves and all equipment liable to damage, shall be disconnected before cleaning out. All strainers shall be thoroughly cleaned out during and at the completion of the clean out operation.

4.2.9.4. Balancing

(i) Prior to balancing, all isolation/gate valves shall be checked to be in the fully open position for the pumping system.

4.2.9.5. Records

(i) All pressure, flow and balancing tests shall be recorded by Contractor and certified by S.O. or S.O.'s representatives.

(ii) The S.O. reserves the rights to order a re-test if the Contractor fail to produce authentic test record.

4.2.10. Testing of Storage Water Tank

4.2.10.1. After flushing, the tank shall be filled with water to maximum operating capacity level and the level of water surface shall be carefully recorded. The tank shall be accepted as satisfactory if after a period of 48 hours there is:

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(i) No measured reduction in water level, due allowance being made for evaporation from the surface of water;

(ii) No visible sign of leakage from any part of tank;

(iii) No deformation of any part of the surface.

4.2.10.2. If the test results do not satisfy the above conditions of test, the Contractor shall locate and rectify all defects and leakages and the test shall be repeated. The Contractor shall bear all costs and expenses for all tests and remedial works.

4.2.11. Testing of Pump (If Applicable)

4.2.11.1. All pumps and motors shall be checked for flow rates, pressures and RPM. The input signal device sensors and controllers shall be checked to ensure the pumps cut-in and cut-out at predetermined water levels.

4.2.12. Post Occupancy Testing, Adjusting, Balancing and Commissioning

4.2.12.1. Further adjustments to the system controls such as re-balancing, re-tuning, re-checking and re-adjustment etc. shall be made whilst the building is occupied and the installation is in use during the defects liability period. The cost of the adjustment shall be included in the tender.

4.3. Sanitary Plumbing System

4.3.1. The S.O. reserves the right to request for water, air or smoke tests as well as for hydraulic performance to be performed by the Contractor at his expense including the furnishing of the necessary equipment. The testing procedure shall be in accordance with MS 1402: Part 3.

4.3.2. Water Test

4.3.2.1. There is no justification for a water flood test to be applied to the whole of the plumbing system. The part of the system mainly at risk is that below the lowest sanitary appliances and this may be tested by inserting a test plug in the lower end of the pipe and filling the pipe with water up to the flood level of the lowest sanitary appliances, provided that the static head does not exceed 6 m. This is a visual inspection.

4.3.3. Air Test

4.3.3.1. Air test may be performed by inserting expanding rubber testing plugs in the lower and upper ends of the main soil pipe and main ventilating pipes and sealing the plugs with water necessary. The water seals of all sanitary appliances shall be fully charged.

4.3.3.2. The testing plug at the upper end of the ventilation pipe should be fitted with a tee-piece with cock on each branch. A flexible tube manometer should be fixed to one branch while air pressure is being introduced into the system through the other branch until the desired pressure is indicated on the manometer scale.

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4.3.3.3. The air test applied shall be 3.8 mbar (38mm water gauge) in period not less than 3 minutes without loss.

4.3.4. Smoke Test

4.3.4.1. Smoke can be introduced into the system by a small machine under the source pressure as for the air test. The whole system shall be filled with smoke before the openings are sealed with plugs.

4.3.4.2. The pressure on the smoke shall be maintained for three (3) minutes after the last opening has been sealed.

4.3.4.3. Smoke test is not recommended if UPVC pipe material is adopted. Rubber jointing components can also be adversely affected.

4.3.4.4. Smoke testing shall normally only be used instead of air test when an undetectable leak in the system occurs.

4.3.5. Hydraulic Performance

4.3.5.1. Hydraulic performance discharge tests shall be made from all appliances singly and correctively. Obstruction in any of the pipe lines shall be traced and the whole system examined for proper hydraulic performance including the retention of an adequate water seal in each trap.

5. Comprehensive Service and Maintenance for Internal Cold Water and Sanitary Plumbing System

5.1. General

All work to be performed shall be in accordance with this specification and the commercial practice.

5.2. Workmanship and Materials

5.2.1. The work described in this specification shall be performed by skilful workmen in the service, maintenance and repair of the internal cold water and sanitary plumbing system and shall be executed in accordance with the good engineering practice.

5.2.2. All materials to be supplied in connection with work under this Specification shall be new, unused, genuine, and shall generally be the best quality in manufacturing and performance.

5.3. Supervision

5.3.1. The Contractor shall have a competent Plumber in charge of the service, maintenance and repair work to be carried out under this Specification and shall be in the direct employ of the Contractor, and acceptable to the S.O..

5.3.2. The Contractor shall have in his direct employ workmen who are skilled in the service, maintenance and repair of internal cold water and sanitary plumbing system.

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5.4. Scope of Work

5.4.1. The work covered under this Specification is to service and maintain all equipment comprising the complete internal cold water and sanitary plumbing system strictly accordance with the servicing and maintenance schedule as set out in sub-section 5.6.

5.4.2. The Contractor shall rectify any defects in any parts of the complete internal cold water and sanitary plumbing system observed during routine inspection and service, and shall repair such defects if required to do so by the S.O..

5.4.3. The Contractor shall also provide emergency repair service at any time if required to do so by the S.O..

5.5. Consumable Materials

5.5.1. The Contractor shall include in his service and maintenance contract for the supply of the following consumable materials as and when required.

5.5.1.1. All oils and greases required for the lubrication of motor bearing, packing, pivots and other moving parts.

5.5.1.2. All cotton waste, soap detergent and other cleaning materials required for cleaning purpose.

5.5.1.3. All consumable filter elements.

5.5.1.4. All tap washers.

5.5.1.5. All electric contact points required to replace worn electric contact points in switchgears, electric control gears and electric relays.

5.5.1.6. All electric fuses required to replace blown or defective fuses.

5.5.1.7. All indicator lamps required to replace blown lamps.

5.5.2. The cost of these consumable materials shall not be charged for separately, but shall be included in the schedule quoted by the Contractor for the service and maintenance of the complete internal cold water and sanitary plumbing system.

5.6. Servicing and Maintenance Schedule

5.6.1. The Contractor shall inspect and service all equipment comprising the complete internal cold water and sanitary plumbing system periodically as scheduled in the approved check list except where otherwise directed by the S.O..

5.6.2. The Contractor shall report in writing to the S.O. any defect/s observed in any part or parts of the complete internal cold water and sanitary plumbing system. The technical report shall state the causes of the defects observed, and shall include the estimate of repairs required for non-consumable material or any part or equipment damaged by catastrophic event or vandalism.

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5.7. Check List (Monthly Report)

5.7.1. Pumps (If Applicable)

5.7.1.1. Check all seals, glands and pipe line for leakage.

5.7.1.2. Check all pump bearing and lubricate with oil or grease.

5.7.1.3. Check the alignment and condition of coupling.

5.7.1.4. Check all bolt and nut for tightness.

5.7.1.5. Clean pumps casing and shaft.

5.7.1.6. Check and record pump running pressure.

5.7.2. Electric Motor Pumps (If Applicable)

5.7.2.1. Check motor bearing and rewinding.

5.7.2.2. Check carbon brush and slip rings and clean as necessary.

5.7.2.3. Check and record motor running amperes, voltages and resistance of cable.

5.7.3. All Electrical Starters, Electrical Control Gears, and Ancillary Electrical Apparatus (If Applicable)

5.7.3.1. Clean and adjust all bearings, pivots and other moving parts as necessary.

5.7.3.2. Clean or renew electric contactors as necessary.

5.7.3.3. Renew electric fuse as necessary.

5.7.3.4. Check the performance of the complete pumping and associated equipment as necessary.

5.7.4. Cold Water Piping

5.7.4.1. Check water leakages in piping and rectify accordingly.

5.7.4.2. Check water leakages in valve and rectify accordingly.

5.7.4.3. Check excessive vibration of piping during pumping.

5.7.4.4. Clean strainer baskets.

5.7.4.5. Check all water taps for leakages and replace rubber washer as necessary.

5.7.4.6. Check ball float valves and adjust as necessary.

5.7.4.7. Check water level control indicator.

5.7.4.8. Check water leakage at any part of jointing of panel water tank.

5.7.5. Internal Sanitary Plumbing System

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5.7.5.1. Check access covers, caps and cleaning eyes.

5.7.5.2. Check any water leakage at any part of jointing of internal sanitary pipe system.

5.7.5.3. Check discharge pipe systems:

(i) It shall be kept in a clean and sound condition.

(ii) Any blockages shall be removed by using hand operated rods and capable passing through the system without damaging the internal surfaces of pipes and fittings.

5.8. Inspection and Records

5.8.1. Inspect and check all other equipment under this Contract, whether or not these are specifically mentioned in the check list.

5.8.2. The Contractor is responsible for the operation of the plant and equipment on correct methods of operating the plant and equipment and on the maintenance points to be watched.

5.8.3. Report in writing to the S.O. any defects observed in any part or parts of the complete internal cold water and sanitary plumbing system. The report shall state the cause/s of the defect/s observed and shall include an estimate of the cost of repairs required.

5.8.4. Service and maintenance records shall be properly updated and kept by Contractor or as instructed by S.O..

5.9. Sampling of Storage Water

5.9.1. The Contractor shall have deemed to have included the sampling and testing of water in storage tanks.

5.9.2. The Contractor shall be responsible for ensuring that water quality testing is regularly done on the cold or domestic water supply network to monitor the water quality provided to the end user against the most current revision of the State Water Authority guidelines for domestic and drinking water.

5.9.3. Samples for testing to be performed every six months shall include:

5.9.3.1. Chemical Analysis

5.9.3.2. Bacteriological Analysis

5.9.4. In the event the cold or domestic water quality does not meet the most recent revision of the State Water Authority guidelines for domestic and drinking water (the most current revision at the time of sampling), the Contractor shall immediately notify the S.O. and recommend appropriate action for approval.

5.9.5. The above mentioned tests shall be performed again until the approval of S.O. is obtained.

5.10. Repairs

5.10.1. The Contractor shall repair any defects in the complete internal cold water and sanitary plumbing system on the instruction of the S.O..

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5.10.2. All repairs on the complete internal cold water and sanitary plumbing system shall be guaranteed by the Contractor against defects in workmanship and materials for a period of one year to take effect from date of completion of the repairs. During the guarantee period, the Contractor shall rectify defects in repairs carried out by him with no additional charge to the government.

5.11. Service and Maintenance Records

5.11.1. The Contractor shall provide a service and maintenance record book for the complete internal cold water and sanitary plumbing system being serviced and maintained by the Contractor. This record book shall be kept in the plant or maintenance room of internal cold water and sanitary plumbing system being serviced and maintained, and brief details of all services, maintenance and repairs carried out. The address and telephone number of the Contractor's personnel and person in charge shall also be recorded into this record book to facilitate emergency service call.

5.11.2. The Contractor shall also keep an accurate detailed record in duplicate of all service, maintenance and repair work carried out by him on the complete internal cold water and sanitary plumbing system as well as ancillary equipment. This record shall be in the form of a Maintenance/Repair Sheet, and shall be countersigned by the S.O. each time the internal cold water and sanitary plumbing system as well as ancillary equipment is attended to by the Contractor.

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KETUA PENGARAH KERJA RAYA

DIRECTOR-GENERAL OF PUBLIC WORKS

Rujukan: JKR.KPKR:121.010/05 Jld. 36 (9)

Tarikh : 23 Oktober 2023

Semua Pengarah Kanan/ Pengarah Cawangan Ibu Pejabat JKR

Semua Pengarah Kerja Raya Negeri

Semua Pengarah Kerja Raya Wilayah Persekutuan

Semua Pengarah Pembinaan

Pengarah JKR KESEDAR

Pengarah JKR KETENGAH

Semua Jurutera Daerah

SURAT ARAHAN KPKR BIL. 23/2023

PINDAAN NO.2 KEPADA SPESIFIKASI PIAWAI UNTUK KERJA BANGUNAN 2020 (*STANDARD SPECIFICATION FOR BUILDING WORKS 2020*)

1.0 TUJUAN

1.1 Surat Arahan ini bertujuan untuk memaklumkan mengenai pindaan kepada dokumen Spesifikasi Piawai Untuk Kerja Bangunan 2020 (*Standard Specification for Building Works 2020*).

1.2 Surat Arahan ini dikeluarkan adalah khusus untuk membuat pindaan kepada seksyen-seksyen di bawah sahaja:

Jabatan Kerja Raya Malaysia
Public Works Department Malaysia
Aras 33, Menara Kerja Raya, Ibu Pejabat JKR Malaysia, Jalan Sultan Salahuddin, 50480 Kuala Lumpur
Tel: 03-2618 8421 Faks: 03-2618 8799 https://www.jkr.gov.my

CERTIFIED TO ISO 9001:2015 CERT. NO.: QMS 03597
CERTIFIED TO ISO 14001:2015 CERT. NO.: EMS 00227
CERTIFIED TO ISO 45001:2018 CERT. NO.: OHS 00604
CERTIFIED TO ISO 50001:2018 CERT. NO.: EnMS 00111
CERTIFIED TO ISO 37001:2016 CERT. NO.: 00249

1.2.1. ***Section A : Preliminaries and General Conditions***

1.2.2. ***Section C : Foundation & Works Below Lowest Floor Level***

1.2.3. ***Section E : Wall System***

1.2.4. ***Section F : Sewerage***

1.2.5. ***Section J : Structural Steel and Metalworks***

1.2.6. ***Section L : Water Reticulation***

1.2.7. ***Section P : Roads and Hardstanding***

1.2.8. ***Section S : Drainage***

2.0 LATAR BELAKANG

2.1 Pindaan ini telah dibentangkan dan diluluskan dalam Mesyuarat Pengurusan Tertinggi (MPT) JKR Malaysia Bil.4/2023 pada 5 Julai 2023. Pindaan ini perlu dibuat bagi mengambilkira keperluan semasa industri dan kaedah pembinaan terkini.

2.2 Dokumen Spesifikasi Piawai Untuk Kerja Bangunan 2020 (*Standard Specification for Building Works 2020*) telah dikeluarkan pada 11 Disember 2020, Pindaan Kepada Spesifikasi Piawai Kerja Bangunan (*Section A: Preliminaries and General Conditions*) yang telah dikeluarkan pada 27 April 2021 melalui Surat Arahan KPKR Bil.17/2021 dan Pindaan No.1 telah dikeluarkan pada 2 Mac 2022 melalui Surat Arahan KPKR Bil.5/2022. Walau bagaimanapun, terdapat pindaan yang perlu dibuat khususnya pada seksyen yang dinyatakan pada para 1.2.

3.0 KAEDAH PELAKSANAAN

3.1 Pindaan bagi seksyen berkaitan hendaklah dijadikan sebagai adendum (Pindaan No.2) dan dijilidkan bersama-sama dengan dokumen Spesifikasi Piawai Untuk Kerja Bangunan 2020 (*Standard Specification for Building Works 2020*) dan adendum (Pindaan No.1).

3.2 Kaedah pelaksanaan adalah seperti di **Lampiran 1**.

3.3 Pindaan Spesifikasi Piawai Untuk Kerja Bangunan 2020 (*Standard Specification For Building Works 2020*) ini boleh diakses melalui laman sesawang JKR (http://jpedia.jkr.gov.my) di bawah tajuk ***Wiki Specs>>*** **Cawangan Kontrak dan Ukur Bahan>> Spesifikasi Piawai Untuk Kerja-Kerja Bangunan 2020**.

4.0 KUAT KUASA

4.1 Surat Arahan ini hendaklah dibaca bersekali dengan Surat Arahan KPKR Bil. 28/2020 bertarikh 11 Disember 2020 dan Surat Arahan KPKR Bil. 5/2022 bertarikh 2 Mac 2022.

4.2 Surat Arahan ini berkuat kuasa pada tarikh surat ini ditandatangani dan akan disemak sekiranya terdapat arahan dasar terkini atau perkembangan baharu yang memerlukan kajian semula dan pengemaskinian.

4.3 Dengan berkuat kuasanya Surat Arahan ini, penggunaan Surat Arahan KPKR Bil.17/2021 bertarikh 27 April 2021 adalah **DIBATALKAN**.

Sekian, terima kasih.

"MALAYSIA MADANI"

"BERKHIDMAT UNTUK NEGARA"

(DATUK Ir. AHMAD REDZA BIN GHULAM RASOOL)

Rujukan: JKR.KPKR:121.010/05 Jld. 36 (9)

Tarikh : 23 Oktober 2023

s.k

- Timbalan Ketua Pengarah Kerja Raya (Sektor Pakar)
- Timbalan Ketua Pengarah Kerja Raya (Sektor Infra)
- Timbalan Ketua Pengarah Kerja Raya (Sektor Bangunan)
- Pengarah Cawangan Dasar dan Pengurusan Korporat

Ruj. Kami: JKR.KPKR:121.010/05 Jld. 36 (9)
Tarikh: 23 Oktober 2023

LAMPIRAN 1

SECTION	ASAL	PINDAAN NO.1	PINDAAN NO.2
	SAKPKR BIL.28/2020	***SAKPKR BIL.17/2021 & SAKPKR BIL.5/2022***	***SAKPKR BIL.23/2023***
A Preliminaries & General Conditions	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : A/1 – A/36 ***MANSUH***	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **01** Tarikh : **27 April 2021** Muka Surat : A/1 – A/36 ***MANSUH***	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **02** Tarikh : **5 Julai 2023** Muka Surat : A/1 – A/36 ***TERKINI***
B Excavation & Earthworks	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : B/1 – B/17 ***MANSUH***	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **01** Tarikh : **24 Disember 2021** Muka Surat : B/1 – B/17 ***TERKINI***	-Tidak Berkenaan-
C Foundation & Works Below Lowest Floor Level	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : C/1 – C/69 ***MANSUH***	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **01** Tarikh : **24 Disember 2021** Muka Surat : C/1 – C/69 ***MANSUH***	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **02** Tarikh : **5 Julai 2023** Muka Surat : C/1 – C/69 ***TERKINI***
D Concreting	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : D/1 – D/68 ***MANSUH***	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **01** Tarikh : **24 Disember 2021** Muka Surat : D/1 – D/64 ***TERKINI***	-Tidak Berkenaan-

LAMPIRAN 1 (sambungan)

SECTION	ASAL	PINDAAN NO.1	PINDAAN NO.2
	SAKPKR BIL.28/2020	***SAKPKR BIL.17/2021 & SAKPKR BIL.5/2022***	***SAKPKR BIL.23/2023***
E Wall System	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : E/1 – E/20 ***MANSUH***	-Tidak Berkenaan-	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **02** Tarikh : **5 Julai 2023** Muka Surat : E/1 – E/19 ***TERKINI***
F Sewerage	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : F/1 – F/12 ***MANSUH***	-Tidak Berkenaan-	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **02** Tarikh : **5 Julai 2023** Muka Surat : F/1 – F/13 ***TERKINI***
G Roofing	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : G/1 – G/11 ***KEKAL***	*-Tidak Berkenaan-*	-Tidak Berkenaan-
H Timber, Joinery And Ironmongery	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : H/1 – H/37 ***KEKAL***	*-Tidak Berkenaan-*	*-Tidak Berkenaan-*

LAMPIRAN 1 (sambungan)

SECTION	ASAL	PINDAAN NO.1	PINDAAN NO.2
	SAKPKR BIL.28/2020	***SAKPKR BIL.17/2021 & SAKPKR BIL.5/2022***	***SAKPKR BIL.23/2023***
I Ceiling	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : I/1 – I/12 ***KEKAL***	-Tidak Berkenaan-	-Tidak Berkenaan-
J Structural Steel And Metalworks	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : J/1 – J/9 ***MANSUH***	-Tidak Berkenaan-	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **02** Tarikh : **5 Julai 2023** Muka Surat : J/1 – J/7 ***TERKINI***
K Plastering, Paving, Tiling And Carpet	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : K/1 – K/20 ***KEKAL***	-Tidak Berkenaan-	-Tidak Berkenaan-
L Water Reticulation	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : L/1 – L/10 ***MANSUH***	-Tidak Berkenaan-	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **02** Tarikh : **5 Julai 2023** Muka Surat : L/1 – L/11 ***TERKINI***

LAMPIRAN 1 (sambungan)

SECTION	ASAL	PINDAAN NO.1	PINDAAN NO.2
	SAKPKR BIL.28/2020	***SAKPKR BIL.17/2021 & SAKPKR BIL.5/2022***	***SAKPKR BIL.23/2023***
M Rainwater Collection	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : M/1 – M/6 ***KEKAL***	-Tidak Berkenaan-	-Tidak Berkenaan-
N Glazing	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : N/1 – N/7 ***KEKAL***	-Tidak Berkenaan-	-Tidak Berkenaan-
O Painting	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : O/1 – O/10 ***KEKAL***	-Tidak Berkenaan-	-Tidak Berkenaan-
P Roads And Hardstanding	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : P/1 – P/11 ***MANSUH***	-Tidak Berkenaan-	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **02** Tarikh : **5 Julai 2023** Muka Surat : P/1 – P/12 ***TERKINI***

LAMPIRAN 1 (sambungan)

SECTION	ASAL	PINDAAN NO.1	PINDAAN NO.2
	SAKPKR BIL.28/2020	***SAKPKR BIL.17/2021 & SAKPKR BIL.5/2022***	***SAKPKR BIL.23/2023***
Q Fencing And Gates	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : Q/1 – Q/4 ***KEKAL***	-Tidak Berkenaan-	-Tidak Berkenaan-
R Landscaping And Turfing	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : R/1 – R/10 ***KEKAL***	-Tidak Berkenaan-	-Tidak Berkenaan-
S Drainage	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : S/1 – S/8 ***MANSUH***	-Tidak Berkenaan-	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **02** Tarikh : **5 Julai 2023** Muka Surat : S/1 – S/14 ***TERKINI***
T Signage	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : T/1 – T/4 ***KEKAL***	-Tidak Berkenaan-	-Tidak Berkenaan-

LAMPIRAN 1 (sambungan)

SECTION	ASAL	PINDAAN NO.1	PINDAAN NO.2
	SAKPKR BIL.28/2020	***SAKPKR BIL.17/2021 & SAKPKR BIL.5/2022***	***SAKPKR BIL.23/2023***
U Slope Stabilisation	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : U/1 – U/89 ***KEKAL***	-Tidak Berkenaan-	-Tidak Berkenaan-
V Ground Improvement	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : V/1 – V/58 ***MANSUH***	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **01** Tarikh : **24 Disember 2021** Muka Surat : V/1 – V/58 ***TERKINI***	-Tidak Berkenaan-
W Hydroseeding	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : W/1 – W/5 ***KEKAL***	-Tidak Berkenaan-	-Tidak Berkenaan-
X Internal Cold Water And Sanitary Plumbing System	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : X/1 – X/35 ***MANSUH***	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : **01** Tarikh : **24 Disember 2021** Muka Surat : X/1 – X/31 ***TERKINI***	-Tidak Berkenaan-

LAMPIRAN 1 (sambungan)

SECTION	ASAL	PINDAAN NO.1	PINDAAN NO.2
	SAKPKR BIL.28/2020	***SAKPKR BIL.17/2021 & SAKPKR BIL.5/2022***	***SAKPKR BIL.23/2023***
Sanitary Fitting	No.Dokumen: JKR20800-0226-20 No.Keluaran : 01 No.Pindaan : 00 Tarikh : 02 Januari 2020 Muka Surat : Y/1 – Y/5 ***KEKAL***	-Tidak Berkenaan-	-Tidak Berkenaan-

TABLE OF CONTENTS

SECTION A: PRELIMINARIES AND GENERAL CONDITIONS		PAGE
1.	Scope of Works	A/1
2.	Standards	A/1
3.	Contract Documents	A/2
4.	Adjoining Property	A/2
5.	Goods, Materials and Workmanship	A/3
6.	Use of Local Materials	A/3
7.	Sustainable Materials and Products	A/4
8.	Metrication	A/4
9.	Ordering	A/4
10.	Supply of Materials by Government	A/4
11.	Shop Drawings, Samples and Mock-ups	A/5
12.	Contractor's Plant	A/5
13.	Construction Plan	A/5
14.	Project Signboard	A/8
15.	Progress Photographs	A/8
16.	Sufficient Notice to Local Authorities/Utility Providers/Regulatory Bodies	A/9
17.	Access and Temporary Roads	A/9
18.	Temporary Diversion and Relocation of Existing Overhead and Services Underground	A/9
19.	Temporary Power and Water Supplies for the Works	A/9
20.	Site Security	A/10
21.	Care and Protection of Materials and Works	A/10
22.	Legislation and Regulations	A/10
23.	Erosion and Sedimentation Control (ESC)	A/10
24.	Access Roads and Maintenance of Existing Roads	A/12
25.	Control of Workmen, Plant and Machinery at Site	A/12
26.	Particulars of Employees	A/13
27.	Contractor's Temporary Accommodation and Facilities for Workmen	A/13
28.	Contractor's Office and Storage	A/13
29.	Office Accommodation for S.O.	A/14
30.	Telephone for S.O.	A/14
31.	Personal Protective Equipment for S.O.	A/14
32.	Office Equipment and Facilities for S.O.	A/15
33.	Material Testing Laboratory and Staff	A/15
34.	Survey Instruments and Personnel	A/16
35.	Safe Working Area	A/16
36.	Safety, Health and Welfare	A/16

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37. Sanitation A/18
38. Waste Management A/18
39. Environmental Protection Works A/19
40. Water and Air Quality, Noise and Vibration Control A/20
41. Nominated Sub-contractors A/22
42. Nominated Suppliers A/23
43. Coordination of Mechanical and Electrical Services A/23
44. Keeping the Site Tidy A/25
45. As-built Drawings A/25
46. Total Asset Management A/26
47. Site Investigation Works A/28
48. Clearing, Cleaning and Making Good on Completion A/28

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1. Scope of Works

1.1. The Works covered in this Contract comprise the provision by the Contractor at his own risk and cost of all materials, scaffolding, tools, plant, labour, transport, water, light and everything else necessary for the construction and completion of 1.……all to the approval of the S.O..

1.2. The Conditions of Contract for the Works, which is embodied in the Form of Contract (Form PWD 203/Form PWD 203A), shall be read in conjunction with this Specification. A copy of the Form of Contract is available for inspection on the Tender Table on any working day up to the time appointed for receiving tenders. If the tenderer considers that any of the clauses of the Contract involves expenses, he shall allow for the money value of such clauses in his Tender.

2. Standards

2.1. All Standards referred to in this Specification together with any addenda issued shall be deemed to be the editions current at the time of Tender. If the Malaysian Standard (MS) exists, which the S.O. deems to be equivalent to the British or other Standard specified, then the MS shall be followed. Other equivalent standards specifying superior material may be used with the approval of the S.O..

2.2. In the event of any discrepancy between the provision of this Specification and the provision within the relevant Standards or Codes of Practice (CP) as mentioned in this Specification, then the provision of this Specification shall take precedence.

2.3. The following references shall mean:

(i) AASHTO - The American Association of State Highway and Transportation Officials
(ii) ANSI - American National Standards Institute
(iii) API - American Petroleum Institute Specification
(iv) AS/NZS - Australian/New Zealand Standard
(v) ASTM - The American Society for Testing and Materials
(vi) AWWA - American Water Works Association
(vii) BS - British Standards Specification as issued by the British Standards House, London (the latest amendment)
(viii) CNS - China National Standard
(ix) CP - British Standard Code of Practice issued by the Council for Code of Practice in Great Britain (the latest amendment)
(x) DIN - Deutsche Industrie Norm (German Institute for Standardisation)
(xi) EN - European Standard which is a standard that has been adopted by one of the three recognized European Standardisation Organisations (ESOs), that is CEN (European Committee for Standardization), CENELEC (European Committee for Electrotechnical Standardisation) and ETSI (European Telecommunications Standards Institute)
(xii) JIS - Japanese Industrial Standard
(xiii) MS - Malaysian Standards as issued by the Standard & Industrial Research Institute of Malaysia (the latest amendment)
(xiv) APHA - American Public Health Association

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3. Contract Documents

3.1. The Contract Documents shall consist of:

3.1.1. PWD Form of Contract (for contract based on Specification and Drawings or for contract based on Quantities) and addendum to the Conditions of Contract;

3.1.2. Form of Tender;

3.1.3. Letter of Acceptance;

3.1.4. Special Provisions to the Conditions of Contract as listed in the PWD Form of Contract;

3.1.5. Contract Drawings;

3.1.6. Specifications and addendums;

3.1.7. Summary of Tender and Schedule of Rates (for contract based on Specifications and Drawings);

3.1.8. B.Q. (for contract based on Quantities); and

3.1.9. Any other relevant documents included therein.

3.2. The documents shall be taken as mutually explanatory of each other and in case of any discrepancy or inconsistency, the following rules shall apply:

3.2.1. The Conditions of Contract (PWD Form 203/ PWD Form 203A) shall take preference over all other documents.

3.2.2. Special Provisions to Conditions of Contract shall take preference over Conditions of Contract.

3.2.3. Addendum to Conditions of Contract shall take preference over Conditions of Contract.

3.2.4. In Drawings, large scale details shall take preference over small scale Drawings.

3.2.5. The Addendum Specification shall take preference over the Standard Specifications and Drawings.

3.2.6. Drawings shall take preference over Standard Specifications.

3.3. Any discrepancies shall be referred as soon as possible to the S.O. who shall decide which shall be followed.

4. Adjoining Property

Where the property adjoining the Site is in constant use by the Employer/adjoining owners and occupiers, the Contractor shall arrange and carry out the Works so as to cause minimum interference or interruption to the use of adjoining properties including

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roads, footpaths, other access and any existing services thereto. He shall comply with all instructions or directions given by the S.O. in these matters.

5. Goods, Materials and Workmanship

5.1. Materials and workmanship throughout the Works shall be in accordance with the Drawings and Specifications and to the approval of the S.O..

5.2. Where required, all works shall be executed by competent and skilled workers in the related field.

5.3. Wherever in this Specification any proprietary goods or materials are specified, goods or materials of alternative manufacture may be considered for acceptance provided they comply in all respect as regards to appearance and quality, and are approved by the S.O..

5.4. If, however, the Contractor has shown beyond reasonable doubt that the specified goods or materials cannot be obtained and the S.O. is satisfied with regard to the non-availability of the goods and materials, the benefit of cost savings, if any, resulting from the Contractor's proposal or substitution of goods or materials approved by the S.O., shall be deducted from the Contract Sum.

6. Use of Local Materials

6.1. The Contractor shall use locally manufactured materials and goods as listed in the 'Senarai Bahan/Barangan Binaan Tempatan' issued by IKRAM QA Services Sdn. Bhd. and/or 'Senarai Bahan/Barangan Buatan Tempatan' issued by SIRIM QA Services Sdn. Bhd., whichever is relevant. If the Contractor fails to comply with this requirement, a penalty shall be imposed and/or the materials supplied shall be rejected.

6.2. The locally manufactured materials and goods which are not listed aforesaid, may be permitted if the materials have been tested and certified by IKRAM QA Services Sdn. Bhd. and/or SIRIM QA Services Sdn. Bhd. whichever is relevant. If the testing cannot be carried out by IKRAM QA Services Sdn. Bhd. and/or SIRIM QA Services Sdn. Bhd., the Contractor may apply and, subject to the approval of the S.O., carry out the testing by other agencies.

6.3. Under no circumstances will the Contractor be permitted to incorporate or supply imported materials, plant, equipment, or other goods into the Works or forming part of the scope of the Works except those approved by the Government, prior to the execution of the Contract. The Contractor shall substitute any materials, plant, equipment, or other goods proposed to be imported but not approved by the Government, with suitable local materials, plant, equipment, or other goods, including making any necessary sub-sequential changes or adjustments to the design of the Works to accommodate such substitution, all to the concurrence of the S.O..

6.4. The Contractor shall ensure that the procurement of approved imported materials, plant, equipment, or other goods are obtained directly from the country of origin based on Free on Board (F.O.B) or other similar basis. The transportation and insurance of such imported materials, plant, equipment, or other goods from the country of origin to the Site shall be arranged by the Contractor through approved Government's Multi Modal Transport Operators (MTO). The Contractor shall allow in his tender all costs and time required in complying with the requirements of this

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sub-section including the cost required for the services provided by the MTO.

6.5. The Contractor shall submit documentary evidence of compliance with this sub-section to the S.O. within one (1) month from the date of each delivery to the Site of such materials, plant, equipment, vehicles or other goods.

7. Sustainable Materials and Products

7.1. Notwithstanding the materials and products shown on the Drawings or specified herewith, the Contractor is encouraged to propose, at no additional cost, alternative equivalent materials or "Green" products to be used in the Works, subject to the approval of the S.O., such as:

7.1.1. Environmentally friendly materials or "Green" products that are certified under the SIRIM Eco-Label certification or any labels under the Global Eco-Label Network (GEN) certification.

7.1.2. Product registered under MyHijau Mark Scheme.

7.1.3. Products self-declared "Green" by the manufacturer with certification from recognised independent certifying bodies and not a member of GEN.

7.2. The contractor shall refer to SIRIM/JKR Standard on Manual for Green Product Scoring System (GPSS) for additional information on sustainable materials and products.

8. Metrication

Unless otherwise specified hereinafter or shown on the Drawings, only materials of metric dimension shall be used for the Works. Materials of equivalent imperial dimension may only be used if the Contractor can satisfy the S.O. that the required materials are not available in metric dimension.

9. Ordering

The Contractor shall place his orders for specified materials at the earliest possible date after notification of acceptance of tender or at such times as may be specifically stated for any particular material.

10. Supply of Materials by Government

10.1. If the Contractor fails for any reason to supply any materials, which he has contracted to supply, or if he fails to supply any such materials in sufficient time to enable the Contract to be completed by the agreed date for completion, the Government may supply any portion, or all of such materials.

10.2. If the Government supplies such material, the cost in respect thereof to be borne by the Contractor shall be either the current market rates or the actual cost to the Government, whichever is greater, plus 5% on cost charges.

10.3. The cost to be borne by the Contractor, as detailed above, shall be deducted from any money due or to become due to the Contractor under this Contract and failing

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which such costs shall be recovered from the Performance Bond or as a debt due from the Contractor.

10.4. No action by the S.O. under this sub-section shall be deemed in any way to affect or modify the right of the Government to claim for damages in the event of the Contractor's failure to complete the Works by the agreed date of completion.

11. Shop Drawings, Samples and Mock-ups

11.1. The Contractor shall submit for approval relevant shop drawings as requested by the S.O..

11.2. The Contractor shall submit samples of materials or execute samples of workmanship for the S.O.'s approval, and for further samples as required until the samples submitted or executed are in accordance with this Specification.

11.3. The Contractor shall prepare sample installations as required to match specified works in all respects before proceeding with work.

11.4. Mock-up units approved and accepted by the S.O. shall be referred as the Standard of comparison for the work.

11.5. The Contractor shall submit for approval as requested by the S.O., manufacturer's specifications, installation instruction, general recommendation for the work, including certified laboratory test reports and other data required to show compliance with these specifications.

12. Contractor's Plant

12.1. The Contractor shall provide, erect, keep insured, maintain and remove on completion all requisite scaffolding, hoist, ladder, staging, tarpaulins, tools, vehicles, tackles and other plants and apparatus (excluding piling and pile testing equipment), as required by all trades as are necessary for the execution of the Works.

12.2. All mechanical plant used by the Contractor shall be of such type, size and capacity suitable to the type and nature of the Works and site conditions where the Works are to be executed.

12.3. The Contractor shall take note the required cranage for the erection and completion of precast components and to ensure that the said cranes are or will be available during the construction stages.

13. Construction Plan

13.1. Within fourteen (14) days after the receipt of the Letter of Acceptance, the Contractor shall submit to the S.O. for his approval the following:

13.1.1. Programme of Works

A detailed work programme using the Critical Path Method (CPM) including electronic and printed copies of all data. The programme shall represent the sequence and the dependencies of work and must represent the intended work sequence. The programme shall be

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presented in the form of Gantt chart and network diagrams indicating, among others the critical activities, interface dates, resources and cost required to complete the works within the Contract period.

The work programme shall be prepared, updated and revised as specified in the JKR Work Programme Guideline and as directed by the S.O.. The Contractor shall be required to update all information and maintain the planned programme weekly/monthly using the CPM or as instructed by the S.O..

The work programme shall be prepared and maintained by trained and qualified personnel. The Contractor shall submit relevant documents such as curriculum vitae and certificates of the said personnel to the S.O. for approval.

13.1.2. Method Statements

The Contractor shall also furnish in writing to the S.O. or S.O.'s Representatives particulars of the Contractor's method statements for carrying out such works and of the construction plant and temporary works, if any, which the Contractor intends to supply, use or construct as the case may be. The submission to and approval by the S.O. or the S.O.'s Representatives of such programme or the furnishing of such particulars shall not relieve the Contractor of any of his duties or responsibilities under the Contract.

13.1.3. Contractor's Organisation Chart

The Contractor shall submit to the S.O. the organisation chart of his project team showing the personnel involved, their designations and relationship including their roles and responsibilities.

13.1.4. Schedules

13.1.4.1. The Contractor shall submit the following schedules:

(i) Maintenance and Calibration Schedule of the plant and equipment to be used in the Works.

(ii) Inspection and Testing Schedule of the plant and equipment, itemising the type and frequency of inspection and testing.

13.1.5. Quality Assurance Plan (QAP)

13.1.5.1. Applicable for project value more then RM10 Million.

13.1.5.2. Contractor to Submit Quality Assurance Plan

(i) The Contractor shall submit to the S.O. an outline Quality Assurance Plan for comment within fourteen (14) days of the date of Letter of Acceptance. Within twenty-eight (28) days thereafter the Contractor shall submit to the S.O. for approval a properly documented Quality Assurance Plan that shall take proper account of the S.O.'s comment on the outline Quality Assurance Plan. The approval by the S.O. of such plan shall not relieve

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the Contractor of any of his obligations under the Contract. The Contractor shall update and revise the said Quality Assurance Plan during the progress of the work in order to comply with the contract, all to the approval of the S.O..

(ii) Details of all procedures and compliance documents shall be submitted to the S.O. for information before each design for temporary works and execution stage of the Works is commenced. When any document of a technical nature is issued to the S.O. evidence of the prior approval by the Contractor himself shall be apparent on the document itself.

(iii) Quality Assurance Plan shall set out the specific quality procedures, practices, resources and sequence of activities to meet the requirements of the Contract and Specifications and shall include the proposed organization structure of the Contractor including quality assurance team, quality procedures, Contractor's plant, construction programme, method statements, environmental management, health and safety, selection and testing of materials, placement, installation, site operational control, non-conforming reporting (NCR), closing out NCR for the taking over, coordination with local and statutory authorities, internal quality audit control, remedying of defects , commissioning and maintenance (if any).

(iv) All Quality Assurance Plan submitted by the Contractor to the S.O. shall conform to the relevant standards set out by the International Standards Organisation (ISO) and in conjunction with the Public Works Department Quality Management System.

13.1.5.3. Contractor to Adhere Quality Assurance Plan

The Contractor shall implement the quality assurance procedures in the approved Quality Assurance Plan and shall submit a monthly quality assurance report to be endorsed by a Quality Assurance Officer incorporating all test results, test certificates, photographs and lab reports relating to the quality of materials and workmanship.

13.1.5.4. Quality Assurance Team

(i) The Contractor shall appoint a suitably qualified and experienced person to act solely as Quality Assurance Officer full time on Site to lead the Quality Assurance Team. The Quality Assurance Officer shall meet the following requirements:

a) Possess a relevant technical Degree from a university recognised by the Government of Malaysia, and

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b) Possess not less than 5 years' experience in the construction industry, and

c) Possess a Construction Industry Development Board (CIDB) Green Card, and

d) Has any one of the following;

i. Minimum 2 years relevant experience in the implementation of MS ISO 9001 in the construction industry, or

ii. Has attended field internal audit activities for MS ISO 9001, or Possess Internal Auditor Certificate from agency or body recognised by MAMPU

(ii) The Contractor shall provide a Quality Assurance Team and resources that are required to ensure the effective operation of the Quality Assurance Plan

a) Verification of Implementation

i. The Contractor shall at his own cost provide all access, assistance and facilities to enable the S.O.'s Representative to audit/verify the implementation of the Quality Assurance Plan and adherence thereto.

ii. The S.O.'s Representative may, at his discretion, reject any of the Works which in his opinion have not been executed in accordance with the Quality Assurance Plan and which ultimately does not conform with the specification, or the resultant execution of the work was not done in a good and workmanlike manner and to the accepted standard and good practice. The contractor shall re-execute at his own cost and without any entitlement to any extension of time all such parts of the Works so rejected.

14. Project Signboard

The Contractor shall provide, erect, paint and maintain a project signboard as shown on the relevant drawing or as directed by the S.O.. The signboard shall be erected at a prominent position at the Site as approved by the S.O..

15. Progress Photographs

15.1. The Contractor shall take progress photographs at monthly intervals or more frequent as directed by the S.O.. The photographs must be taken from different angles including aerial view as directed by the S.O. and the average number of

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photographs shall be sufficient enough to show the progress of the Works. For building works, the average number per month shall not be less than six (6) per block of building.

15.2. The Contractor shall supply six (6) sets of bound printed copies of the approved photographs, all properly titled and dated. The photographs shall also be provided in jpeg or other approved format with each image set at minimum size of 1920 x 1080 pixels and at resolution of 60 frames per second and submitted to the S.O. monthly, in compact discs or removable storage devices.

16. Sufficient Notice to Local Authorities/Utility Providers/Regulatory Bodies

16.1. The Contractor shall give sufficient notice to the relevant Local Authorities/Utility Providers/Regulatory Bodies before commencing or to inspect any works in relation to their scope of services. Failure to give sufficient notice shall not entitle the Contractor to extension of time due to any subsequent delays in connection with the Works.

16.2. Any notice given to the above-mentioned authorities shall also be copied to the S.O..

17. Access and Temporary Roads

The Contractor shall provide and maintain all necessary temporary entrance to the Site and temporary culverts, tracks, bridges, et cetera for access to and within the Site as long as required to the approval of the S.O.. The position where the site access is to be made shall be as indicated on the site plan or as approved by the S.O. and the Contractor shall make all arrangements and obtain all approvals and permissions required at his own cost.

18. Temporary Diversion and Relocation of Existing Overhead and Services Underground

18.1. Before commencing any excavation, et cetera, the Contractor shall enquire from the various authorities whether any underground pipes, cables, et cetera are present on the Site and if so, he shall make arrangements for the disconnection, removal and if necessary, the relocation and reconnection of such services and pay all necessary cost and fees in connection with all temporary diversion and relocation of existing services.

18.2. If during excavation, the Contractor comes across any underground cables, et cetera, he shall immediately stop work and refer to the S.O. for further instructions and make arrangements for the disconnection, et cetera The Contractor shall be responsible for making good all damage to the cables, et cetera, and shall indemnify the Government against any claims as a result of such damage.

19. Temporary Power and Water Supplies for the Works

19.1. The Contractor shall provide adequate power supplies for temporary lighting and for the execution of the Works. Electricity shall be obtained from Tenaga Nasional Berhad (TNB) or the local electricity supply company. Where such electricity supply cannot be provided, generator set(s) may be used but safety precautions must be taken. The use of kerosene lamps shall not be allowed.

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19.2. The Contractor shall provide all water required for the use in the Works including providing and removing all temporary plumbing and storage facilities on completion.

19.3. The Contractor shall pay all associated costs and fees for the power and water supplies.

19.4. The Contractor shall pay all permanent bills until the issuance of Certificate Practical Completion (CPC).

20. Site Security

The Contractor shall provide all necessary personnel and lighting for the security of the site at all times until completion of the whole works.

21. Care and Protection of Materials and Works

The Contractor shall provide and maintain everything necessary for proper protection of materials and Works from any damage by weather, carelessness or otherwise. Any damage caused shall be made good at the Contractor's own cost to the approval of the S.O..

22. Legislation and Regulations

22.1. The Contractor shall at all times comply with the provisions of all legislation, regulations and by-laws currently in force with regard to and in connection with the construction works, the environment, safety and health. The relevant legislation, regulations and by-laws including any revisions thereto are as listed in but not limited to **APPENDIX A/1**.

22.2. The Contractor shall be liable for and shall indemnify the Government against any damages, expenses, liability, losses, claims, prosecution, proceedings, fines and penalties caused by any non-compliance or contravention of the above legislation, regulations and by-laws.

23. Erosion and Sedimentation Control (ESC)

23.1. The Contractor shall execute the Erosion and Sediment Control Plan (ESCP) and all control measures as shown on the Drawings in such a manner and order as directed by the S.O. that will minimize accelerated erosion and sedimentation during the construction phase. The Contractor shall be responsible for compliance with MSMA relating to erosion and sediment control.

23.2. The Contractor shall execute ESCP which requires for inspection of erosion and sediment control devices and facilities on a weekly basis and following precipitation events, as well as maintenance, replacement or repairs to inadequate or damaged controls and devices to ensure effective and efficient operation.

23.3. The Contractor shall maintain all the temporary works regularly throughout the construction period, or as directed by the S.O. and making good of any damaged portions during the course of the works.

23.4. The Contractor shall make proper provision for the drainage of surface water from

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the work site (run-off) including rainwater from surrounding areas (run-on) which drain on to the site.

23.5. The Contractor shall provide, form, fix and maintain such pumps, chutes, walls, drains, bunds and other temporary works necessary for the proper drainage of the Site so that no ponding, flooding or other damage or disturbance is caused to areas surrounding the works throughout the duration of the Contract.

23.6. The Contractor shall execute protection and maintenance of erosion control as stated in SECTION B: EXCAVATION AND EARTHWORKS sub-section 7..

23.7. Silt/Sediment traps shall be constructed as shown on the Drawings unless otherwise directed by the S.O.. The silt/sediment traps shall be maintained regularly throughout the contract period, including desilting when required or as directed by the S.O. and making good of any damages during the course of the Works. The desilted material shall be transported to disposal site approved by the S.O..

23.8. The Contractor shall construct construction stabilization access as shown on the Drawing unless otherwise directed by the S.O. for reducing tracking of mud and dirt onto public's roads by Contractor's vehicles. The construction stabilization access can be made from aggregates, asphaltic concrete and concrete based on longevity, required performance and site condition. The use of asphalt concrete grindings for stabilized construction access/roadway shall be not allowed. Stabilized construction access shall be maintained by the Contractor until construction staging requires removal or upon final stabilization of the construction site. Upon removal of the stabilized construction access, the area shall be graded and stabilized.

23.9. The Contractor shall construct wash trough/wash bay complete with water jet as shown on the Drawing unless otherwise directed by the S.O. for cleaning all debris, dirt and mud from the wheels and tyres of Contractor's vehicles leaving the Site. The position of the wash trough/wash bay shall be as indicated on the site plan or as approved by the S.O.. The wash trough/wash bay shall be maintained regularly throughout the contract period as directed by the S.O..

23.10. The Contractor shall construct temporary waterway crossing as shown on the Drawing unless otherwise directed by the S.O., for providing erosion-free access point across a waterway for contractor's vehicles or equipment and may be necessary to prevent contractor's equipment from causing erosion of the waterway and tracking of pollutants into the waterway.

23.11. The Contractor shall install check dam as shown on the Drawings unless otherwise directed by the S.O., for preventing erosion by reducing the velocity of storm water flows in diversion channel in steep terrain. The check dam shall be constructed of rocks or logs which are secured against damage during significant floods. It shall be of sufficient height and spacing to allow small pools to form between each one and also promote sedimentation behind the dam. The check dam shall be inspected after each rainfall and when a sediment accumulation of approximately one third (1/3) of the check dam height is observed, the sediment shall be removed.

23.12. The Contractor shall construct protection works to the drainage inlets and outlets as shown on the Drawings unless otherwise directed by the S.O. for trapping sediment and debris. The drainage inlet and outlet protection work may consist of rock, grouted rip-rap, concrete rubble, gravel, sand bag, wire mesh or trash screen shall be constructed in such a manner that will facilitate cleanout and disposal of

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trapped sediment / debris and minimizes interference with construction activities.

24. Access Roads and Maintenance of Existing Roads

24.1. All access roads to the site shall be built away from the existing watercourses, streams and rivers with proper drainage system and be paved for a distance of at least 10 metre from where these access roads join existing roads.

24.2. The Contractor shall maintain all access roads including the drainage system throughout the construction period to the satisfaction of the S.O..

24.3. Where the Contractor uses existing/private roads as his access, he shall be responsible for any damage to the existing roads, bridges, drains, culverts, roadside furniture, and all other appurtenances and services on such roads caused by any work carried out by him throughout the construction period. The Contractor shall repair any damages and reinstate the same to their original condition to the satisfaction of the S.O..

24.4. All temporary diversion affecting public/private roads must be approved by the Government, private landowners and the S.O.. All such diversions must be equipped with temporary diversion signs and comply with the current JKR requirements Adequate workmen for controlling traffic diversion must be provided.

24.5. If the Contractor fails to carry out his obligations as stated above, the S.O. shall carry out such maintenance and restoration and all costs incurred shall be borne by the Contractor or deducted from any money due or to become due to the Contractor under this Contract.

25. Control of Workmen, Plant and Machinery at Site

25.1. The Contractor shall be responsible for controlling all persons under his employment and those employed by his sub-contractors, merchants and haulers at the work site and shall take all necessary precautions to prevent damage and nuisance of any kind and shall indemnify the Government against any claim arising therefrom.

25.2. The Contractor shall ensure, so far as is practicable, the safety, health and welfare at work of all his workmen including:

25.2.1. The provision and maintenance of plant and system of work that is safe and without risks to health;

25.2.2. Ensuring safety and absence of risks to health in connection with the use or operation, handling, storage and transport of plant and substances;

25.2.3. The provision for such information, instruction, training and supervision as is necessary to ensure the safety and health at work of his workmen;

25.2.4. The maintenance of place of work condition, the provision and maintenance of the means of access to and egress from place of work that are safe and without risks;

25.2.5. The provision and maintenance of a working environment for his workmen that is safe, without risks to health, and adequate as regards facilities for their welfare at work;

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25.2.6. Ensuring all workmen have valid CIDB Green Cards before entering the construction site.

26. Particulars of Employees

The Contractor shall on each working day furnish, maintain and update a full list of all his workers to the S.O. including all workers employed by his sub-contractors or Nominated Sub-contractors on the work site giving all particulars in the format as approved by the S.O..

27. Contractor's Temporary Accommodation and Facilities for Workmen

27.1. If any, the Contractor shall provide and maintain temporary accommodation including all necessary facilities and services for water supply, drainage, sanitation and lighting for his staff. Before any works can commence the Contractor shall submit to the S.O., details of the proposed buildings and services and shall obtain the S.O.'s approval together with any other necessary approvals in writing from the relevant Authorities.

27.2. The Contractor shall be responsible for all fees and other charges or expenses incurred in connection with such office and housing and shall keep the whole area in a clean, tidy and well-maintained condition. The Contractor shall provide adequate first aid facilities appropriate to the size and composition of his staff and labour force.

27.3. The Contractor shall be responsible for controlling all persons under his employment and those employed by his sub-contractors at the work site and shall take all necessary precautions to prevent damage and nuisance of any kind and shall indemnify the Government against any claim arising therefrom.

27.4. When instructed by the S.O. upon completion of the project, the Contractor shall remove all such buildings and appurtenant works from the site, clean up the area and restore it to the satisfaction of the S.O..

28. Contractor's Office and Storage

28.1. The Contractor shall provide and maintain on the Site in positions as approved by the S.O. the following adequate, secure and weatherproof temporary building(s) for use during the execution of the Contract.

28.1.1. Office for Contractor's use

28.1.2. Shed for storage of cement with the floor raised 300 mm above the ground.

28.1.3. Shed for bar-bending and similar Works

28.1.4. Store for chemical / hazardous substance

28.1.5. Store for other building materials

28.1.6. +…….

[+] Insert other item if required

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28.2. The Contractor shall store or stack at all times, all materials, tools, et cetera in a safe and orderly manner so as not obstruct any passageway or place of work.

29. Office Accommodation for S.O.

29.1. The Contractor shall provide and maintain a site office for the use of the JKR supervisory staff all in accordance with JKR design type as shown on the relevant Drawings inclusive of all fittings and furniture as stated therein.

29.2. The Contractor is permitted to provide relocatable site office as an alternative to the JKR design type. The quality of such relocatable site office shall be of equivalent standard but not inferior to the JKR design type and shall be equipped with similar fittings and furniture as indicated in the JKR design site office.

29.3. Where relocatable site office is to be provided, the Contractor shall submit details of the relocatable site office together with his tender. Such details shall include the name of the manufacturer, floor area and layout, list of fittings and furniture and brochures (if available). The Contractor shall also indicate whether the proposed site office is new or had been previously used.

29.4. Unless otherwise shown on the Drawings, the office is to be sited, positioned and constructed as approved by the S.O..

29.5. The Contractor is also permitted to rent a premise of equivalent floor area and standard not inferior to the JKR design type and equipped with similar furniture, fittings and equipment. Where a rented premise is to be provided, the Contractor shall submit details, which shall include the layout and a list of furniture and fittings to be provided to the S.O. for approval.

29.6. The Contractor shall make proper arrangement for and pay all charges in connection with conservancy. The site office shall comply with local building by-laws. It shall be erected or provided by the Contractor and approved by the S.O. within four (4) weeks from the date of possession of Site.

29.7. On completion of the Works, unless otherwise instructed, the site office with all fittings and furniture shall become the property of the Contractor and shall be removed from the Site forthwith.

30. Telephone for S.O.

The Contractor shall arrange and provide telephone at the S.O.'s site office including provision of high speed internet access and sufficient capacity for the sole use of the S.O. and his representatives in connection with the supervision and administration of the Contract and pay for all installation, rental, call charges and disconnection.

31. Personal Protective Equipment for S.O.

31.1. Personal Protective Equipment

The Contractor shall provide personal protective equipment as listed in latest revision of JKR Specifications for Occupational Safety and Health In Engineering Constructions Works for the use of the S.O. and his supervisory staff throughout the duration of the Contract which comply with the DOSH requirements.

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32. Office Equipment and Facilities for S.O.

32.1. Office Equipment for S.O..

32.1.1. The Contractor shall provide the equipment and facilities as listed in **APPENDIX A2** for the use of the S.O., his representatives and staff. All equipment and facilities provided shall be delivered, tested and installed within four (4) weeks from the Date for Possession of Site.

32.1.2. The facilities provided shall be maintained by the Contractor or his appointed agent throughout the contract period. Maintenance shall include all necessary monthly servicing according to the manufacturer specifications and supply of accessories and consumables.

32.1.3. Within thirty (30) days from the issuance of the Certificate of Practical Completion, the equipment shall be returned to the Contractor.

32.1.4. If the Contractor fails to provide or maintain any equipment or facilities as listed in **APPENDIX A/2** the Government shall have the right to procure the equipment from other sources or maintain it and all expenses arising shall be borne by the Contractor and an appropriate adjustment shall be made to the Contract Sum.

32.1.5. Suitable types of fire extinguishers shall be installed and maintained at required locations on the Site throughout the Contract period.

32.2. Transport Services for S.O..

32.2.1. The Contractor shall provide suitable transportation service by means of vehicle(s) including licensed and competent driver(s) as stipulated in **APPENDIX A/3**.

32.2.2. The Contractor shall ensure that the vehicle(s) is/are in a good and well-maintained condition.

32.2.3. The vehicle(s) shall be in the custody of the Contractor at all times and be readily available for the use of the S.O. and his staff.

32.2.4. The Contractor shall provide comprehensive insurances to cover all drivers and passengers and ensure that all road tax is valid throughout the period of service.

32.2.5. Replacement vehicle(s) shall be provided when the normal vehicle is not available such as during periods of servicing, maintenance or repair. If the Contractor fails to provide the required transport, the officer shall have the option to arrange alternative transport and the Contractor shall bear the expenses incurred.

32.2.6. Within thirty (30) days from the issuance of the Certificate of Practical Completion, the vehicle(s) shall be returned to the Contractor.

33. Material Testing Laboratory and Staff

33.1. Where specified, the Contractor shall provide a testing laboratory within the site with a minimum floor area 60 m^2 all in accordance with the relevant drawings including water and electricity supply. The Laboratory shall be equipped with the

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necessary equipment required to carry out the tests as identified in **APPENDIX A/4** (List of Laboratory Equipment). The Contractor shall be responsible for the maintenance of the Laboratory and all equipment including all necessary calibration throughout the duration of the Contract. The laboratory may be jointly used by the S.O. and the Contractor.

33.2. Alternatively, the Contractor may rent a premise of equivalent floor area and standard not inferior to that of the JKR specified type with similar fittings and necessary equipment as identified in **APPENDIX A/4**.

33.3. All equipment shall be returned to the Contractor within thirty (30) days after the issuance of the Certificate of Practical Completion.

33.4. All tests shall be carried out by qualified laboratory staff(s) and shall be witnessed and approved by the S.O..

33.5. Subject to the S.O.'s approval, the Contractor may also propose an accredited laboratory approved by SIRIM or accredited by Department of Standard Malaysia as an alternative to the construction of a testing laboratory.

33.6. All works subject to laboratory test shall not be permitted to commence until the laboratory and necessary equipment have been provided or the accredited laboratory has been approved by the S.O..

34. Survey Instruments and Personnel

The Contractor shall provide for the sole use of the S.O. and his staff all such instruments, equipment and survey personnel as may be required until thirty (30) days after the issuance of the Certificate of Practical Completion. The Contractor shall ensure that all instruments and equipment are maintained in good working condition at all times.

35. Safe Working Area

The Contractor shall at all times comply with *Guidelines for Public Safety and Health* at Construction Sites, DOSH, and other Occupational Safety and Health requirements stated and as listed in *JKR Specifications for Occupational Safety and Health In Engineering Constructions Works JKR No. 20700-0349-19* to ensure safe working area.

36. Safety, Health and Welfare

36.1. The Contractor shall be required to provide a complete First Aid Kit as stated under *Factory and Machinery (Safety, Health and Welfare) Regulation 1970* which shall be kept and properly maintained in the Contractor's site office. The kit shall be in the charge of either the Contractor's site representative or some other responsible person who shall be on the Site during all working hours to ensure that the first aid facilities are available without delay at all times when Works is in progress. At least one (1) designated person of the Contractor's staff shall be trained in first aid duties.

36.2. The Contractor shall refrain from dumping and/or depositing any form of materials that are capable of collecting water which afford breeding places for mosquitoes, rodents, insects and vermin of any kind. All excavation and any portion of the site where water stagnates or accumulates shall be kept dry by pumping, bailing or other operations. The Contractor shall pay all charges as may be required by the

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MOH and/or Local Authority and employ whatever destructive measures as are necessary.

36.3. All Works shall be carried out without unreasonable noise level and dust emission. The Contractor shall take measures to ensure that all equipment and machinery are in proper working condition so as to minimize the amount of noise and dust generated. The S.O. may require the Contractor to submit a proposal on how to reduce excessive noise and dust.

36.4. The Contractor is prohibited from discharging oil and grease to any water course. Storage tanks for oil and grease shall be placed on concrete base with upstand edges to contain any spillage. Any spilled oil and grease shall be promptly removed by the Contractor. The Contractor shall collect, and store used oil, grease and other scheduled wastes and dispose these according to methods approved by DOE.

36.5. Where the contract period is more than six weeks, the Contractor shall register with DOSH within seven (7) days after commencement of Works.

36.6. All safety measures shall be carried out in accordance with *Occupational Safety and Health Act (OSHA) 1994*, *JKR Specifications for Occupational Safety and Health In Engineering Constructions Works JKR No. 20700-0349-19* and relevant local by-laws. The Contractor shall be held solely responsible for all accidents arising from any negligence in this respect. The Contractor shall employ throughout the entire contract period a competent and qualified person as Safety and Health Practitioner as below:

36.6.1. Site Safety Supervisor (SSS) to be stationed minimum 15 hours a week for all projects.

36.6.2. Safety and Health Officer (SHO) to be stationed full time for contracts worth more than RM20 million.

36.7. The Contractor shall ensure all sub-contractors and nominated sub-contractors who employ more than 20 persons shall appoint a Contractor Safety Supervisor (CSS) to be stationed minimum 5 hours a week.

36.8. The Contractor shall submit Safety and Health Plan (S-Plan) in writing duly signed by the Director of the company to the S.O. within one (1) month after the receipt of the Letter of Acceptance. The S-Plan shall be as per requirements in *JKR Specifications for Occupational Safety and Health In Engineering Constructions Works JKR No. 20700-0349-19*. The Contractor shall submit revised S-Plan whenever required.

36.9. The Contractor shall form a Safety and Health Committee in accordance with the Occupational Safety and Health Regulations 1996 and organise meetings at minimum once in every three (3) months.

36.10. The Contractor shall conduct Occupational Safety and Health (OSH) related training and programmes for the workmen including sub-contractors in accordance with *JKR Specifications for Occupational Safety and Health In Engineering Constructions Works JKR No. 20700-0349-19.*

36.11. The Contractor shall carry out site safety and health inspections and submit monthly safety and health reports to the S.O. in accordance with *JKR Specifications for Occupational Safety and Health In Engineering Constructions Works JKR No. 20700-0349-19.*

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36.12. The Contractor shall provide and maintain safety and health statistic scoreboard at the entrance of site office and workplace in accordance with *JKR Specifications for Occupational Safety and Health In Engineering Constructions Works JKR No. 20700-0349-19.*

36.13. The Contractor shall provide and maintain adequate traffic safety signage, warning signs and warning lights at place of Works and close proximity to public.

36.14. The Contractor shall provide and maintain traffic control by competent persons including provision of flagmen where Works is in close proximity to public roads.

36.15. The Contractor shall carry out site safety and health inspections as per DOSH requirements and/or instructed by the S.O..

37. Sanitation

37.1. The Contractor shall provide and maintain sufficient water efficient temporary toilets at appropriate locations on site as approved by the S.O.. Toilets shall be complete with adequate water closets, urinals, hand-basins with proper sanitary system and maintained in a clean and sanitary condition in accordance with the requirements of the MOH.

37.2. All wastewater must be treated such that its discharged effluent meets the requirements of all existing legislation and regulations.

38. Waste Management

38.1. The contractor shall ensure all waste generated on site shall be managed in accordance with the latest statutes and other related legislation as follows:

Type of waste generated on site	Statutory requirement
Scheduled waste / hazardous waste	• *Environmental Quality Act 1974* • *Environmental Quality (Scheduled Wastes) Regulations, 2005*
Construction & demolition waste	• *Solid Waste and Public Cleansing Management Act 2007* • *Solid Waste and Public Cleansing Management (Scheme for Construction Solid Waste) Regulations 2018*
Domestic waste	

38.2. Actions need to be carried out to ensure all waste generated on site are managed properly as required by the law (but not limited to) are as follows:

38.2.1. The Contractor shall submit in the approved format the Construction Waste Management Plan (CWMP) to the S.O. for approval within fourteen (14) days from the date of site possession.

38.2.2. The Contractor shall provide adequate Roll-On Roll-Off (RORO) Bin for construction waste and Mobile Garbage Bin (MGB) for domestic waste.

38.2.3. The Contractor shall provide a minimum of one (1) suitable location on site for segregation and collection of construction and domestic waste.

38.2.4. The Contractor shall provide proper storage facility and container for

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Schedule Waste Management in accordance with the Drawings.

38.2.5. The Contractor shall appoint a licensed contractor(s) to collect the construction waste, scheduled waste and domestic waste from the site to approved locations for disposal or to recycle the waste.

38.2.6. The contractor shall keep all records relating to disposal of waste from site.

39. Environmental Protection Works

39.1. Environmental Impact Assessment (EIA)

For projects subjected to EIA under Section 34A of the Environmental Quality Act (EQA) 1974, the contractor shall ensure full compliance to all EIA approval conditions stipulated by Department of Environment (DOE) or other relevant authorities.

39.2. Environmental Management Plan (EMP)

39.2.1. The Contractor shall prepare the EMP for the following situations:

39.2.1.1. Projects worth more than RM20 Million including earthworks.

39.2.1.2. Project sites located in Environmental Sensitive Area (ESA) as defined in the National Physical Plan by PLAN Malaysia (Jabatan Perancangan Bandar dan Desa.)

39.2.1.3. Projects where Environmental Impact Assessment (EIA) has been carried out.

39.2.2. The EMP shall be prepared by a registered environmental consultant and submitted to the DOE/NREB/EPD (for EIA projects) or the S.O. (for Non-EIA projects) for approval. The contractor shall ensure EMP must be approved before commencement of site clearing and earthwork activities on site. The EMP shall be concise, up to date and site specific. The EMP shall refer to the following but not limited to:

39.2.2.1. DOE/NREB/EPD format for the preparation of EMPs (For EIA projects);

39.2.2.2. The approved EIA report and conditions imposed (if any);

39.2.2.3. JKR format based on latest Guideline/Arahan Teknik Jalan (ATJ) on Environmental Protection and Enhancement Works (EPW) (For Non-EIA projects).

39.2.2.4. The Contractor also required to submit the following documents as per **Table A1** to the S.O.:

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Table A1. Submission of Documents

Documents	No. of Copies	Reporting Frequency	Timing
Environmental Management Plan (EMP)	5	Once only (to be updated when necessary)	EMP must be approved before commencement of site clearing and earthwork activities on site*
Environmental Monitoring Report (EMR)	5	Monthly	14 days after monitoring**
Environmental Audit Report (EAR)	5	Quarterly	14 days after audit***
Environmental Closure Audit Report (ECAR)	5	Once Only	14 days prior to issuance of Certificate of Practical Completion***

Note * To be carried out by registered environmental consultant with DOE/NREB/EPD
** Parameters to be tested needs to be carried out by accredited laboratory
*** To be carried out by registered environmental auditor with DOE/NREB/EPD

39.3. Environmental Officer (E.O)

39.3.1. The Contractor shall appoint a qualified person as a full time E.O as per S.O.'s approval for environmental management works, throughout the contract period for the implementation of EIA and JKR Sistem Pengurusan Alam Sekitar (SPAS) or project more than RM 20 million including earthwork:

For EIA project:
E.O. shall have degree in Civil Engineering or environmental science with 3-years related experience and be certified with CESSWI/CISEC/CePSWaM or equivalent as required by DOE/NREB/EPD.

For non-EIA project:
E.O. shall have degree in Civil Engineering or environmental science with 1-year related experience.

40. Water and Air Quality, Noise and Vibration Control

40.1. The Contractor shall carry out monitoring of water and air quality, noise and vibration as indicated in the EMP and tests to be carried out by accredited laboratories. Parameters to be tested are as specified in **TABLE A2 (APPENDIX A/5).**

40.2. Water Quality

40.2.1. All silt fence, silt traps, sedimentation basin and other erosion and sediment control measures as shown in ESCP drawing must be constructed and maintained by the Contractor.

40.2.2. The water used for cleaning vehicle tires in wash troughs should be distributed through any sediment settling sump overflow and directed into the silt trap. The used water should not be allowed to discharge directly into existing drainage system.

40.2.3. Water quality standards and monitoring schedule from the silt traps/

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sedimentation basin/rivers/stream/ water bodies shall comply as specified in **TABLE A2 (APPENDIX A/5)** or as directed by the S.O.. Silt traps and sediment basin discharges shall be monitored monthly and shall be collected within 30 minutes after rainfall event of more than 20mm (For Non-EIA projects) or 12.5 mm (For EIA projects).

40.2.4. The contractor is prohibited from discharging oil, grease, paint and sewage to any watercourse.

40.2.5. The contractor shall carry out monthly water quality monitoring at locations on existing water bodies as indicated in the EMP. Water quality sampling shall also be tested by an accredited laboratory.

40.3. Air Quality

40.3.1. The Contractor is not allowed to carry out open burning of cleared vegetation, debris and construction waste et cetera, shall not be allowed unless prior approval is obtained from the Director General of the DOE.

40.3.2. The Contractor shall provide suitable numbers of spraying equipment for regular spraying of water over the existing roads, tracks and access roads, near settlements, completed as well as incomplete road and other barren areas of the site used by the contractor especially during the dry season or as and when directed by the S.O..

40.3.3. When the Contractor's trucks or equipment utilizes public or private roadways, all dirt and materials shall be removed from the trucks/ equipment by hosing, lorry wash-trough, et cetera before leaving the site.

40.3.4. The Contractor shall provide for the prompt removal of all dirt and other materials spilled from his or his sub-contractor's vehicles on public or private roadways.

40.3.5. For Contractor's trucks carrying sand, aggregates, earth and other loose construction materials liable to spillage, tarpaulin must be used to cover such open trucks when passing through villages and settlements or on all roadways.

40.3.6. The Contractor shall also ensure dust control at quarry / batching plant (if any) and usage of generator set (genset) complies with environmental requirement as stipulated in the *Environmental Quality (Clean Air) Regulations, 2014.*

40.4. Noise and Vibration Control

40.4.1. All work shall be carried out with least disturbance and noise. The contractor shall ensure all his equipment and machineries are in proper working condition so as to minimize the amount of noise generated. The S.O. may require the contractor to replace any machinery that to his discretion is emitting excessive noise.

40.4.2. The Contractor shall ensure that at any time, the noise and vibration levels resulting from his works at or across real property boundary should not exceed the Recommended Limit as Specified in **TABLE A2 (APPENDIX A/5).** No person unless duly authorized by law or carrying our legitimate duties shall use explosives or results in explosions which create a vibration disturbance across a real property boundary or on a

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public space or right of way.

40.4.3. The Contractor shall comply with the general recommendations set out in *The Planning Guidelines for Environmental Noise Limits and Control and The Planning Guidelines* for Vibration Limits and Control in the Environment together with any specific requirements described in the Contract.

40.4.4. The Contractor shall indemnify and keep indemnified the Government, S.O. and the S.O.'s Representatives against any liability for damages on account of noise and vibration disturbance created while or in carrying out of the works and from and against all claims, demands, proceedings, damages, costs charges and expenses whatever in regard or in relation to such liability.

40.4.5. The contractor shall carry out noise and vibration monitoring at locations as indicated in the EMP. The parameter to be tested is as specified in **TABLE A2 (APPENDIX A/5).**

41. Nominated Sub-contractors

41.1. The Contractor shall allow in his tender price for attendance and facilities upon all Nominated Sub-contractors. Such attendance and facilities shall include the following:

41.1.1. Ascertaining from Nominated Sub-contractors all particulars relating to their work in regard to sizes and positions in which chases, holes, mortices, et cetera are required to be formed or left.

41.1.2. Making good of walls, ceilings, floors, roofs, et cetera and finishes thereto including touching up of all paintwork necessitated, damaged or disturbed by the Nominated Sub-contractor's work.

41.1.3. Supplying all setting out information.

41.1.4. Giving all necessary dimensions and taking responsibility for their accuracy.

41.1.5. Affording free and full use of standing scaffolding whilst it remains erected on the Site.

41.1.6. Affording free and full use of storage accommodation for materials, equipment and plant which are for incorporation into the Works and/or which require protection against weather and deterioration, messrooms, sanitary and welfare facilities.

41.1.7. Providing site space only for Nominated Sub-contractor's temporary office, workshops, workmen's accommodation and storage of materials, tools, plant and equipment which are not for incorporation into the Works and not requiring protection against weather or deterioration.

41.1.8. Providing temporary water supply, electric power supply, artificial lighting and paying all fees and charges for fuel, water and electricity consumed including for testing and commissioning of the whole Nominated Sub-contractor's works.

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41.1.9. Liaising with the relevant supply/service authorities for the expeditious installation of the connections for permanent water and electricity supplies in the Works making available such supplies to the Nominated Sub-contractors; and paying all fees and charges for such installation, deposits for such supplies/services on behalf of the Government. All such payments made, shall be reimbursed to the Contractor on production of receipted bills.

41.1.10. Providing competent personnel in compliance with the latest Electricity Regulations to take responsibility for the operation of the electrical installation from the time the permanent electricity supply is made available until testing, commissioning and handing over of the Works.

41.1.11. Protecting, watching and taking full responsibility for all Nominated Sub-contractor's work and unfixed materials and goods intended for use thereon.

41.1.12. Removing rubbish and debris off the Site and cleaning the Works internally and externally.

41.2. It is deemed that the Nominated Sub-contractor shall include in the Sub-contract Sum, inter alia, the costs in connection with the following:

41.2.1. Unloading, getting in, storing and all handling and hoisting of these materials, plant and tools into required positions.

41.2.2. Providing, erecting, maintaining and removing of all his temporary office, workshops and workmen's accommodation including paying all assessment and other charges.

41.2.3. Connecting to temporary water and power supplies made available by the Contractor for the execution of the Works, supplying and running distribution pipes, hoses, cables, leads, electrical gear, et cetera but excluding payment for water and electricity consumed.

41.2.4. Provision of fuel, gas, steam, oil lubricants, chemicals and everything else necessary (other than water and electricity) for the test running and commissioning of the Sub-contract Works.

41.2.5. Any scaffolding, staging, et cetera that are required for the Sub-contract Works not covered by sub-section 42.1(v) above.

42. Nominated Suppliers

The Contractor shall allow in his tender, price for attendance upon all Nominated Suppliers which is to include taking delivery, unloading, setting in, checking and accepting delivery, returning empties, handling, storing and hoisting of the materials/goods supplied by the Nominated Suppliers. Packing and carriage to Site shall be borne by the Nominated Supplier unless specifically stated to the contrary.

43. Coordination of Mechanical and Electrical Services

43.1. General

This section shall describe the scope of works, qualifications, competency, roles

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and responsibilities of the Mechanical and Electrical (M&E) Services Coordination Team.

43.2. Scope of Work

43.2.1. The Contractor shall be responsible for coordinating the implementation of all M&E works and related activities within the project scope. For this purpose, the Contractor shall appoint M&E Services Coordinators full time on site during the whole duration of the works. The appointment shall be approved by the S.O..

43.2.2. The Contractor shall ensure all M&E requirements are implemented in a timely manner and adequately integrated with all services involved such as architectural, structural and other related services.

43.2.3. The Contractor shall conduct regular coordination meetings among all sub-contractors, nominated or otherwise, from related disciplines to evaluate and resolve all issues or problems regarding integration and coordination of all services.

43.3. Minimum Requirement of M & E Services Coordinator Based on Project Cost As Followed:

Project Cost (RM)	Minimum Requirement of M&E Coordinator
Below 10 Million	1 CoW
Between 10 to 50 Million	1 Engineer & 1 CoW
More Than 50 Million	1 Engineer & 2 CoW

43.4. Qualification and Competency of M&E Coordinators

43.4.1. Engineer

Degree in related engineering field with minimum three (3) years of working experience in building construction.

43.4.2. Clerk of Works (CoW)

Diploma in related engineering field with minimum five (5) years of working experience in building construction.

43.4.3. Responsibilities of M&E Services Coordinator

43.4.3.1. The M&E Services Coordinator shall be responsible, on behalf of the Contractor for:

(i) Ensure all M&E works are well coordinated with architectural and structural works including but not limited to modular coordination, factory fabrication, on site supervision and inspection for the implementation of IBS.

(ii) Guide the overall M&E works and implementation of related activities within the project scope and providing timely and relevant information.

(iii) Ensure that all layout, schematic, detail and Builder's Work in Connection (BWIC) drawings (for architectural,

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structural, mechanical and electrical works) are received from the S.O..

(iv) Supervise all the installation and construction works to ensure the works are sufficiently coordinated.

(v) Identify and resolve issues or problems related to integration and coordination of services by producing coordinated services drawing, new method of installation et cetera.

43.5. Coordinated Drawings

The Contractor shall prepare and submit to the S.O. a complete set of Coordinated Drawings which comprise Architectural, Structural, Mechanical and Electrical works pertaining to all the services incorporated into the Works by his sub-contractors, nominated sub-contractors or otherwise. The Coordinated Drawings submitted by the Contractor must integrate with all the drawing for the whole Works and must ensure efficient and orderly installation of all the parts of the Works to ensure of non-interference with structural framing, ceilings, partitions, equipment's, lights, mechanical and electrical and other services, with emphasis to safety maintainability and serviceability for the lifetime of the Works. The Contractor shall guarantee that the said Coordinated Drawings shall be free and independent of any fault and they are fit for the purpose.

44. Keeping the Site Tidy

44.1. The Contractor shall make every effort to keep the Site in a reasonably clean and tidy condition for the duration of the Works. He shall, in addition, from time to time and on the completion of any area of the Works or where directed by the S.O., remove rubbish, surplus materials, or any other construction debris from such areas as may be attributable to his work under this Contract and generally maintain the Site in a satisfactory condition, to the approval of the S.O..

44.2. The Contractor shall gather up and clear away all rubbish as it accumulates during the progress of the Works at least twice each week at times approved by the S.O.. The services shall be continued until the completion of the Works. Garbage or construction waste shall be disposed in a locally available landfill or hauled to disposal sites approved by the S.O..

45. As-built Drawings

45.1. The Contractor shall provide and deliver to the S.O. approved As-built drawings after completion of each section of the Works in the form of:

45.1.1. Four (4) sets of As-built drawings as actually constructed pertaining to the Works including all services and facilities systems and all supporting documents such as Operation and Maintenance Manual, Testing and Commissioning Certificates.

45.1.2. Four (4) sets of Digital Copies in AutoCAD (.dwg) or any other compatible format to be stored in compact discs or removable storage.

45.1.3. Four (4) sets of Digital Copies in Acrobat (.pdf) or any other compatible format to be stored in compact discs or removable storage.

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45.1.4. The As-built drawings supplied shall be comprehensive and to the satisfaction of the S.O. as to allow for a complete understanding of the Works as they were actually built incorporating all Works arising from variations, expenditure of Provisional Sums and Prime Cost Sums.

46. Total Asset Management

46.1. Introduction

46.1.1. This is the requirement for the application of Total Asset Management (TAM) principles and best practices to fulfill Dasar Pengurusan Aset Kerajaan (DPAK) for all assets including building, road and other infrastructure.

46.1.2. Total Asset Management practices cover the asset whole life-cycle as outlined in the Manual Pengurusan Aset Menyeluruh Kerajaan (MPAM), namely the following phases:

46.1.2.1. Asset Planning

46.1.2.2. Asset Creation

46.1.2.3. Asset Utilization

46.1.2.4. Asset Disposal

46.2. General Requirement

46.2.1. The overall planning of the project shall incorporate all the required buildings and facilities specified in the project brief and shall reflect the operational policies of the project.

46.2.2. The contractor shall have a team of experienced and adequate knowledge in operation and maintenance to ensure.

46.2.2.1. Quality of design and construction

46.2.2.2. Excellent supervision

46.2.2.3. Compliance to specification and method statement

46.2.2.4. Excellent cost control and construction period management

46.2.3. The contractor shall execute the government interest in continuous improvement agenda and applying best practices in the implementation of government programmes and projects.

46.3. Asset creation Phase

46.3.1. The highest performance deliverables shall be considered in order to fulfil government services delivery.

46.3.2. Asset creation shall be in compliance to contract requirements, existing

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laws and regulations.

46.3.3. The design shall incorporate design for maintainability to avoid loss to the government and affect productivity due to the following:

46.3.3.1. High operation and maintenance cost

46.3.3.2. Longer waiting time for repair works

46.3.3.3. High downtime of system/components

46.3.3.4. Risk of accident/injury during maintenance and repair works

46.3.4. Planning, design and construction of the building shall consider the following, but not limited to:

46.3.4.1. Catering for cultural diversity of the building users

46.3.4.2. Effective space planning for usage and maintenance

46.3.4.3. Ease of maintenance including accessibility for maintenance purpose.

46.3.4.4. Security and safety

46.3.4.5. Comfort and ergonomics

46.3.4.6. Good environmental qualities

46.3.4.7. Sustainable building, energy efficient and fulfill water tightness condition

46.3.4.8. Maintainability, serviceability and accessibility

46.3.4.9. Operational efficiency of completed facility

46.3.4.10. Life Cycle Cost (Total Cost of Ownership)

46.3.4.11. Functionality

46.3.5. Space for maintenance team and works shall be provided (e.g. Utilities Room, Janitor Room)

46.4. Identification, Labelling and Registration of Asset

Identification and labelling (No. Daftar Premis Aset (DPA, Blok, Aras & Ruang) asset informations shall be as per of latest Garis Panduan Pengumpulan Data & Pelabelan Aset Tak Alih (PeDATA): Aset Bangunan and Sistem Kod Aset Tak Alih (SKATA) in construction drawings.

46.5. Project Construction Stage

All material, equipment and spare parts selected by the contractor shall be of high good quality (as per specification), sustainable, durable, safe, economical and

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easy to maintain and easily available as approved by S.O./P.D.

46.6. Asset Registration and Labelling Works

46.6.1. The contractor shall collect and fill up asset information's as per requirement of Garis Panduan Pengumpulan Data & Pelabelan Aset Tak Alih (PeDATA): Aset Bangunan (latest version PeDATA). All related form & template shall be done gradually and submitted to the S.O./P.D. for approval.

46.6.2. The contractor shall ensure that all coding and labelling of government assets including but not limited to No. DPA, Blok, Aras & Ruang shall be done according to current government requirements.

46.7. Project Handover

46.7.1. The contractor shall provide all information required by the S.O./P.D for the purpose of asset registration. The details are described in sub-section 46.4. and 46.6..

46.7.2. The Contractor shall submit digital copy in the form of Microsoft Word/ MS Excel files of the followings to the S.O./P.D:

46.7.2.1. Label identification layout plan drawings using 'SKATA room naming convention' in hard cover binding.

46.7.2.2. Asset Information's form (D.A.3 - D.A.6) & template (MS Excel) format as approved by S.O./P.D.) and List of DAK Komponen (as per Borang D.A 7 in Garis Panduan Pengumpulan Data & Pelabelan Aset Tak Alih (PeDATA): Aset Bangunan

46.8. The contractor shall compile the asset informations as per requirement of latest version Garis Panduan Pengumpulan Data & Pelabelan Aset Tak Alih (PeDATA): Aset Bangunan for the approval of the S.O./P.D..

47. Site Investigation Works

47.1. All Site Investigation Works Carried Out Shall Comply to *Standard Specification For Road Works Section 17: Site Investigation* JKR/SPJ/2013-S17 or The Latest Edition Published By JKR.

48. Clearing, Cleaning and Making Good on Completion

48.1. The Contractor shall ensure the existing roadside drains bounding the Site are clear of any construction debris, soil, et cetera, at all times before handing over of the Works to the S.O. upon completion.

48.2. Upon completion of the Works, the Contractor shall remove and clear away from Site all temporary buildings, temporary works, temporary installation and equipment, and ensure the Site is in a clean and tidy condition.

48.3. Before handing over of the Works, the Contractor shall scrub all floors, pavings, staircases et cetera and clean out all gutters, gulleys, manholes, sumps and drains. The Contractor shall also clean all glass panes and leave every part of the completed Works included in this Contract in a clean, sound and tidy condition to the approval of the S.O..

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APPENDIX A/1

LEGISLATION AND REGULATIONS

1. BS 5228: Code of Practice for Noise control on Construction and Demolition Site
2. Construction Industry Development Board Act, 1994
3. Electricity Regulations, 1994
4. Electricity Supply Act, 1990
5. Environmental Quality Act (EQA), 1974
6. Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 2015
7. Environmental Quality (Clean Air) Regulation 2014
8. Environmental Quality (Scheduled Waste) Regulation 2005
9. Environmental Quality (Industrial Effluents) Regulation 2009
10. Environmental Quality (Sewage) Regulation 2009
11. Explosives Act, 1957
12. Factory and Machinery Act (FMA), 1967 Rev 2006 and Regulations under the Act.
13. Federal Territory (Planning) Act 1982 (Act 267)
14. Fire Services Act, 1988
15. Forestry Act 1984 (Act 313)
16. Guidelines for Hazard Identification, Risk Assessment and Risk Control, 2008, DOSH
17. Guidelines for Public Safety and Health at Construction Sites, 2007, DOSH
18. Guidelines for the Prevention of Falls at Workplaces, 2007, DOSH
19. Guidelines on Occupational Safety And Health In Tunnel Construction, 1998, DOSH
20. Guidelines on Occupational Vibration, 2003, DOSH
21. Industry Code of Practice for Safe Working in A Confined Space, 2010, DOSH
22. Irrigation Areas Act, 1953
23. Land Conservation Act 1960 (Act 385)
24. Local Government Act, 1976
25. MS 2318: Code of Practice for Demolition of Buildings, 2010
26. National Land Code (Act 56 of 1965)
27. Occupational Safety and Health Act (OSHA), 1994 and Regulations under the Act.
28. Protection of Wildlife Act, 1972 (Act 76)
29. Solid Waste and Public Cleansing Management Act 2007 (Act 672)
30. Standard ISO 45001: Occupational Safety and Health Management System
31. Standard ISO 14001: Environmental Management System
32. Street, Drainage and Building Act, 1974
33. Street, Drainage and Building Act, 1974: Act 133 and Amendment, 1978
34. The Planning Guidelines for Environmental Noise Limits and Control (DOE, 2004)
35. The Planning Guidelines for Vibration Limits and Control in Environment (DOE, 2004)
36. The Radiation Protection (Basic Safety Standards) Regulations 1987
37. Town and Country Planning Act 1976, (Act 172)
38. Uniform Building By-Law (UBBL), 1984
39. Workers Minimum Amenities Act 1990 (Act 446)

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APPENDIX A/2

LIST OF S.O.'S FACILITIES AND EQUIPMENT

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APPENDIX A/3

LIST OF S.O.'S TRANSPORT SERVICES

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APPENDIX A/4

LIST OF LABORATORY EQUIPMENT

The Contractor shall provide and maintain the following testing laboratory equipment, those which are deemed necessary only for the project, and shall become the property of the Contractor at the end of the Contract: -

Test	Equipment
1. Slump Test	1. Mixing Pan (500mm x 500mm) 2. Slump Cone (100mm x 200mm x 300mm) 3. Steel Tamping Rod (600mm x 16mm) 4. Measuring Tape
2. Compressive Strength Test (Fresh Concrete)	1. Steel Mold Cube (150mm (H) x 150mm (W) x 150mm (L)) 2. Steel Mold Cylinder (150mm (D) x 300mm (H)) 3. Scoop 4. Steel Tamping Rod 5. Compression Test Machine
3. Compressive Strength Test (Cores Sample)	1. Coring Machine 2. Core Bit 3. Compression Test Machine
4. Concrete Cover Test	1. Electromagnetic Covermeter
5. Rapid Chloride Penetrability Test	1. Vacuum Saturation Apparatus 2. Applied Voltage Cell 3. Voltage Application and Data Readout Apparatus 4. Corecase 5. Diamond Saw
6. Rebound Hammer Test	1. Rebound Hammer Apparatus 2. Steel Brush
7. Ultrasonic Pulse Velocity Test	1. Voltmeter 2. Calibrator Block 3. Transmitter and Receiver Transducer
8. Penetration Resistance Test	1. Driver Unit (Powder Actuated Device) 2. Probe 3. Measuring Unit
9. Carbonation Test	1. Phenolphthalein 2. Methylated spirit 3. Bottle spray 4. Distilled water 5. Beakers
10. Water Absorption Test	1. Balance weighing 2. Drying oven 3. Water tank 4. Desiccator
11. Sorption Test	1. Balance weighing 2. Drying oven 3. Steel Tray 4. Caliper 5. Desiccator

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Test	Equipment	Quantity
a) Soil Testing Equipment	1. Moisture content tins – 76mm x 25mm with lids	25
	2. Electric balance of 1kg capacity, accurate to 0.01g with a tare correction not less than 100g	1
	3. Electric forced draught oven, capacity of 0.08 cu.m	1
	4. Desiccator containing anhydrous silic gel	1
	5. Liquid limit penetrometer set with all accessories and digital penetration measurement gauge 0.01 mm precision	1
	6. Glass plate – 500mm x 500mm x 10 mm	2
	7. Flexible spatula of about 160 mm long	2
	8. Evaporating dish of about 150 mm diameter	2
	9. Stopwatch readable to 1s	1
	10. Linear shrinkage moulds 140mm x 12.5mm radius	5
	11. 203mm diameter B.S. sieves – 75mm, 63mm, 50mm, 37.5mm, 28mm, 25mm, 20mm, 14mm, 12.5mm, 9.5mm, 6.3mm, 5mm, 4.75mm, 3.35mm, 2.36mm, 2mm, 1.18mm,600µm, 425µm, 300µm, 212µm, 150µm, 75µm, 63µm, lid and pan together with vibrating machine	1 of each
	12. 203mm diameter B.S. sieves - 75µm, 425µm	1 of each
	13. Sample splitter – 50mm, 12mm	2 of each
	14. Balance of 10kg capacity, accurate to 1kg	1
	15. Modified compaction proctor set with rammer 4.5kg and moulds as specified in MS 1056	1
	16. Modified compaction mould sample extruder as specified in MS 1056	1

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Test	Equipment	Quantity
	17. Steel scoop	1
	18. Measuring flask – 1000c.c	1
	19. Vernier calliper – 150mm	1
	20. Steel rule – 300mm	1
	21. Compression machine suitable for laboratory and field C.B.R.s with all fittings necessary for field and laboratory operation as specified in MS 1056	1
	22. C.B.R. moulds fitted with collars and base plates for compaction and soaking and tripods for small measurement fitted with dial gauges having 0.01mmdivisions and 25mm travel as specified in MS 1056	10
	23. Annular surcharge disc of 2.26kg weight	10
	24. Complete field density kit, sand replacement typesuitable for volume measurement of 0.005 cu.m to an accuracy of not less than 0.0001 cu.m as specified MS 1056	2
	25. Crowbar, pick and spade	1 of each
	26. Drying pans – 406mm x 406mm x 76mm	1
	27. Mackintosh / JKR Probe	1
	28. Malaysian Standard MS 1056 – Soils for Civil Engineering Purposes – Test Method, latest edition	1
	29. Malaysian Standard MS 2038 – Site Investigations – Code of Practise	1

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APPENDIX A/5

TABLE A2 : ENVIRONMENTAL QUALITY STANDARDS TO BE COMPLIED WITH BY THE CONTRACTOR

Aspects	Parameter	JKR Minimum Requirement for Non-EIA Projects	Environment Quality (Sewage) Regulations, 2009		National Water Quality Standards (NWQS)	
			Standard A	Standard B	Class IIA	Class IIB
Soil	Soil loss	Minimum earthwork Phase construction ≤ 6 berms/benches for slopes (≤ 6m per berm) Reuse topsoil				
Water [1,2]	Turbidity	≤ 200 NTU	-	-	≤ 50 NTU	
	Suspended Solid	≤ 100 mg/l	≤ 50 mg/l	≤ 100 mg/l	≤ 50 mg/l	
	Biochemical Oxygen Demand $_5$ @ 20°C $(BOD)_5$	≤ 50 mg/l	≤ 20 mg/l	≤ 50 mg/l	≤ 3 mg/l	
	Chemical Oxygen Demand (COD)	≤ 100 mg/l	≤ 120 mg/l	≤ 200 mg/l	≤ 25 mg/l	
	pH	5.5 – 9	6 – 9	5.5 – 9	6-9	
	E-Coli	≤ 400 counts / 100 ml	-	-	≤100 counts/ 100ml	≤400 counts / 100 ml
	Dissolved Oxygen(DO)	≥ 4 mg/l	-	-	5-7 mg/l	
	Oil and Grease	≤ 10 mg/l	≤ 5 mg/l	≤ 10mg/l	≤ 40 µg /l, N	
	Ammoniacal Nitrogen (river)	-	≤ 10 mg/l	≤ 20mg/l	≤ 0.3 mg /l	
Silt trap and sediment basin discharge	Turbidity	≤ 250 NTU				
	Total Suspended Solid	≤ 50 mg/l				
Air[3]	Particulate Matter (PM_{10}) (24hr) Particulate Matter ($PM_{2.5}$) (24hr)		≤120 µg/m^3/day ≤50 µg/m^3/day			

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Noise[4]	Equivalent Noise Level (L_{eq}), L_{10}, L_{90}	Receiving Land Use (residential)
		Day time (7.00 am – 7.00 pm) $L_{90} \leq 60$ dBA; $L_{10} \leq 75$ dBA; $L_{max} \leq 90$ dBA;
		Evening (7.00 pm – 10.00 pm) $L_{90} \leq 55$ dBA; $L_{10} \leq 70$ dBA; $L_{max} \leq 85$ dBA;
		Night time (10.00 pm – 7.00 am) Noise Sensitive Areas : $L_{Aeq} \leq 40$ dBA
		Suburban Areas : $L_{Aeq} \leq 45$ dBA Urban Areas : $L_{Aeq} \leq 50$ dBA
Vibration[5]	Vertical Vibration Peak Velocity (mm/s)	Not more than 3 mm/s at receiver location or across real property boundary.

Reference:

1) 2nd Schedule (Regulation 7), Environmental Quality (Sewage) Regulations 2009, Environmental Quality Act 1974.
   (i) Standard A: For location with downstream water intake
   (ii) Standard B: For location with no downstream water intake
2) National Water Quality Standards for Malaysia
   (i) Class IIA: Water Supply II – conventional treatment required
      a. Fishery II – sensitive aquatic species
   (ii) Class IIB: Recreational use with body contact
3) Recommended Malaysian Guidelines on Ambient Air Quality
4) Schedule 1 & Schedule 6, Planning Guidelines for Environmental Noise Limits & Control, (DOE, 2004)
5) Planning Guidelines for Vibration Limits and Control of the Environment (DOE, 2004)

Note: N - No visible floatable materials or debris or no objectionable odour, or no objectionable taste

For EIA Projects, all requirements should comply with Conditions of Approval (CoA) stipulated by DOE or other relevant authorities.

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TABLE OF CONTENTS

SECTION C: FOUNDATION WORKS AND WORKS BELOW LOWEST FLOOR LEVEL		PAGE
1.	Description	C/1
2.	General Requirements	C/1
3.	Soil Investigation Works	C/2
4.	Shallow Foundations	C/2
5.	Deep Foundations	C/8
6.	Subterranean Termites Treatment	C/58
7.	Damp Proof Membrane (DPM)	C/59
8.	Damp Proof Course (DPC)	C/59
9.	Filling Under Floors, Aprons Etc.	C/59
10.	Hardcore	C/59

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1. Description

This work shall consist of the supply, installation/ construction and testing of foundation works in accordance with this Specification and the lines, levels, grades and cross-sections shown on the Drawings and as directed by the S.O..

2. General Requirements

2.1. Setting Out

Setting out shall be carried out using the data and reference points as shown on the Drawings. The foundation position shall be marked with suitable identifiable pegs or markers at least 300mm length driven into the ground and the location marked with contrasting material. If raking piles are to be installed then the setting out pins, pegs or markers is located in an offset position at piling platform level taking into account of depth to cut-off level and rake value of the pile. In addition, the alignment of pins, pegs or markers shall indicate the direction of the rake. Immediately before pile installation or casting of foundation, the foundation point shall be checked by the Contractor again.

2.2. Excavation

2.2.1. Foundations shall be excavated to the levels and dimensions as shown on the Drawings, with sides trimmed and bottoms levelled and stepped as required.

2.2.2. All excavations shall be carried down to the required level as shown on the Drawings unless otherwise, the depths of foundation are decided on the site by the S.O.. The Contractor shall, at his own cost and expense, make good any over excavation below the required depth with suitable granular material or concrete as approved by the S.O..

2.3. Method Statement for Construction Operations

2.3.1. Two (2) weeks before the commencement of foundation works, the Contractor shall submit to the S.O., a detailed method statement for the foundation works. The method statement shall contain the followings:

2.3.1.1. A detailed construction sequence;

2.3.1.2. Shop Drawings showing details of all special requirements for the construction activities such as hoisting of piles, reinforcement cages, cast in fixing, etc;

2.3.1.3. Design calculation of key temporary works endorsed by a Professional Engineer;

2.3.1.4. Materials, plant and labour requirement at each construction stage;

2.3.1.5. Rate of production output based on resources allocated;

2.3.1.6. Other information relevant to the foundation works.

2.3.2. If requested by the S.O., the Contractor shall submit additional information pertaining to the method of construction (including temporary works and the use of the construction plant), calculation of the stresses, strain and deflection that will arise in the permanent works of any part thereof during construction.

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2.3.3. The Contractor shall not deviate from the methods which have been approved by the S.O. Approval by the S.O on the Contractor's proposed methods of construction shall not, in any way, relieve the Contractor of any of his duties or responsibilities under the Contract.

2.4. Unexpected Ground Conditions

The Contractor shall give a written notice immediately to the S.O. of any circumstances which, in the Contractor's opinion, indicate ground conditions that may differ from those expected by the Engineer as shown in the Drawings. The Contractor shall submit to the S.O. a report which contains all information available to the Contractor that will materially assist the S.O. in verifying the conditions reported, and to modify the design, if necessary.

2.5. Adjacent Structures

2.5.1. The Contractor shall carry out a dilapidation survey of adjacent properties to establish the existing condition of the adjacent structures and facilities prior to commencement of foundation works. Dilapidation surveys shall be conducted by a registered building surveyor and the result of the survey shall be submitted to the S.O. for record.

2.5.2. The Contractor shall pay very careful attention to the construction constraints imposed by adjacent structures. The Contractor shall take adequate measures to ensure his foundation works do not disturb or damage existing adjacent structures and surrounding environment. The Contractor shall provide a proposal for monitoring adjacent structures and surrounding environment for any detrimental effects arising from execution of the foundation works, so that appropriate and timely preventive action can be taken to minimise damage. The Contractor's proposal and monitoring programme shall be certified by a Professional Engineer.

2.5.3. The Contractor shall be responsible and bear the cost incurred including claims for damages arising from his execution of the foundation works.

2.6. Existing Services

The Contractor shall give all required notices to the appropriate utility authorities before commencement of foundation works. The Contractor shall also locate existing services by piloting, protect existing services, rectify any damage or interference to them and provide temporary support while repairs are being carried out if so required.

3. Soil Investigation Works

A soil investigation report shall be made available (if any) at the S.O.'s office for the Contractor information. The Contractor shall study the soil investigation report in detail and make his own interpretation of the information provided and make due allowance for the effect of site condition on his construction operation. No responsibility is assumed by the S.O.'s for any opinion or conclusion given in the soil investigation report.

4. Shallow Foundations

4.1. Definition

Shallow foundation is a foundation constructed in depth of not exceeding 3.0m from formation level. The depth to width ratio of the foundation is D/B≤ 3. Unless otherwise specified, shallow foundations shall conform with *MS 1756*. On no

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account shall isolated foundations be founded on made up or filled ground unless detailed engineering analysis has been carried out.

4.2. Type of shallow foundation

4.2.1. Pad Foundation

Pad Foundation is spread or isolated foundation of rectangular or square reinforced concrete pad that supports localized single point loads such as structural columns.

4.2.2. Strip Foundation

Strip Foundation is continuous strip of reinforced concrete that supports continuous loads such as walls.

4.2.3. Raft Foundation

Raft Foundation is a combined strip or pad foundation that may cover the entire area under a structure supporting several columns and walls.

4.3. Materials

4.3.1. Concrete

The materials and workmanship for concrete shall be as specified under SECTION D: CONCRETING of this Specification.

4.3.2. Reinforcement

The steel reinforcement shall be as specified under SECTION D: CONCRETING of this Specification.

4.4. Confirmatory of Allowable Bearing Capacity of Soil

4.4.1. The Contractor shall conduct probe test to confirm the required allowable bearing capacity. For pad foundation, the probe test shall be conducted at every column position. Other types of shallow foundation probe test shall be conducted as stated in the Drawings. The Probe test shall be carried out according to *Standard Specification for Road Works "SECTION 17: SITE INVESTIGATION"*. The Contractor shall submit the results to the S.O. for approval.

4.4.2. In the case where the allowable bearing capacity required is more than or equals to 150 kN/m^2, the Contractor shall carry out the plate bearing test as stated in the Drawings.

4.5. Plate Bearing Test

4.5.1. General

4.5.1.1. To verify the allowable bearing capacity, the Contractor shall carry out plate bearing test as shown on the Drawings and/or as instructed by the S.O.. The recommended size of the test plate shall not be less than 500mm in diameter. Selection of bearing plate is such that it shall not warp or deform under the applied load.

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4.5.1.2. The design and construction of the load application system shall be satisfactory for the required test. These details shall be made available prior to the commencement of testing.

4.5.2. Preparation at Test Level

4.5.2.1. Notice of Excavation

The Contractor shall give at least 48 hours' prior notice of commencement of excavation of the specified location to be tested.

4.5.2.2. Method of Excavation

(i) Excavation to the test level shall commence as quickly as practicable to minimize the effects of stress relief, particularly when in cohesive soils. Temporary ground support shall be installed as and when necessary. Where the test is to be carried out below the groundwater level in permeable ground, the equipment for lowering the water level shall be installed and water level shall be lowered before the excavation reaches the water table in order to prevent ground disturbance.

(ii) All loose materials and any embedded fragments shall be removed so that the area for the plate is generally level and as undisturbed as possible. For uneven surface, place a layer of sand, nowhere exceeding 100mm in thickness to obtain a level soil surface. The depth of the test area should be the same as the foundation depth of the structure to be built on site.

4.5.2.3. Supervision

(i) The setting up of plate bearing test equipment shall be carried out under competent supervision and the equipment shall be checked to ensure that the setting-up is satisfactory before the commencement of load test.

(ii) All tests shall be carried out only under the direction of an experienced and competent supervisor conversant with the test equipment and test procedures. All personnel operating the test equipment shall have been trained in its use.

4.5.2.4. Notice of Test

The Contractor shall give at least 24 hours' prior notice of the commencement of the test. No load shall be applied to the test area before the confirmation of the specified test procedure.

4.5.3. Protection of Testing Equipment

4.5.3.1. Protection from Weather

Throughout the test period, all equipment for measuring load and movement, and beams shall be protected from adverse effects of sun, wind and precipitation.

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4.5.3.2. Prevention of Disturbance

Construction activities and persons who are not involved in the testing processes shall be kept at a sufficient distance from the test location to avoid disturbance due to any unavoidable activity and its effects.

4.5.4. Method of Loading

4.5.4.1. Test Load

(i) The test load shall be applied in one (1) of the following ways:

a) By means of a jack which obtains its reaction from the load heavier than the required load such as concrete blocks, water in tanks or others;

b) By means of a jack which obtains its reaction from tension piles or other suitable anchors.

(ii) In all cases, the reaction load or its supports shall be placed sufficiently far from the proposed test position to reduce the influence on the results to a tolerable level. Care shall be taken to ensure that the reaction load remains stable throughout the test without the possibility of load tilting or collapsing.

(iii) In addition to the reaction load, it shall be necessary to provide a loading frame, a bearing plate, a loading column and a hydraulic jack or other appropriate type of load measuring device. The loading column shall be of sufficient strength to prevent undue buckling under the maximum load. The total weight of the kentledge or reaction force provided shall be at least 1.2 times the maximum test load.

(iv) In all cases the Contractor shall ensure that when the hydraulic jack and load measuring device are mounted on the loading column, the entire system shall be stable up to the maximum load to be applied. If in the course of carrying out a test, any unforeseen occurrence should take place, further loading shall not be applied until a proper engineering assessment of the prevailing conditions has been made and steps taken to rectify any fault.

(v) Where an inadequacy in any part of the system might constitute a hazard, means shall be provided to enable the test to be controlled from a position clear of the kentledge stack or test frame.

(vi) The hydraulic jack, pump, hoses, pipes, couplings and other apparatus to be operated under hydraulic pressure shall be capable to withstand a pressure of 1.5 times the maximum pressure used in the test without leaking. Test certificate shall be submitted before carrying the test.

(vii) The maximum test load expressed as a reading on the gauge in use shall be displayed and all operators shall be made aware of this limit.

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(viii) When method (a) is used, care shall be taken to ensure that the centre of gravity of the kentledge is on the axis of the loading column. The longitudinal axis of the loading column and the centre of the bearing plate shall coincide, and the contact shall be such that any tendency for the plate to tilt is resisted.

(ix) When method (b) is used, all anchor piles shall be at a distance of at least three (3) times the bearing plate diameter from the centre of the plate.

(x) If the anchor piles are to be permanent working piles, their levels shall be observed during application of the test load to ensure no residual uplift occurs.

(xi) Alternatively, the Contractor may propose the use of other types, patented or otherwise, in which case the requirements as below shall be fully complied with.

4.5.4.2. Contractor's Load Test System

The Contractor may propose to use other different types from those specified. The proposal shall be submitted to the S.O. at least 90 days before the date of testing. The suitability or adequacy of any system shall be determined by the S.O.. In the event that the testing system proposed by the Contractor is acceptable, the Contractor shall obtain a Professional Engineer's endorsement on the load settlement results.

4.5.4.3. Deformation Measurement System

The deformation measurement components of the test apparatus shall be made to the required accuracy. Where a dial gauge or other measuring device is used on the plate, a reference beam may serve as the datum. At least four (4) dial gauges or other measuring devices are to be used for measuring the displacement. All settlement devices shall be readable to 0.01 mm. In addition, the levelling equipment shall be readable to 0.1 mm and placed at stable datum when specified. The levelling staff shall have a bubble attached to it so that the verticality of the staff can be checked.

4.5.5. Testing Procedure

4.5.5.1. General

Prior to the performance of any load test, the Contractor shall submit to the S.O. for his approval, Work Drawings showing the method and equipment he proposes to use in the performance of the load test and the measurement of settlements.

4.5.5.2. Maintained Load Test

(i) The Maintained Load Test shall be carried out as follows:

a) The Full Test Load (FTL) on a tested ground shall be three (3) times that of the Allowable Bearing Capacity specified on the Drawings.

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b) The test shall be carried out in three (3) cycles with first cycle test up to working load, second cycle test up to twice the Allowable Bearing Capacity and third cycle test up to full test load.

c) The load shall be applied in increments of 20% of the working load, until a maximum test load is reached. Each increment of load shall be applied as smoothly and as expeditiously as possible. Settlement readings and time observations shall be taken before and after each new load increment.

d) Settlement reading shall be taken for every 3 minutes. A time-settlement graph shall be plotted to indicate when the rate of settlement of 0.05mm per minute is reached. A further increment of load shall be applied when this rate of settlement is achieved, or until a minimum time of 15 minutes has elapsed, whichever is later. The process shall be repeated until the maximum test load is reached.

e) The maximum load at each cycle shall then be maintained for a minimum of 2 hours, and time-settlement readings shall be taken at regular intervals, as for the earlier load stages.

f) The test load shall then be decreased in four (4) equal stages, and time-settlement readings shall be as specified a foresaid, until the movement ceases. At least 15 minutes interval shall be allowed between the unloading decrements.

g) During testing, if the result from each dial gauge or other measuring devices differ by more than 20%, the Contractor shall release the load and recheck the arrangement of the load cell and redo the load test.

h) Settlement readings shall be made immediately after and before every load increment is applied or removed.

The procedure of plate bearing test shall be as specified in **Table C1**.

4.5.6. Submission of Results

4.5.6.1. Full test data, complete field test records and results from the readout unit shall be jointly signed by the S.O.'s representative and the Contractor's authorised agent and submit to the S.O. immediately upon completion of the load test. The submission shall also consist of the following information:

(i) Stage of loading

(ii) The depth of the test level from ground level

(iii) The plate sizes

(iv) Period for which the load was held

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(v) Final load and load increment

(vi) Maximum settlement

4.5.6.2. These are to be plotted as time-settlement graphs.

4.5.7. Interpretation of Test Results

The S.O.'s interpretation and conclusions on the test results shall be final. Unless otherwise specified, the plate bearing test shall be deemed to have failed if the total settlement at any stage of loading exceeds 25mm.

5. Deep Foundations

5.1. Definition

Deep foundation is defined as those where the depth is more than 3m below the formation level. The types of deep foundation covered under this specification are as follows, and not limited to:

(i) Precast reinforced concrete piles

(ii) Prestressed spun concrete piles

(iii) Steel H section piles

(iv) Steel pipe piles

(v) Bored cast in-situ piles

(vi) Micro piles

(vii) Caisson

5.1.1. Trial Pile

A trial pile is a pile installed for ultimate pile load test for which the pile is normally tested to 2.5 to 3.5 times working load, or until failure occurs so that the design parameters can be verified. The location of the trial pile shall be as per drawing or as directed by the S.O.. The trial pile shall not be used as a working pile.

5.1.2. Preliminary Pile

A preliminary pile is a pile installed before the commencement of the main piling works for the purpose of establishing the pile installation criteria for subsequent working piles and for confirming the adequacy of the design, dimensions and working load. This pile can be used as a working pile unless otherwise directed by the S.O..

5.1.3. Working Pile

A working pile is a pile which is installed as part of the permanent foundation work.

5.1.4. Working Load

The Working Load is the Design Load modified to allow for group effect, pile

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spacing or any other factors changing the efficiency of the total foundation from that of a single isolated pile and is at least equal to the dead plus imposed loads on the pile together with the down drag or uplift loads as appropriate.

5.1.5. Test Load

Test load is load applied to a selected pile to confirm that it is suitable for the load at the settlement specified. The Full Test Load (FTL) on a pile shall be twice the Working Load (WL) noted on the Drawings.

5.2. General Requirement

5.2.1. Position

For a pile cut off at or above ground level the maximum permitted deviation of the pile centre from the centre points shown on the Drawings shall not exceed 75mm in any direction. No pile edge shall be nearer than 150mm from the edge of any pile cap.

5.2.2. Verticality

The maximum permitted deviation of the finished pile from the vertical is 1 in 75 at any level.

5.2.3. Rake

The piling rig shall be set and maintained to attain the required rake. The maximum permitted deviation of the finished pile from the specified rake or the rake shown on the Drawings is 1 in 25.

5.2.4. Forcible Corrections

Forcible corrections to concrete piles shall not be permitted. Forcible corrections may be permitted to specific types of piles if approved by the S.O.. However, no forcible corrections shall be made to piles which have deviated beyond the permissible limits specified in sub-sections 5.2.1., 5.2.2., 5.2.3..

5.2.5. Piles Out of Alignment or Position

The Contractor shall, if instructed by the S.O., extract and reinstall any pile which has deviated out of position or alignment by more than the specified limit, or alternatively the substructure shall be modified and certified by a Professional Engineer with Practicing Certificate to the approval of the S.O.. The cost of such extraction and reinstallation or any extra cost in the design and construction of a modified foundation shall be borne by the Contractor if such extra works have been made necessary due to the error and/or negligence of the Contractor.

5.2.6. Welding

5.2.6.1. Unless otherwise specified or shown on the drawing, all welds shall be full penetration butt welds complying with the requirements of *BS EN 12334*.

5.2.6.2. Redriving of the piles shall only be allowed after the welded joints have sufficiently air cooled to 100°C or below.

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5.2.7. Welders' Qualification

5.2.7.1. All welding works shall be executed by qualified welders with valid certificate issued by approved Authorities such as CIAST.

5.2.7.2. Only welders who are qualified to *BS EN 287-1* or who have attained a similar standard shall be employed on the Works. Proof of welders' proficiency shall be made available on request by the S.O..

5.2.8. Preboring And Jetting of Piles

5.2.8.1. Piles shall not be prebored without the written approval of the S.O.. Preboring of piles may be allowed for the following reasons:

(i) To ease pile drivability by breaking through hard layers;

(ii) To reduce lateral soil displacement where this could cause damage to nearby structure;

(iii) To investigate and possibly deal with obstruction in the ground.

5.2.8.2. The piles shall be in contact with surrounding soil and the completed piles shall comply with the requirements of this Specification. Diameter of preboring shall be in accordance with sub-section 5.7.2.1. of this Specification. If boring is oversize, any gap between the tube and ground shall be filled with compacted sand prior to driving the pile.

5.2.8.3. In some soils, jetting may lift adjacent structure or cause undermining of nearby foundations. Pile shall not be jetted without the written approval of the S.O.. Prior to jetting any pile, the Contractor shall submit to the S.O. details of the equipment to be used and the proposed method to be adopted.

5.2.9. Damage to Piles

5.2.9.1. The Contractor shall execute the work in such a manner so as to minimise damage to piles.

5.2.9.2. All piles damaged during handling, transporting, pitching, and driving or at any other time shall be replaced by the Contractor at his own expense. All piles found damaged shall be taken out from site.

5.2.10. Safety Precautions

The Contractor shall take safety precautions throughout the piling operation in accordance with the requirements of the relevant laws and by-laws.

5.2.11. Records

The Contractor shall keep records of the installation of each pile and shall submit two (2) signed copies of these records to the S.O. not later than the next working day after the pile has been installed. The signed records shall form part of the records for the Works. Any unexpected driving or boring conditions shall be noted in the records.

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5.2.12. As-built Locations Plan

The Contractor shall submit an As-built pile location plan certified by a Licensed Surveyor to the S.O. within seven (7) working days of completion of the last pile. Partial as-built plan may be submitted throughout construction of the foundation for verification by the S.O..

5.3. Precast Reinforced Concrete Piles

5.3.1. Material

5.3.1.1. Reinforced Concrete

(i) The materials shall be as specified in **Table C2** or as in *MS 1314*.

(ii) The materials and workmanship for concrete shall be as specified under SECTION D: CONCRETING of this Specification.

5.3.1.2. Pile Shoes

(i) The type of pile shoes to be used shall be as shown on the Drawings and shall comply with *MS 1314*:

a) "Chilled-hardened" cast iron shoes as used for making grey iron castings to *BS EN 1561*, Grade 10; or

b) Mild steel to *BS EN 10025* or equivalent, Grade 50B; or

c) Cast steel to *BS EN 10293*, Grade A.

(ii) Mild steel straps cast into the shoes shall be as shown on the Drawings. Rock shoes where required shall consist of wrought iron shoes and mild steel straps cast into "Chilled-hardened" cast iron blocks, as shown on the Drawings.

(iii) The shoes shall be truly coaxial and firmly embedded on to end of the pile.

5.3.2. Supply and Delivery of Piles

The Contractor shall only use precast concrete piles supplied by approved manufacturers. The Contractor shall produce the mill certificate and Perakuan Pematuhan Standard (PPS) from CIDB to the S.O. for approval. No piles shall be allowed for transportation before achieving concrete strength of 30N/mm^2.

5.3.3. Handling and Storage

5.3.3.1. The method and sequence of lifting, handling, transporting and storing piles shall be such that piles are not damaged or having crack width greater than 0.1mm. Only the designed lifting and support points shall be used. During transport and storage, piles shall be placed on adequate supports located under the lifting points of the piles. Piles shall be stored and stacked on firm ground not liable to settlement under the weight of piles. The supports shall be vertically above one another. All piles within a stack shall be in groups of the same length. Packings of uniform

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thicknesses shall be provided between piles at the lifting points.

5.3.3.2. No pile shall be driven before the specified characteristic strength of appropriate grade of concrete has been achieved.

5.3.4. Installation of Precast Reinforced Concrete Piles

5.3.4.1. Pitching of Piles

Piles shall be pitched accurately in the positions as shown on the Drawings. At all stages during driving and until the pile has set or been installed to the required length, all exposed piles shall be adequately supported and restrained by means of leaders, trestles, temporary supports or other guide arrangements to maintain position and alignment and to prevent buckling and damage to the piles.

5.3.4.2. Driving of Piles

(i) Each pile shall be installed continuously until the specified set and/or depth has been reached, unless otherwise approved by the S.O.. The installation equipment used shall be of such type and capacity to the approval of the S.O.. A follower (long dolly) shall not be used unless approved by S.O., subject to the following requirements:

a) The first pile in each pile system and every tenth pile driven thereafter shall be driven full length, without a follower, to verify that adequate pile length is being attained to develop the desired pile capacity.

b) The follower and pile shall be held and maintained in equal and proper alignment during driving;

c) The follower shall be of such material and dimension to permit the piles to be driven to the length determined necessary from the driving of the full-length piles;

d) The final position and alignment of the first two (2) piles installed with follower in each substructure unit shall be verified to be in accordance with the location tolerances specified in sub-section 5.2.1. before additional piles are installed.

(ii) Follower shall not be used in driving of raked pile.

(iii) A detailed record of the driving resistance over the full length of each pile shall be kept. The log shall record the number of blows for every 0.3m of pile penetration. The Contractor shall inform the S.O. without delay if an unexpected change in driving characteristics is encountered. Where required by the S.O. set shall be taken at approved intervals during the driving to establish the behaviour of the piles.

(iv) A set shall be taken only in the presence of the S.O. unless otherwise approved. The Contractor shall provide all facilities to enable the S.O. to check driving resistances. The final set of a pile other than as friction pile, shall be recorded as the penetration in millimetres per 10 blows. The

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temporary compression of the pile shall be recorded if required.

(v) When a set is being measured, the following requirements shall be met:

a) The pile shall be in good condition, without damage or distortion;

b) The hammer blow shall be in line with the axis of the pile and the impact surface shall be flat and perpendicular to the hammer axis;

c) The hammer shall be in good condition, delivering the required energy per blow and operating correctly;

d) The rebound shall be measured and recorded accordingly.

(vi) When an acceptable resistance or set appears to have been reached, the driving of pile should be suspended for an interval sufficient to permit the soil to recover from the disturbance of pile driving, and then resumed to determine whether there is any increase or decrease in resistance.

(vii) In soils that dilate when disturbed e.g. silts and some shales, negative pore pressure can be set up temporarily and the driving resistance may fall as these pore pressure returns to normal. In clays disturbance can cause positive pore pressure to develop and the strength of the soil may increase as these dissipate. The necessary time interval before redriving may vary from one (1) hour to two (2) hours for non-cohesive soils or two (2) days or more for clays.

(viii) The resistance at the start of redriving is more likely to be representative of the true bearing value of the pile, and each redriving result should be taken into consideration when deciding the pile penetration length.

(ix) Piles shall be driven in an approved sequence to minimise the detrimental effects of heave and lateral displacement of the ground. When required, careful levelling from a datum unaffected by the piling shall be made on the pile heads already driven, before and after driving subsequent piles. Piles which have been displaced vertically by more than 3 mm as a result of driving adjacent piles shall be redriven to the required resistance.

5.3.4.3. Repair of Damaged Pile Heads

(i) If a pile is to be subjected to further driving, concrete in the damaged pile head shall be cut off square at sound concrete, and all loose particles shall be removed by wire brushing, followed by washing with water. Care shall be exercised to ensure that the reinforcement in the pile head is not in any way damaged. Any damaged reinforcement shall be made good to the satisfaction of the S.O.. The head shall be replaced with concrete of similar grade or higher.

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(ii) The new head shall be cast truly in line with the remainder of the pile and be properly cured and allowed to harden sufficiently to develop the strength necessary for further driving. If a pile has been driven to the required set or depth but the level of sound concrete of the pile is below cut-off level, the pile shall be made good to the cut-off level as described above so that the completed foundation will safely withstand the specified ultimate load.

5.3.4.4. Lengthening of Piles

(i) Where piles have to be lengthened, other than by means of welding of steel plates as detailed on the Drawings, the reinforcement shall be stripped of all surrounding concrete for a distance equal to forty (40) times the diameter of the main reinforcement measured from the pile head for spliced joints and 300mm for butt welded joints and all lateral reinforcement shall be removed.

(ii) The new concrete shall be of the same grade or higher as the original concrete on pile and shall be adequately compacted.

(iii) The lengthening bars shall butt on the exposed bars in true alignment and shall be butt welded as specified or shall be spliced with bars of the same diameter as the main pile bars, 60 diameters in length and lapping the main bars for a distance of 40 diameters above and below the joint and shall be securely bound with 1.63mm soft annealed iron wire.

(iv) New binders of similar size shall be provided and spaced at half the centres of the binders in the main body of the pile and shall be securely bound with 1.63mm soft annealed iron wire and the pile extended by concreting in properly constructed mounds to the length required.

(v) Care shall be taken to form the joint between the old and new concrete as specified hereinbefore. The old concrete shall be adequately roughened, and all loose particles shall be removed by wire brushing, followed by washing with clean water. The extension shall be truly in line at all stages of handling and driving with the remainder of the pile and be properly cured and allowed to harden sufficiently to develop the strength necessary for further driving.

5.3.4.5. Pile Joint

The bending strength test of pile joint shall be done for laterally loaded pile only to determine the bending capacity at each respective joint. The test shall be done as in sub-section 5.3.4.6. provided that the joint is positioned at the centre of the span. The bending capacity at the pile joint shall be greater than the bending capacity of the pile body by 10%. The result shall be submitted to S.O. for approval prior to driving of any pile.

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5.3.4.6. Pile Bending Strength Test

Pile bending strength test shall be performed in accordance with Appendix C/1 of this Specification.

5.3.4.7. Cutting and Preparation of Pile Heads

(i) Piles shall be driven in an approved sequence to minimise the detrimental effects of heave and lateral displacement of the ground. When required, careful levelling from a datum unaffected by the piling shall be made on the pile heads already driven, before and after driving subsequent piles. Piles which have been displaced vertically by more than 3 mm as a result of driving adjacent piles shall be redriven to the required resistance.

(ii) When a pile has been driven to the required set or depth, the head of the pile shall be cut off to the level specified or shown on the Drawings. This shall be done carefully to avoid shattering or otherwise damaging the rest of the pile. Any cracked or defective concrete shall be cut away and made good with new concrete properly bonded to the old. The length of reinforcing bars projecting above this level shall be as shown or specified on the Drawings. If the length of reinforcing bars left projecting is insufficient, then they shall be extended by either of the following methods:

a) Butt Welding

The extension bars shall butt on the projecting bars in true alignment and shall be butt welded in accordance with sub-section 5.6.3. of this Specification.

b) Splicing

The projecting bars shall be stripped of all surrounding concrete as necessary to allow splices of length 60 diameters with extension bars. The extension bars shall be securely bound to the projecting bars with 1.63mm soft annealed iron wire. The concrete of the pile shall be made good either before or together with the casting of the pile cap, all to the satisfaction of the S.O.. Care shall be taken to avoid cracking or otherwise damaging the rest of the pile. Any cracked or defective concrete shall be cut away and made good with new concrete properly bonded to the old.

5.4. Prestressed Spun Concrete Piles

5.4.1. Material

5.4.1.1. Concrete

(i) The materials shall be as specified in **Table C2** or as in *MS1314.*

(ii) The materials and workmanship for concrete shall be as specified under SECTION D: CONCRETING of this Specification.

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5.4.1.2. Reinforcement

(i) The prestressing tendons and the non-prestressing reinforcement of the piles including workmanship shall be as specified under SECTION D: CONCRETING of this Specification and as per manufacturer details and shall comply with *MS 1314*.

(ii) Prestressing steel shall comply with *JIS G3137* or *BS 4486* or *BS 5896* or *ASTM A416* or equivalent.

(iii) A Certificate of Conformance is required for every delivery of reinforcement.

5.4.1.3. End Plates

Details of end plates of each length of pile shall be as per manufacturer details and shall comply with MS 1314. Each end plate shall be machine-finished and provided with a chamfer to accommodate the welding when two (2) lengths of pile are jointed.

5.4.1.4. Pile Shoes

If specified, the type of pile shoes to be used shall be as per manufacturer details and shall comply with *MS 1314*.

5.4.2. Supply and Delivery of Piles

The contractor shall only use Prestressed Spun Concrete piles supplied by approved manufacturers. The Contractor shall produce the mill certificate and Perakuan Pematuhan Standard (PPS) from CIDB to the S.O. for approval. No piles shall be allowed for transportation before achieving concrete strength of 30N/mm2.

5.4.3. Handling and Storage

Handling, storing and transporting prestressed concrete pile shall be done in such a manner as to avoid excessive bending stresses, cracking, spalling or injurious result. Piles that are damaged during handling and transporting shall be replaced by Contractor at his own expenses. All damaged and rejected piles shall be removed from the site.

5.4.4. Installation of Prestressed Spun Concrete Piles

5.4.4.1. Pitching and Installation of Piles

Pitching and installation of piles shall be in accordance with sub-sections 5.3.4.1. and 5.3.4.2. Piles shall not be installed until the concrete has achieved the specified characteristic strength.

If repair of damaged pile head is required, refer sub-section 5.3.4.3.

5.4.4.2. Lengthening of Piles

Where lengthening of piles is required, the details of the joint shall be as shown on the Drawings and in accordance with sub-section 5.6.3.. When two (2) lengths of pile are jointed, the end plates

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shall bear over their complete areas. Shims for packing shall not be accepted. For laterally loaded pile, the pile joint shall be in accordance with sub-section 5.3.5.5..

5.4.4.3. Cutting and Preparation of Pile Heads

When a pile has been driven to the required set or depth, the head of the pile shall be cut off to the level specified or shown on the Drawings using a diamond cutter. Pile heads shall be constructed to details as per manufacturer details and shall comply with *MS 1314*.

5.5. Steel H-Section Piles

5.5.1. Material

All steel H- section piles including the cast steel shoe shall comply with the requirement of *BS EN 10025* and/ or *BS EN 10029*, *BS EN 10210*, *BS EN 10113*, *BS EN 10293*, *BS 7668* or *JIS A5526*. The profile and grade to be used are as specified or as shown on the Drawings. The Contractor shall provide mill certificate of the manufactured H-section pile as may be requested by S.O..

5.5.2. Manufacture and Storage of Steel H-Section Piles

5.5.2.1. Manufacturing Tolerances

(i) All piles shall be of the type and cross-sectional dimensions as designed. For standard rolled sections the dimensional tolerances and weight shall comply with the relevant established standard. Length tolerance of H-section steel bearing piles shall be ± 50mm in accordance with *BS EN 10034*.

(ii) The rolling or proprietary tolerances for H-section steel bearing piles shall be such that the actual weight of the section does not differ from the theoretical weight by more than ± 2.5%.

5.5.2.2. Straightness of Sections

(i) All piles shall be of the type and cross-sectional dimensions as designed. For standard rolled sections the dimensional tolerances and weight shall comply with the relevant established standard. Length tolerance of H-section steel bearing piles shall be ± 50mm in accordance with *BS EN 10034*.

(ii) For standard rolled sections the deviation from straightness shall be within the compliance provisions of BS EN 10034. When two (2) or more rolled sections are joined by butt-jointing, the deviation from straightness shall not exceed 1/600 of the overall length of the pile.

(iii) For proprietary sections made up from rolled sections and for tubular piles the deviation from straightness on any longitudinal face shall not exceed 1/600 of the length of the pile nor 5mm in any 3m length.

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(iv) Based on the results of pile driving resistance and/or load tests carried out on piles driven on the Site, the S.O. may, from time to time, instruct the lengths of piles to be modified.

5.5.2.3. Strengthening of Piles

Unless otherwise approved by the S.O., the strengthening of the toe of the pile in lieu of a shoe, or the strengthening of the head of a pile, shall be made from material of the same grade or strength class as the pile and to the details as shown on the Drawings.

5.5.2.4. Marking of Piles

Each pile shall be clearly marked with white undeletable marking at the flanged head showing its reference number and overall length. In addition, each pile shall be marked at intervals of 500mm along its length before being driven. The length of piles to be supplied shall be as shown on the Drawings subject to revision by the S.O..

5.5.2.5. Handling and Storage

(i) All piles shall be of the type and cross-sectional dimensions as designed. For standard rolled sections the dimensional tolerances and weight shall comply with the relevant established standard. Length tolerance of H-section steel bearing piles shall be ± 50mm in accordance with *BS EN 10034*.

(ii) All operations such as handling and transporting of piles shall be carried out in such a manner that damage to piles and their coatings is minimized. Piles that are damaged during handling and transporting shall be replaced by the Contractor at his own expense. All damaged and rejected piles shall be removed from the Site forthwith.

(iii) Piles within a stack shall be in groups of the same length and on approved supports.

5.5.3. Installation of Steel H-Section Piles

5.5.3.1. Pitching and Driving of Piles

Pitching and driving of piles shall be in accordance with sub-sections 5.3.4.1. and 5.3.4.2

5.5.3.2. Lengthening of Piles

(i) Where lengthening of piles is required, the piles shall be joined by butt welding. Butt welded joints shall be stiffened with plates fillet welded on all four (4) sides as detailed on the Drawings. All welding shall be continuous and complying with *BS 638, BS EN 1011-1* and *BS EN 1011-2* and *BS EN 1993* for arc welding and *BS EN ISO 4577* for resistance welding as appropriate. All welding procedures shall comply to *BS EN ISO 15607*, *BS EN ISO 15609-1, BS EN ISO 15613* and *BS EN ISO 15614-1*. The type and size of weld shall be as detailed on the Drawings. The Contractor shall make available full details of the welding procedure and

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electrodes with drawings and schedule as requested by S.O..

(ii) Weld tests shall be performed by radiographic or ultrasonic methods as specified. Provided that satisfactory results are being obtained, one (1) test of a length of 300mm shall be made for 10% or more of the number of welded splices.

5.5.3.3. Cutting and Preparation of Pile Heads

(i) When a pile has been driven to the required set or depth and before encasing in concrete, the piles shall be cut to within 20mm tolerance of the levels shown on the Drawings. Pile heads shall be constructed to the details as shown on the Drawings.

(ii) The remaining section which can be reused for lengthening of piles shall be stored and protected as directed by the S.O..

5.6. Steel Pipe Piles

5.6.1. Materials

All steel pipes shall comply with *BS EN 10296*, *BS EN 10297* and *BS EN 10305* with regard to sectional dimensions and the steel shall comply with the requirements of *BS EN 10113* or *BS EN 10025*. Mill certificates shall be provided to the S.O. prior to pile installation.

5.6.2. Manufacture and Storage of Steel Pipe Piles

5.6.2.1. Fabrication of Piles

(i) Pile lengths shall be set up so that the differences in dimensions are matched as evenly as possible. The length of piles to be supplied shall be as shown on the Drawings and subject to revision by the S.O..

(ii) Based on the results of pile driving resistance and/or load tests carried out on piles driven on the Site, the S.O. may, from time to time, order the lengths of piles to be modified.

(iii) For tubular piles where the load will be carried by the wall of the pile, and if the pile will be subjected to loads that induce reversal of stress during or after construction, the external diameter at any section as measured by using a steel tape on the circumference shall not differ from the theoretical diameter by more than ± 1%.

(iv) The ends of all tubular piles as manufactured shall be within a tolerance on ovality of ± 1% as measured by a ring gauge for a distance of 100mm at each end of the pile length.

(v) The root edges or root faces of lengths of piles that are to be shop butt-welded shall not differ by more than 25% of the thickness of pile walls not exceeding 12mm thick or by more than 3mm for piles where the wall is thicker than 12mm. When piles of unequal wall thickness are to be butt-welded, the thickness of the thinner material shall be the criterion.

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5.6.2.2. Matching of Pile Lengths

Longitudinal seam welds and spiral seam welds of lengths of pipe piles forming a completed pile shall, whenever possible, be evenly staggered. However, if in order to obtain a satisfactory match of the ends of piles or the specified straightness, where the longitudinal seams or spiral seams are brought closely to one (1) alignment at the joint, then they shall be staggered by at least 100mm.

5.6.2.3. Straightness of Piles

The deviation of pile from straightness shall be within the compliance provisions of *BS EN 10034* and in accordance with sub-section 5.5.2.2..

5.6.2.4. Fabrication of Piles on Site

When pile lengths are to be made up on Site, all test procedures and dimensional tolerances shall conform to the Specification for the supply of pipe materials. Adequate facilities shall be provided for supporting and aligning the lengths of pile.

5.6.2.5. Handling and Storage

All piles within a stack shall be in groups of the same length and on approved supports. All operations such as handling, transporting and pitching of piles shall be carried out in a manner such that no damage occurs to piles and their coatings. Piles that are damaged during handling and transporting shall be replaced by the Contractor at his own expense. All damaged and rejected piles shall be removed from the Site forthwith.

5.6.2.6. Marking of Piles

Each pile shall be clearly marked with white undeletable marking near the pile head showing its reference number and overall length. In addition, for pile installation monitoring purposes, each pile shall be marked at intervals of 300mm along its length before being driven.

5.6.3. Workmanship

5.6.3.1. Welding Procedures

(i) The Contractor shall submit for approval, full details of the welding procedures and electrodes with Drawings and schedules as may be necessary. Tests shall be undertaken as may be required by the S.O. and shall be in accordance with the requirements of *BS EN 288*

(ii) All welding procedures shall have been qualified to *BS EN ISO 15607, BS EN ISO 15609-1, BS EN ISO 15613* and *BS EN ISO 15614-1* and the Contractor shall make available full details of the welding procedures and electrodes, with Drawings and schedules as may be necessary. Tests shall be undertaken as may be required by the S.O..

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5.6.3.2. Weld Tests

(i) During production of welded tube piles, at least one (1) radiograph or ultrasonic test approximately 300mm long shall be required on each end of a length as a spot check on weld quality. This shall be taken on a circumferential or longitudinal weld and its position shall be as directed by the S.O..

(ii) For spirally welded piles, one (1) of the following tests shall be carried out:

a) For tubes of wall thickness 12mm or less, three (3) spot check radiographs, one (1) at each end of each length of the tube as manufactured and one (1) at a position to be chosen at the time of testing by the S.O. and spot check radiographs as required by the S.O. on the weld joints between strip lengths;

b) For tubes of any wall thickness, continuous ultra-sonic examination over the whole weld, supplemented where necessary by radiographs to investigate defects revealed by the ultrasonic examination.

Weld tests shall be performed by radiographic or ultrasonic methods as specified. Provided that satisfactory results are being obtained, one (1) test of a length of 300mm shall be made for 10% or more of the number of welded splices in the case where the load will be carried by the wall or section of the pile will not normally exceed 10%. Results shall be made available to the S.O. within ten (10) days of completion of the tests.

5.6.3.3. Standards for Welds

(i) Longitudinal Welds in Tubular Piles

For piles of longitudinal or spiral weld manufactured where the load will be carried by the wall of the pile, and if the pile will be subject to loads which induce reversal of stress during or after construction other than driving stresses, the standard for interpretation of non-destructive testing shall be the American Petroleum Institute Specification 5L. The maximum permissible height of weld reinforcement shall not exceed 3.2mm for wall thicknesses not exceeding 12.7mm and 4.8mm for wall thicknesses greater than 12.7mm.

(ii) Circumferential Welds

a) For circumferential welds in tubular piles the same maximum height of weld reinforcement as specified above for longitudinal welds in tubular piles shall apply, the standard for interpretation of non-destructive testing shall be the American Petroleum Institute Specification 5L.

b) If the results of any weld test do not conform to the specified requirements, two (2) additional specimens

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from the same length of pile shall be tested. In the case of failure of one (1) or both of these additional tests, the length of pile covered by the test shall be rejected.

5.6.4. Protective Coatings

The term 'coating' shall include the primer and the coats specified. If protective coatings are specified, the preparation of surfaces and the application of the coatings shall be carried out by skilled labour having experience in the preparation of the coatings specified.

Corrosion protection of permanent steel structure in accordance with environment classified as C4 according to *BS EN ISO 12944-2* shall require durability resistance of 25 years.

The protective coating system shall comply with *BS EN ISO 12944-5* and shall comprise of at least:

5.6.4.1. First Coating or Prime Coat Zinc Epoxy 0.08mm thick

5.6.4.2. Two (2) layers of Intermediate coating 0.08mm thick epoxy for each layer

5.6.4.3. Top coating of Polyurethane 0.08mm thick

5.6.4.4. Surface Preparation

(i) All surfaces to be coated shall be clean and dry

(ii) Surface preparation to cleanliness SA 2 ½ in accordance with *BS EN ISO 12944-4* and *BS EN ISO 8501-1*.

(iii) Blast-cleaning shall be done after fabrication. Unless an instantaneous-recovery blasting machine is used, the cleaned steel surface shall be air-blasted with clean dry air and vacuum-cleaned or otherwise freed from abrasive residues and dust immediately after cleaning.

5.6.4.5. Application and Type of Primer

(i) Immediately after surface preparation, the surface shall be coated with an approved primer or the specified coating to avoid recontamination. No primer coat shall be applied to a metal surface which is not thoroughly dry. Within 4 hours after surface preparation, before visible deterioration takes place, the surface shall be coated with an appropriate primer or the specified coating.

(ii) The primer shall be compatible with the specified coating and shall be such that if subsequent welding or cutting is to be carried out it shall not emit noxious fumes or be detrimental to the welding.

5.6.4.6. Control of Humidity during Coating

(i) No coating shall be applied when the surface metal temperature is less than 3°C above the dew point temperature or when the humidity could have an adverse effect on the coat.

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(ii) When heating or ventilation is used to secure suitable conditions to allow coating to proceed, care shall be taken to ensure the heating or ventilation of a local surface does not have an adverse effect on adjacent surfaces or work already done.

5.6.4.7. Part to Be Welded

The coating within 200mm of a weld shall be applied after welding. The method of application shall comply with the manufacturer's recommendations.

5.6.4.8. Thickness, Number and Colour of Coats

(i) The minimum dry film thickness of the finished coating, including the minimum dry film thickness of each coat and the minimum number of coats that are to be applied, shall be as specified and shown on the Drawings. Coatings shall be applied in accordance with the manufacturer's instructions.

(ii) The nominal thickness of the finished coating and each coat shall be as specified. The average coat or finished coating thickness shall be equal to or greater than the specified nominal thickness. In no case shall any coat or finished coating be less than 75% of the nominal thickness. Each coat shall be applied only after an interval that ensures the proper hardening or curing of the previous coat.

(iii) Where more than one (1) coat is applied to a surface, each coat shall be different colour from the previous coat. The colour sequence and final coating colour shall be established prior to application of coatings.

5.6.4.9. Inspection of Coatings and Acceptability

(i) The finished coating shall be generally smooth, of a dense and uniform texture and free from sharp protuberances or pin holes.

(ii) Any coat damaged by subsequent processes or which has deteriorated to an extent such that proper adhesion of the coating may not be obtained or maintained, shall be recleaned to the original standard and recoated with the specified sequence of coats.

(iii) The completed coating shall be checked for thickness and continuity by an approved magnetic gauge or detector. Areas where the thickness is less than that specified shall receive approved additional treatment.

(iv) When specified, the completed coating shall be checked for adhesion by means of an adhesion test to *BS EN ISO 2409, BS 3900-E6*, carried out on 10% of the piles. The adhesion of any completed coating shall not be worse than Classification 2. If adhesion tests on the initial batch are satisfactory, then on further batches only 1% of the piles shall be tested. Adhesion tests shall not be carried out until seven (7) days after coating.

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5.6.5. Installation of Steel Pipe Piles

5.6.5.1. Pitching and Driving of Piles

Pitching and driving of piles shall be in accordance with sub-sections 5.3.4.1. and 5.3.4.2..

5.6.5.2. Lengthening of Piles

Unless otherwise approved, where lengthening of piles is required, the piles shall be joined by butt welding along the entire periphery as detailed on the Drawings. All procedures shall be in accordance with sub-sections 5.5.3.2..

5.6.5.3. Cutting and Preparation of Pile Heads

When a pile has been driven to the required set or depth and before encasing in concrete, the pile shall be cut to within 20mm of the levels shown on the Drawings and protective coatings shall be removed from the surfaces of the pile head 100mm above the soffit of the concrete. Pile heads shall be constructed to details as shown on the Drawings. If a steel structure is to be welded to piles, the piles shall be cut square and to within +/- 5mm.

5.6.5.4. Concreting of Pile Shaft

(i) If concreting is specified or shown on the Drawings after the pile has been cut off to the specified level, the shaft shall be filled with concrete in a continuous operation. The method of placing shall be approved by the S.O..

(ii) The reinforcement cage in the pile shall be made sufficiently rigid and kept in its correct position during concreting.

(iii) The length of the reinforcing bars projecting above the pile cut-off level shall be as shown on the Drawings.

(iv) Mixing and placing concrete infill shall be done in accordance to sub-section 5.7.4..

5.7. Bored Cast-In-Situ Piles

5.7.1. Materials

5.7.1.1. Concrete

The materials and workmanship for concrete shall be as specified under SECTION D: CONCRETING of this Specification. The grade of the concrete shall be as shown on the Drawings.

5.7.1.2. Reinforcement

The steel reinforcement shall be as specified under SECTION D: CONCRETING of this Specification. The details of the steel reinforcement shall be as shown on the Drawings.

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5.7.2. Boring Operations

5.7.2.1. Diameter of Piles

(i) The diameter of piles shall not be less than the specified designed diameter at any level throughout its length.

(ii) The auger width shall be checked as necessary and recorded for each pile to ensure the specified diameter is achieved. A tolerance of 0% to +5% on the auger width is permissible.

5.7.2.2. Boring

(i) Boring shall be carried down to the depth as required and directed by the S.O.. When deemed necessary by the S.O., the Contractor shall take soil samples while the pile is being bored. The samples shall be taken to an approved Laboratory for testing, if necessary or as directed by the S.O..

(ii) Sampling and all subsequent handling and testing shall be carried out in accordance with *BS EN ISO 1997, BS EN ISO 14688, BS EN ISO 14689, BS EN ISO 22475* and *BS EN ISO 22476.*

(iii) Piles shall not be bored at a distance less than three (3) times diameter close to other piles which have been cast less than 24 hours or contain unset concrete.

5.7.2.3. Coring in Rock

(i) The Contactor shall submit a method statement when coring in rock. Chiselling of rock may cause micro cracks in surrounding rock and is not allowed. Rock coring shall mean coring of sound bedrock using a coring bucket or any other approved method. Confirmatory test to verify sound rock shall be carried out by the Contractor.

(ii) Definition of coring in rock shall fulfil all two (2) criteria below:

a) Change of tools to rock coring tools, and

b) The rock materials shall be verified by carrying out point load test on at least five (5) rock samples to achieve minimum corrected point load strength index Is(50) of 2.0 MPa on samples not less than 30mm and not more than 85mm with the preferred dimension about 50mm based on *ASTM D5731*. The Minimum five (5) samples shall be taken for every 1m depth of rock coring.

c) Any coring/boring in other materials that do not fulfil the definition of rock coring mentioned above shall be considered as boring in soils.

d) The provision of point load test equipment at site for the above-mentioned testing shall be by Contractor's own cost and time. The point load test equipment shall be

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calibrated, and a valid calibration certificate shall be made available to the S.O. upon requested.

5.7.2.4. Socketing in rock to fulfil design criteria

The socketed length shall be as specified in the Drawing or as directed by the S.O.. The starting of the socketing length may not be the same as the coring depth of rock. Rock socket length shall be measured from the flattened horizontal bedrock surface. This flat horizontal surface shall be proved using Kelly bar or steel bar at a minimum of five positions over the borehole.

5.7.2.5. Permanent Casing

Permanent casings which form part of the designed pile shall be as specified on the Drawings.

5.7.2.6. Temporary Casing

(i) Temporary casings of approved quality or an approved alternative method shall be used to maintain the stability of pile excavations which might otherwise collapse.

(ii) Temporary casings shall be free from significant distortion. They shall be of uniform cross-section throughout each continuous length. During concreting they shall be free from internal projections and encrusted concrete which might prevent the proper formation of the piles being cast.

(iii) If a temporary casing is required to stabilise the borehole, it shall be extended beyond the unstable strata for one (1) metre or more to prevent the inflow of soil and the formation of cavities in the surrounding ground.

5.7.2.7. Stability of Piling Excavations Using Support Fluid

(i) Where the use of support fluid or a column of water is approved for maintaining the stability of boring, the level of fluid or column of water in the excavation shall be maintained such that the fluid pressure always exceeds the pressure exerted by the soil and external ground water. The fluid water level shall be maintained at a level not less than 1m above the level of the external ground water.

(ii) An adequate temporary casing shall be used in conjunction with the method to ensure the stability of the strata near ground level until concrete has been placed.

(iii) In the event of a rapid loss of bentonite suspension, polymeric fluids or water from the piling excavation, the excavation shall be backfilled with lean concrete or well compacted sand as specified in SECTION D:CONCRETING of this Specification without delay and the instructions of the S.O. shall be obtained prior to resuming boring at that location.

5.7.2.8. Support Fluid

(i) Support fluid material, bentonite, shall comply with the

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manufacturer's certificate and mix proportion. A certificate shall be obtained by the Contractor from the manufacturer of the bentonite powder, showing the properties of each consignment delivered to the site. This certificate shall be made available to the S.O.. Test should be carried out at regular interval to ensure consistency of the batching process.

(ii) Polymer can be used as an alternative to bentonite to maintain stability of the bores with the approval of the S.O..

(iii) Bentonite or polymer shall be mixed thoroughly with water complying with MS 28 to make a suspension which will maintain the stability of the pile excavation for the period necessary to place concrete and complete construction. Preparation of the suspension shall comply with the manufacturer's instructions.

(iv) Where saline or chemically contaminated ground water occurs, special precautions shall be taken to modify the bentonite suspension or pre-hydrate the bentonite in fresh water to render it suitable in all aspects for the construction of piles.

(v) Minimum frequency of testing are as follows:

a) Fresh drilling fluid

b) Drilling fluid shall be tested before concreting

c) Recycle drilling fluid taken from desanding machine

d) Drilling fluid left in the bored hole for more than 12 hours

(vi) The frequency of testing drilling fluid and the method and procedure of sampling shall be proposed by the Contractor and agreed by the S.O. before the commencement of the work. The frequency may subsequently be varied with the approval of the S.O.. Control tests for density shall be carried out daily on the drilling fluid using suitable apparatus. The measuring device shall be calibrated to read within 0.01g/ml. The results shall be within the ranges stated in **Table C6** for bentonite and **Table C7** for polymer drilling fluids.

(vii) All reasonable steps shall be taken to prevent the spillage of drilling fluid on the site. Discarded drilling fluid shall be removed from the site without delay and such removal shall comply with the regulations of the relevant Authorities.

(viii) If sand content is more than 5%, the Contractor shall carry out desanding to screen out sand from drilling fluid before concreting.

5.7.2.9. Spillage and Disposal

(i) All reasonable steps shall be taken to prevent the spillage of bentonite suspension or water on the site in areas outside the immediate vicinity of the boring operations. Discarded

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bentonite water shall be removed from the site without delay. The disposal of bentonite water shall comply with the regulations of the Local Authorities and other related Government Agencies.

(ii) Entrained solids shall be removed from the polymeric fluid by use of flocculants before disposal of the remaining fluid to the approved designated disposal sites by the Authorities.

5.7.2.10. Pumping of Boreholes

Pumping from the borehole shall not be permitted unless casings have been placed into the stable stratum to prevent the further ingress of water in significant quantities from other strata into the borehole, or, unless it can be shown that pumping will not have a detrimental effect on the surrounding soil or its properties.

5.7.2.11. Continuity of Construction

(i) A pile constructed in the stable soil, without the use of temporary casings or other support, shall be bored and concreted without delay to ensure that the soil characteristics are not significantly altered. The time interval between completion of boring and placing of concrete should preferably be within six (6) hours. Where prolonged delay in construction arises, the bore may have to be backfilled with lean concrete as specified in SECTION D: CONCRETING of this Specification or well compacted sand to minimise deterioration of the shaft.

(ii) If the bored pile installation is carried out using permanent or temporary casing, the time period between completion of boring operation and completion of concreting is recommended not to exceed twenty-four (24) hours.

5.7.2.12. Enlarged Pile Bases

The enlarged pile base shall not be smaller than the dimensions specified and shall be concentric with the pile shaft to within 10% of the shaft diameter. A sloping surface of the frustum forming the enlargement shall make an angle to the horizontal of not less than 55º. At the specified diameter of the under ream at the perimeter of the base there shall be a minimum height of 150mm.

5.7.2.13. Cleanliness of Pile Bases

On completion of boring, loose, disturbed or remoulded soil or fragments of rock shall be removed from the base of the pile.

5.7.2.14. Inspection

For dry boreholes, each hole shall be inspected prior to the placing of concrete in it. The inspection shall be carried out from the ground surface in the case where the borehole diameter is less than 1500mm. Where the borehole diameter exceeds 1500mm, adequate equipment shall be provided to enable the Contractor and the S.O. to descend into the borehole for the purpose of inspection. All works shall conform to the requirement of *BS 5573:1978* Safety Precaution in the Construction of Large

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Diameter Borehole for Piling and Other Purposes. For wet boreholes, i.e. holes filled with drilling fluid or water, a suitable probe shall be provided to ascertain the evenness and cleanliness of the pile base.

5.7.3. Placing of Reinforcement

5.7.3.1. Joints in Longitudinal Bars

Reinforcement shall be such that the full strength of the bar is effective across the joint and the joint shall be made so that there is no relative displacement of the reinforcement during the construction of the pile and the spacing of the reinforcing bars shall be maintained in such a way that proper concreting shall not be impeded.

5.7.3.2. Positions of Reinforcement

Adequate spacer blocks, guide tubes, and lifting wires shall be provided so as to maintain the reinforcing steel in the positions as specified.

Where temporary casings are employed, the longitudinal reinforcement shall extend at least 1m below the bottom of the casing so that movement of the reinforcement during extraction of the casing is minimised.

5.7.4. Concreting Operations

5.7.4.1. Placing Concrete

The method of placing and the workability of concrete shall be such that a continuous monolithic concrete shaft of the full cross-section is formed.

5.7.4.2. Workability of Concrete

The workability of the concrete shall be determined by the slump test as described in MS EN 206.

The suggested slump details for typical concreting situations shall be as specified in **Table C3** of this Specification. The slump shall be measured at the time of discharge into the borehole.

5.7.4.3. Compaction

Internal vibrators shall not be used to compact concrete unless it can be satisfied that they will not cause segregation or arching of the concrete.

5.7.4.4. Placing Concrete in Dry Borings

(i) Approved measures shall be taken to avoid segregation and bleeding and to ensure that the concrete at the bottom of the pile is not deficient in grout.

(ii) Where piles are vertical, concrete may be poured through a tremie so that the flow is directed and does not hit reinforcement bars or the side of the hole. Chutes extending

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to near the base shall be employed for raking piles of large diameter.

5.7.4.5. Placing Concrete under Water or Support Fluid

(i) Concrete to be placed under water or support fluid shall be placed by tremie unless otherwise approved and shall not be discharged freely into the water or support fluid. Before placing concrete, measures shall be taken to ensure that there is no accumulation of silt or other material at the base of the boring.

(ii) The hopper and pipe of the tremie shall be clean and watertight throughout. The pipe shall extend to the base of the boring and a sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the pipe of the tremie and the water or support fluid. The tremie pipe outlet shall be kept at least 1.5 metres below the surface of the concrete at all stages in the pour. The Contractor shall develop a system of level checks for the concrete and pipe outlet to ensure that this requirement is met. The tremie pipe shall be withdrawn upward gently below the concrete level and shall not be subject to any shock or violent movement either in dislodging the concrete within the pipe or for any other reason.

(iii) At all times, a sufficient quantity of concrete shall be maintained within the tremie pipe to ensure that the pressure from it exceeds that from the water or support fluid. The internal diameter of the tremie pipe shall not be less than 150mm for concrete made with 20mm aggregate and not less than 200mm for concrete made with 40mm aggregate.

(iv) The tremie pipe shall be so designed that external projections are minimised, allowing the tremie pipe to pass through the reinforcing cage without causing damage or uplifting. The internal face of the tremie pipe shall be free from projections.

5.7.5. Extraction of Casing

5.7.5.1. Workability of Concrete

Temporary casings shall be extracted while the concrete within them remains sufficiently workable to ensure that the concrete is not lifted together with the casing.

5.7.5.2. Concrete Level

(i) When the casing is being extracted, a sufficient quantity of concrete shall be maintained within it to ensure that the pressure from external water, drilling fluid or soil is exceeded and that the pile is neither reduced in section nor contaminated.

(ii) No concrete shall be placed in the bore once the bottom of the casing has been lifted above the top of the concrete. It shall be placed continuously as the casing is extracted until the desired head of concrete is obtained.

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(iii) The top of concrete level shall be brought to at least 1000mm or more as specified on the Drawings above the cut-off level of the pile or the concrete be allowed to be flushed out from the bore to permit all laitance and weak concrete to be removed and thus ensure that it can be properly keyed into the pile cap.

(iv) Adequate precautions shall be taken in all cases where excess heads of water or drilling fluid could be a cause for concern as the casing is withdrawn because of the displacement of water or fluid by the concrete as it flows into its final position against the wall of the pile shaft. Where double casings are used in the boring, the proposed method of working shall be with the approval of the S.O..

5.7.5.3. Vibrating Extractors

The use of vibrating extractors shall be permitted subject to S.O.'s approval. The work shall be carried out in such a manner and times to ensure the quality of concrete in the bore, minimise nuisance and disturbance to the surrounding.

5.7.6. Construction of Pile Heads

5.7.6.1. Water Levels

In the event of the ground water level being higher than the required pile head casting level shown on the Drawings, the Contractor shall submit his proposals for approval prior to placing concrete. The pile head shall not be left below the ground water level unless approved precautions are taken.

5.7.6.2. Cutting and Preparation of Pile Heads

Pile head shall be cut using handheld cutting equipment or hydraulic splitters. Pile heads after cutting shall consist of sound concrete and free from debris. Pile heads shall be constructed to the details shown on the Drawings.

5.7.6.3. Temporary Backfilling Above Pile Casting Level

After each pile has been cast, any empty bore remaining shall be protected and shall be carefully backfilled as soon as possible with well compacted sand.

5.7.6.4. Piling Records

(i) Complete piling records shall be kept by the Contractor during pile installation. The Contractor shall submit in duplicate the following information to the S.O.:

a) Signed records of all piles as the work proceeds. Individual pile record shall be submitted not later than noon of the next working day after the pile was installed. The signed records shall form record of the work. Any unexpected installation condition shall be noted in the record.

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b) Upon completion, compile a record of the work as carried out and provide As-built Drawings. The Drawings shall be prepared and endorsed by the Licensed Surveyor.

(ii) The format of the record shall be approved by the S.O. and shall contain, but not be limited to the following information where applicable:

a) Date and time of boring, speed of boring for every meter

b) Type of boring machine

c) Date and time of concreting

d) Depth of borehole, detail of soil/rock strata penetrated, soil/rock samples taken, and in-situ tests carried out

e) Concrete mix

f) Type of stabilizing fluids

g) Method of concreting

h) Standing ground water level

i) Length of temporary/permanent casing

j) Length and details of reinforcement.

k) Estimated and actual volume of concrete required to form the pile shaft.

(iii) All record shall bear the names of person who records and person who checks.

5.7.7. Pressure Grouting of Piles

5.7.7.1. Grouting of piles shall be done if encounter any unstable shaft or base disturbance to ensure compatible performance of piles. Method of grouting shall be carefully controlled to prevent pile uplift and avoid other potential problems with prior approval of the S.O..

5.7.7.2. Pressure grouting shall not be used to compensate for poor pile construction practice.

5.8. Micropiles

5.8.1. Materials

5.8.1.1. Reinforcement

The type of reinforcement to be used, the diameter and/or thickness, grade, yield strength and working stress shall be as specified or as shown on the Drawings.

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5.8.1.2. Grout

(i) Unless otherwise specified, the grout shall be non-shrink cement grout. The grout mix design such as the water-cement ratio, the minimum cement and grout strength at 7 and 28 days shall be as specified and shown on the Drawings.

(ii) If admixtures are used, details of admixtures shall be submitted to the S.O. for approval before commencement of works. The use of the admixture shall fully comply with the manufacturer's instructions.

5.8.2. Drilling Operation

5.8.2.1. Diameter of Piles

The diameter of piles shall not be less than the specified/designed diameter at any level throughout its length and shall be in accordance with sub-section 5.7.2.1..

5.8.2.2. Drilling

The Contractor shall submit to the S.O. details of drilling equipment and drilling procedure for approval before commencement of works. Drilling operations shall be carried out in accordance with the relevant requirements of sub-section 5.7.2..

5.8.3. Grouting Operations

5.8.3.1. Mixing and Placing Grout

(i) The Contractor shall provide details of the method and equipment used in grout mixing. Further information such as grouting pressure, grouting procedure, grouting equipment and techniques employed in grouting underwater shall also be furnished for approval.

(ii) Grout shall be mixed on Site and shall be free from segregation, slumping and bleeding. Grout shall be pumped into its final position in one (1) continuous operation as soon as possible and in no case more than half an hour after mixing.

(iii) Micropile shall be grouted in one continuous process. If there is significant loss of grout, the Contractor may choose to carry out pre-grouting in stages as necessary to prevent further loss of grout for the construction of micropile. Method statement of pre-grouting including details of equipment, materials and procedures have to be reviewed and approved by the S.O.. If after the process of pre-grouting and re-drilling of the hole is required, the Contractor has to bear the cost and the time of the pre-grouting and re-drilling.

5.8.3.2. Testing Grout

(i) Grout shall be tested in accordance with *BS EN 445* and *ASTM C939*.

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(ii) If the grout cube as tested fails to satisfy the criteria as prescribed in the Specification and Drawings, the pile constructed using this batch of grout shall be rejected. The Contractor shall undertake all necessary additional and consequential remedial works to the approval of the S.O..

5.8.4. Construction of Pile Heads

5.8.4.1. Lengthening of Piles

Where lengthening is required, the pile reinforcement unit shall be connected on Site to the details as shown on the Drawings. Other means of jointing reinforcement shall be to the approval of the S.O..

5.8.4.2. Cutting and Preparation of Pile Heads

Pile heads shall be constructed to the details as shown on the Drawings.

5.8.5. Casing

Where permanent casing or temporary casing is specified or required upon approval of S.O., the requirements shall be in accordance with sub-section 5.7.5..

5.9. Caisson

5.9.1. Materials

5.9.1.1. Concrete

The material and workmanship for concrete shall be as specified under SECTION D: CONCRETING of this Specification. The grade of the concrete shall be as shown on the Drawings.

5.9.1.2. Reinforcement

The steel reinforcement shall be as specified under SECTION D: CONCRETING of this Specification. The details of steel reinforcement shall be as shown in the Drawings.

5.9.1.3. Permanent Liner

Lining shall be constructed sufficiently quickly after excavation and in sufficiently short section to prevent inflow of soil or excessive inflow of water. In-situ concrete tapered rings used as permanent liners shall be at least 100mm thick and shall not exceed 1m deep. The ring shall be constructed with well compacted concrete. The concrete shall be cast tight up against the side of excavation. The material and workmanship for concrete shall be as specified under SECTION D: CONCRETING of this Specification. The grade of the concrete shall be as shown on the Drawings.

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5.9.2. Excavation operations

5.9.2.1. Diameter of piles

The effective diameters of the caisson shaft and bell out shall not be less than those shown on the Drawings nor exceed the specified dimension by more than 50mm at any level of the whole shaft.

5.9.2.2. Depth of excavation

The anticipated depth of all caissons is as indicated in the Drawings. All caissons shall be taken to a depth pre-determined by the Drawings into the required bearing stratum over the full area of the caisson base. The caisson base shall be levelled. Where bell-outs are required they shall be formed entirely within the bearing stratum

5.9.2.3. Method statement

The Contractor shall adopt a method of construction that will not cause settlement or disturbance of any kind to adjacent structures, pavement, public or private services. The Contractor shall establish an approved monitoring system and take regular readings and prepare and submit reports to the S.O. in the format and quantity as requested. The Contractor shall modify the method of construction if the effects of ground movement are detected in any such structures, pavements and services.

5.9.2.4. Minimum clear working space

The minimum clear working space inside a caisson (i.e. excluding the lining) shall not less than 1.8m. Caissons with enlarge base shall not be used unless otherwise specified.

5.9.2.5. Method of excavation

Excavation for caissons shall be carried out using manual methods or power tools. Blasting shall not be used unless agreed by the S.O.. If blasting is adopted, the following have to be adhered to;

(i) Obtain approval from relevant Authorities and comply with the requirement of statutory Authorities,

(ii) The position of blast holes and the size of charges shall be such that shattering of rock beyond the caisson is minimized,

(iii) The rock face shall not be shattered within the toe-in or bell-out zone at the bottom of the caissons, and

(iv) The caisson opening shall be covered to prevent the projection of fragments of material.

5.9.2.6. Rock Proving

(i) Rock proving load test machine shall be provided at site for testing of recovered rock sample for shaft and base selected by S.O..

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(ii) In addition, the rock below each shall be proved before concreting by sinking minimum 'N' size drill holes, as specified in MS1056, to a minimum of 5m below the proposed caisson base or 3 times the bell out diameter of the caisson whichever is the greater.

(iii) Socket length shall be measured from the flattened horizontal bedrock surface.

5.9.2.7. Inspection and record of caisson shaft and base

(i) Each caisson base shall be inspected, logged and photographed by qualified Engineer from the Contractor before inspection and checking by the S.O.. CV of the Engineer from the Contractor shall be submitted for review and approved by the S.O..

(ii) The shaft of every caisson shall be properly logged, especially one encountering rock surface during excavation.

(iii) Prior to any concreting works, the shaft and base (for rock only) for the caisson shall be properly cleaned by using water jet or other approved method so that no debris or soil stains the shaft surface or base. The base of each completed excavation shall be carefully trimmed and levelled to the minimum required toe level. Approval of the base of any caisson by the S.O. shall not relieve the Contractor of his responsibilities and obligations under the terms of the Contract.

(iv) Photographs at 4 sides of the shaft, i.e. $0^{o,}$ 90°, 180° and 360° and rock base shall be taken by the Contractor after the cleaning works and attached together with the inspection forms for the S.O..

(v) The shaft and base of each caisson must be approved by S.O. before any reinforcement and concreting works are carried out.

5.9.2.8. Stability of the excavation

(i) The shaft and base of each caisson must be approved by S.O. before any reinforcement and concreting works are carried out.

(ii) The stability of excavations for caissons shall be maintained where necessary by linings.

(iii) Shaft lining shall be placed as soon as practicable and not more than 24hours after each increment of excavation is complete.

(iv) Voids between the lining and face of excavation shall be filled with concrete of the same grade as the lining or with others material as agreed by the S.O..

(v) Any unstable layers of subsoil encountered shall be stabilized by grouting or similar methods. No further excavation will be permitted to proceed until the stabilization

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works are completed.

5.9.2.9. Dewatering

(i) The shaft and base of each caisson must be approved by S.O. before any reinforcement and concreting works are carried out.

(ii) A comprehensive Method Statement on dewatering for caisson construction shall be submitted by the Contractor for approval.

(iii) As a minimum measure, individual caissons shall be kept dry during excavation and inspection by pumping from a sump or pilot hole within each caisson as necessary. Submersible pumps shall be used and placed in a sump not more than 0.6m deep and approximately 0.5m diameter sunk in advance of the main excavation. Pump operation shall be continuous until the caisson is concreted.

(iv) The Contractor shall at all times use, to a minimum degree, of dewatering that is required for the works to proceed. It will be the Contractor's responsibility to ensure that draw down outside the site does not exceed the limits as specified by the S.O.. The Contractor's method statement shall include details of measures proposed to meet this requirement. All such measures shall be subject to approval by the S.O..

5.9.2.10. Water pumped from caissons

(i) The Contractor shall at all times use, to a minimum degree, of dewatering that is required for the works to proceed. It will be the Contractor's responsibility to ensure that draw down outside the site does not exceed the limits as specified by the S.O.. The Contractor's method statement shall include details of measures proposed to meet this requirement. All such measures shall be subject to approval by the S.O..

(ii) Water sample pumped from caissons shall be screened through sedimentation or settling tank and quantities of sediment shall be monitored to ensure that excessive fines are not removed from the soil. Should excessive fines be observed from any caisson, pumping from that caisson shall cease and the S.O. notified immediately.

(iii) When required by the S.O., the Contractor shall record the rate of pumping from the individual caissons and shall submit two copies of the records on the following day. The Contractor shall report immediately to the S.O. any marked change in the rate of flow of water from any caisson.

(iv) Water pumped from caissons or the ground shall not be discharged directly onto the ground surface without suitable and adequate provisions for drainage being made.

(v) The Contractor shall be responsible for obtaining all necessary permissions from statutory authorities for discharging water into the public drainage system.

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5.9.2.11. Cessation of excavation

(i) If the excavation and pumping from caissons results in settlement outside the site of more than 25mm, or as otherwise specified by the S.O., caisson construction and dewatering at the appropriate locations shall immediately cease and the S.O. notified.

(ii) The Contractor shall not recommence caisson construction or dewatering until the construction sequence has been reviewed and measures taken to prevent further settlement occurring. In all cases, work shall not be recommended to proceed without the approval of the S.O..

(iii) The Contractor shall be responsible for any damage, and any claims arising from such damage, which may result from settlement caused by caisson construction. The Contractor shall make good the damage as quickly as possible.

5.9.2.12. Emergencies

(i) The Contractor shall submit Emergency Response Plan (ERP) for review and approval by the S.O..

(ii) If the sides of a caisson start to collapse or an emergency arises which could lead to instability of the excavation, the Contractor shall immediately inform the S.O. and implement measures to preserve the stability of the caisson and of neighbouring structures and services.

5.9.2.13. Disposal of spoil

Soil removed from the excavation shall be removed from the site and disposed off in accordance with statutory requirements.

5.9.2.14. Sealing and Scaling of caissons

(i) The Contractor shall submit Emergency Response Plan (ERP) for review and approval by the S.O..

(ii) Leakage of groundwater through liners or into unlined shafts of hand-dug caissons shall be stopped by a method agreed upon by the S.O..

(iii) Loose rock on the face of unlined shaft shall be scaled off and removed before concreting.

(iv) On completion of excavation, spoils shall be removed from the base of caisson before concreting.

5.9.2.15. Inspection of excavations

(i) Each hole shall be inspected prior to the placing of concrete in it. Adequate equipment shall be provided to enable the Contractor and the S.O. to descend into the hole for the purpose of inspection. All works shall conform to the requirement of *BS 5573*: Safety Precaution in the Construction of Large Diameter Boreholes for Piling and Other Purposes.

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(ii) Prior to any concreting works, the shaft and base (for rock only) for the caisson shall be properly cleaned by using water jet or other approved methods so that no debris or soil stains the shaft surface or base. The base of each completed excavation shall be carefully trimmed and levelled to the minimum required toe level and approved by the S.O..

5.9.3. Placing of reinforcement

5.9.3.1. Joints in longitudinal bars

Reinforcement shall be such that the full strength of the bar is effective across the joint and the joint shall be made so that there is no relative displacement of reinforcement during construction of the pile and the spacing of the reinforcing bars shall be maintained in such a way that proper concreting shall not be impeded.

5.9.3.2. Positions of reinforcement

Adequate spacer blocks, guides tubes and lifting wires shall be provided so as to maintain the reinforcing steel in the position as specified.

5.9.4. Concreting operations

5.9.4.1. Placing concrete

(i) All subsoil and debris shall be removed from the caisson to the satisfaction of S.O.. No concrete shall be placed without approval of the S.O..

(ii) The method of placing and the workability of concrete shall be such that a continuous monolithic concrete shaft of the full section is formed.

5.9.4.2. Workability of concrete

(i) The workability of the concrete shall be determined by the slump test as described in *MS EN 206*.

(ii) The suggested slump details for typical concreting situations shall be as specified in **Table C3** of this Specification. The slump shall be measured at the time of discharge into the borehole.

5.9.4.3. Compaction

Internal vibrators shall not be used to compact concrete unless it can be proven that they will not cause segregation or arching of the concrete.

5.9.4.4. Placing concrete in dry borings

(i) Approved measures shall be taken to avoid segregation and bleeding and to ensure that the concrete at the bottom of the pile is not deficient in grout.
(ii) Concrete may be poured through a funnel with a length of tube so that the flow is directed and does not hit

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reinforcement bars or the side of the hole.

5.9.5. Construction of pile heads

5.9.5.1. Water levels

Water levels shall be in accordance with sub-sections 5.7.6.1..

5.9.5.2. Cutting and preparation of pile heads

Cutting and preparation of pile heads shall be in accordance with sub-sections 5.7.6.2..

5.9.5.3. Temporary backfilling above pile casting level

Temporary backfilling above pile casting level shall be in accordance with sub-sections 5.7.6.3..

5.9.6. Piling records

5.9.6.1. Complete piling records shall be kept by the Contractor during pile installation. The Contractor shall submit in duplicate the following information to the S.O.:

(i) Signed records of all piles as the work proceeds. Individual pile record shall be submitted not later than noon of the next working day after the pile is installed. The signed records shall form documented record of the work. Any unexpected installation condition shall be noted in the record.

(ii) Upon completion, compile a record of the work as carried out and provide As-built Drawings. The Drawings shall be prepared and endorsed by the Licensed Surveyor.

5.9.6.2. The format of the record shall be approved by the S.O. and shall contain, but not limited to the following information where applicable:

(i) Caisson number.

(ii) Level of top of concreted caisson shaft referred to Principal Datum.

(iii) Level of top concrete lining referred to Principal Datum.

(iv) Depth to base of caisson from top of concreted shaft.

(v) Date(s) and time(s) of starts and finishes of excavations and concreting.

(vi) Minimum internal diameter of caisson lining.

(vii) Full details of any bell-out and minimum diameter of caisson base.

(viii) Thickness and details of concrete lining.

(ix) Description of ground excavated, and methods employed.

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(x) Length and details of reinforcement.

(xi) Estimated and actual volume of concrete required to form the pile shaft

(xii) Details of all obstructions, delays and other interruptions.

(xiii) Complete record of bedrock proving test.

(xiv) Final log and photographic record of caisson base.

(xv) Results of core test.

(xvi) All tests made on materials used in the works.

5.9.6.3. All records shall bear the names of person who records and person who checks.

5.9.7. Safety precaution

5.9.7.1. General

The Contractor shall at all times comply with the Government regulations for safety on work sites. The working facilities provided and the manner in which the works are conducted shall conform to the requirements of *BS 5573*: Safety Precaution in the Construction of Large Diameter Boreholes for Piling and Other Purposes.

5.9.7.2. Electrical Equipment

All electrical equipment shall be wired in accordance with *'Regulations for the Electrical Equipment of Buildings'*, Latest Edition, published by the *Institution of Electrical Engineers*.

5.9.7.3. Caisson Shafts

(i) The Contractor shall ensure that construction of the concrete caisson lining follows the excavation sufficiently closely to ensure the stability of the works.

(ii) The Contractor shall ensure that the concrete caisson lining extends a minimum of 0.25m above and adjacent surrounding ground at all times.

(iii) The Contractor shall keep all caissons not being worked covered at all times by a stout safety cover capable of supporting a uniformly distributed load of 1.5kN/m2 and preventing entry of water into the caisson. The cover shall be attached rigidly to the top of the concrete lining to fully cover the caisson.

(iv) If an access platform is provided at the top of the caisson the hole through which access to the caisson is gained shall be equipped with a stout 150mm high kicker board around the full perimeter. The area adjacent to the kicker board shall be kept clear at all times of all loose rubble, tools or other objects which may be knocked into the caisson.

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(v) The Contractor shall at all times ensure that there is a hessian rope of minimum diameter 20mm securely fixed at ground level and passing over a block on the frame above the caisson and reaching the bottom of the caisson.

5.9.7.4. Ventilation

(i) The Contractor shall provide sufficient compressors, air pumps, etc. including an adequate number of standby spares, in order to ensure complete ventilation of all shafts whilst work is in progress and prevent the build-up of noxious gases or de-oxygenation.

(ii) Exhaust pipes from boring machines, winches and other equipment shall be so positioned that no exhaust gas enters the caisson or the intake of the air compressors supplying the fresh air to the base of the caisson.

5.9.7.5. Lighting

The Contractor shall maintain adequate artificial lighting at all times in all caisson shafts being worked.

5.9.7.6. Water in Caisson Shafts

The Contractor shall provide suitable methods approved by the S.O. to ensure the safety of the works.

5.9.7.7. Access and Communications

The Contractor shall provide access to all levels of shafts at all times whilst work is in progress and a means of communication with workmen in the shafts of a type that gives immediate notice to and from the surface of hazards which directly affects safety in the shaft.

5.9.7.8. Removal of Persons from Caisson Shafts

The Contractor shall provide a means whereby persons, including those semi-conscious or unconscious, may be removed rapidly and safely from caissons.

5.9.7.9. Oxygen

The Contractor shall provide at all times equipment and spares to enable oxygen to be administered to persons in an asphyxiated condition. The Contractor shall ensure the permanent presence on site during hours of work of an operator fully trained in the use of this equipment.

5.10. Static Pile Load Testing

5.10.1. General

5.10.1.1. To verify the working load, the Contractor shall carry out pile load test as shown on the Drawings and / or as instructed by the S.O..

5.10.1.2. The design and construction of the load application system shall be satisfactory for the required test. These details shall be made

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available prior to the commencement of testing.

5.10.2. Construction of Pile to Be Tested

5.10.2.1. Notice of Construction

The Contractor shall give at least 48 hours' notice of commencement of construction of any preliminary pile which is to be tested.

5.10.2.2. Method of Construction

Each preliminary test pile shall be constructed in a manner similar to that to be used for the construction of the working piles and by the use of similar equipment and material. Extra reinforcement and concrete of increased strength will be permitted in the shafts of preliminary piles where necessary and agreed by the S.O. for carrying out the testing.

5.10.2.3. Boring or Driving Record

For each preliminary pile which is to be tested, a detailed record of the conditions experienced during boring or of the progress during driving, shall be made available daily, not later than noon on the next working day. Where soil samples are required to be taken or in-situ tests to be made, the Contractor shall present the results without delay.

5.10.2.4. Concrete Test Cube

Three (3) test cubes shall be made from the concrete used in the preliminary test pile and from the concrete used for building up the working pile. If the concrete pile is extended or capped for the purpose of testing, a further three (3) cubes shall be made from the corresponding batch of concrete. The cube shall be made and tested in accordance with SECTION D: CONCRETING of this Specification.

5.10.2.5. Cut-Off Level

(i) The cut-off level for the preliminary test pile/working piles shall be as specified on the Drawings or as directed by the S.O..

(ii) Where the cut-off level of working piles is below the ground level at the time of pile installation and where it is required to carry out a load test from that installation level, either allowance shall be made in the determination of the twice working load for friction which may be developed between the cut-off level and the existing ground level, or the piling may be sleeved appropriately or otherwise protected to eliminate friction which can develop over the extended length.

5.10.2.6. Preparation for Pile Head for Testing

(i) For a pile that is tested in compression, the pile head or cap shall be formed to give the plane surface which is normal to the axis of the pile, sufficiently large area to accommodate

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the loading and settlement measuring equipment and adequately reinforced or protected to prevent damage from the concentrated application of load from the loading equipment.

(ii) For a pile that is tested in tension, means it shall be provided for transmitting the test load axially without inducing moments in the pile. The connection between the pile and the loading equipment shall be constructed in such a manner as to provide strength equal to the maximum load which is to be applied to the pile during the test with an appropriate factor of safety on the structural design.

5.10.2.7. Supervision

(i) The setting up of pile testing equipment shall be carried out under competent supervision and the equipment shall be checked to ensure that the setting-up is satisfactory before the commencement of load test.

(ii) All tests shall be carried out only under the direction of an experienced and competent supervisor conversant with the test equipment and test procedures. All personnel operating the test equipment shall have been trained in its use. The Curriculum Vitae (CV) of Tester(s) shall be submitted 48 hours prior to testing works being carried out.

5.10.2.8. Notice of Test

The Contractor shall give at least 24 hours' notice of the commencement of the test. No load shall be applied to the test pile before the commencement of the specified test procedure.

5.10.3. Protection of Testing Equipment

5.10.3.1. Protection from Weather

Throughout the test period, all equipment for measuring load and movement and beams shall be protected from adverse effects of sun, wind and precipitation. Temperature readings shall be taken at the start, end and at the maximum load of each loading cycle.

5.10.3.2. Prevention of Disturbance

Construction activities and persons who are not involved in the testing processes shall be kept at a sufficient distance from the test location to avoid disturbance.

5.10.4. Method of Loading

5.10.4.1. Test Load

(i) The test load shall be applied in one (1) of the following ways:

a) By means of a jack which obtains its reaction from kentledge heavier than the required load.

b) By means of a jack which obtains its reaction from tension piles or other suitable anchors.

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c) By means of a jack which obtains its reaction through bi-directional axial load from the top and bottom section of the tested pile.

(ii) In all cases, the reaction load or its supports shall be placed sufficiently far from the proposed test position to reduce the influence on the results to a tolerable level. Care shall be taken to ensure that the reaction load remains stable throughout the test without the possibility of load tilting or collapsing.

(iii) In addition to the reaction load, it shall be necessary to provide a loading frame, a bearing plate, a loading column and a hydraulic jack or other appropriate type of load measuring device. The loading column shall be of sufficient strength to prevent undue buckling under the maximum load. The total weight of the kentledge or reaction force provided shall be at least 1.2 times the maximum test load.

(iv) In all cases the Contractor shall ensure that when the hydraulic jack and load measuring device are mounted on the pile head, the entire system shall be stable up to the maximum load to be applied.

(v) If in the course of carrying out a test, any unforeseen occurrence should take place, further loading shall not be applied until a proper engineering assessment of the prevailing conditions has been made and steps taken to rectify any fault.

(vi) Where an inadequacy in any part of the system might constitute a hazard, means shall be provided to enable the test to be controlled from a position clear of the kentledge stack or test frame.

(vii) Where method (a) or (b) is used; The hydraulic jack, pump, hoses, pipes, couplings and other apparatus (jack assembly) to be operated under hydraulic pressure shall be capable to withstand a pressure of 1.5 times the maximum pressure used in the test without leaking. For method (c), the rated nominal capacity of jack assembly shall exceed the maximum anticipated jack load by at least 10%. Test certificate shall be submitted before carrying the test.

(viii) The maximum test load expressed as a reading on the gauge in use shall be displayed and all operators shall be made aware of this limit.

(ix) When method (a) is used, care shall be taken to ensure that the centre of gravity of the kentledge is on the axis of the pile. The nearest edge of the crib supporting the kentledge stack shall not be closer than 1300mm to the surface of the test pile. Kentledge shall not be used for testing raked pilesRefer **Figure 10.1** for typical set up requirement.

(x) When method (b) is used, all anchor piles shall be at a distance of at least three (3) pile shaft diameters from the test pile, centre to centre, and in no case, shall they be less than 2000mm from the test pile.

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(xi) If the anchor piles are to be permanent working piles, their levels shall be observed during application of the test load to ensure no residual uplift occurs.

(xii) When method (c) is used,

a) Bi-directional axial compression test shall be carried out in compliance with ASTM D8169-18 unless otherwise approved by S.O..

b) The test shall be carried out only under the direction of an experienced and competent supervisor conversant with the test equipment and test procedures. All personnel operating the test equipment shall have been trained in its use. The Curriculum Vitae (CV) of Tester(s) shall be submitted 48 hours prior testing works.

c) The method consists of bi-directional pile load test; the jack load unit is installed within the pile body and bi-directional base load test; the jack load unit is installed at the pile base.

d) The jack load unit shall be placed in plane surface which is normal to the axis of the pile. The elevation of the load unit shall be located at the approved calculated equilibrium geotechnical capacity of upper and lower segments of the test pile as verified by a Professional Engineer.

e) The steel bearing plates, stiffeners or equivalent as needed to distribute the jack load evenly over the pile cross-section.

f) The upper displacement tell-tale shall be fixed in sufficient distance at the top section of the tested pile.

g) The lower displacement tell-tale for bi-directional pile load test shall be fixed in sufficient distance at the bottom section of the tested pile. Whereas the lower displacement tell-tale for bi-directional base load test shall be fixed at the bottom of the pile base plate.

h) The connection in between the top and bottom section of the tested pile to the jack load unit shall be allowed for opening mechanism at the split zone for the purpose of testing.

i) Tell-tale or any other tests to the pile such as sonic logging, the instrumentation pipes or cabling which is located at the jack load unit shall be in such extendable during the split zone gap opening during pressurizations.

j) The protection measures such as funnel rebar or other methods as approved by the S.O. shall be fixed to the main rebar cage to protect the jack load unit from damages during concreting.

k) The jack load unit shall be fully welded together with the upper steel rebar cage. The bearing plates shall be spot-

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welded with the load unit. The plate shall be made to receive uniform load distribution prior to testing.

l) Minimum two (2) grouting pipes shall be installed together with the jack load unit. The pipes shall be pre-cut at the split zone of the load unit to enable the pipes to split and allow the cement grout to flow and grouting takes place. The sonic logging pipes may also be treated as grouting pipes.

m) Post grouting shall be done to fill up the gap at the split zone. Clean water shall be initially pumped to remove the debris left at the split zone after testing. Grouting shall start when the water returned to the nearby grouting pipe becomes clean. Grouting operation shall be terminated when the returned cement grout is most likely similar to previous grout applied.

n) The test result shall be plotted as load versus displacement curves for the upward and downward displacement independently. The two (2) component curves shall be utilized to construct an equivalent pile-top load versus displacement curve.

o) To simulate compressive load, established correction factor for shaft resistance and reduction of pile weight shall be considered at the pile top section which is formally subjected to tension load behaviour during bi-directional testing. In addition, established correction factor and elastic shortening shall be considered at the pile top section for settlement computation due to the load.

p) The test report shall be endorsed by a Professional Engineer with Practicing Certificate prior to submission to the S.O..

(xiii) Alternatively, the Contractor may propose the use of other types, patented or otherwise, in which case the requirements as below shall be fully complied with.

5.10.4.2. Contractor's Load Test System

The Contractor may propose to use other different types from those specified. The proposal shall be submitted to the S.O. at least 90 days before the date of testing. The suitability or adequacy of any system shall be determined by the S.O.. In the event that the testing system proposed by the Contractor is acceptable, the Contractor shall obtain a Professional Engineer's endorsement on load settlement results.

5.10.4.3. Measurement of Load

(i) The test load shall be measured by calibrated load cell(s) or proving ring calibrated in divisions not exceeding 1% of the maximum load to be applied. If an electronic transducer is used, each reading shall be immediately saved so that in case of power failure the readings are not lost.

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(ii) The load cell or proving ring to be accepted for use shall be calibrated within the test load range without extrapolation and certificate of calibration within a validity of 6 months shall be made available before the load test commences.

(iii) All increments of load shall be maintained to within 1% of the specified load.

(iv) A spherical seating or pivot bearing of appropriate size shall be used to avoid eccentric loading. Care shall be taken to avoid any risk of buckling of the load application and measuring system. Load measuring and application devices shall be in short axial length in order to secure stability. The Contractor shall ensure that axial loading is maintained.

(v) The loading equipment shall enable the load to be increased or decreased smoothly or to be held constant at any required value.

5.10.4.4. Measurement of Settlement

(i) The Contractor shall provide apparatus for measuring settlement consisting of a primary system, at least one (1) auxiliary system for pile head and reference frame scale. Minimum one (1) independent temporary benchmark at least 15m (unless otherwise approved by the S.O. that nearer undisturbed and stable temporary benchmark can be established) from the test site to monitor the settlement reference point, shall be established. If desired, the auxiliary system may also be referenced to these benchmarks.

(ii) All measuring devices, scales and reference points with numbers or letters to ensure accurate data recording shall be clearly identified.

(iii) Settlements shall be measured by use of a reference beam supported independently of the load test pile, reaction pile or piles supporting reaction loads. Settlements shall be measured to the nearest 0.1mm accuracy. The reference beams shall be protected from the effects of temperature changes

5.10.4.5. Primary System

Reference Beams and Displacement Measuring Devices

(i) At least four (4) Linear Voltage Displacement Transducers (LVDT) and a Readout Unit are to be used for measuring the displacement. DC/DC–type displacement transducer having at least 75mm of travel and a linearity of 0.5% or less shall be used. A Readout Unit having a minimum display of three (3) digits, capable of monitoring output from DC/DC – Type LVDT shall be provided.

(ii) The measurement devices parallel to the longitudinal axis of the test pile and the axis of load application shall be aligned.

(iii) An independent reference beam or beams shall be set up to enable measurement of the movement of the pile to be

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made to the required accuracy and shall not be interfered by the load application system.

(iv) Reference beam supports shall be embedded securely and firmly into the ground, at a horizontal distance of not less than 2m from the closest face of the test pile, or 1.5m from the nearest corner of the support crib or platform/reaction pile, whichever is greater.

(v) A clear distance of 150mm to 300mm from the test pile to the reference beam or any projection used to support LVDT shall be maintained. The beam and projections should be at about the same elevation as the attachments to the pile on which the measuring devices will bear.

(vi) The LVDT supports to reference beam shall be attached so as to allow the stem of each device to rest on an attachment to the pile sides.

(vii) Hardware and pile attachment for LVDT devices shall be mounted using materials such as brass, aluminium or 303 series stainless steel, to avoid magnetic interference which the instruments. The pile attachments are angles, about 75mm x 100mm with the 100mm dimension projecting from the pile. For round pile, these attachments shall be placed on the perimeter of the pile at 90 degrees and an equal radial distance. For pile of other cross section, the attachments shall be placed at a convenient location as approved by the S.O..

(viii) Surfaces on which the gauge stems bear should have a smooth finish, such as glass or sheet acrylic, attached by an epoxy or other suitable material approved by the S.O..

(ix) Observation of any movements of the reference beam or beams shall be made and checking of the movement of the pile head relative to a remote reference datum shall be made and stopped at maximum load for each loading.

Refer **Figure C1** for typical set up requirement.

5.10.4.6. Auxiliary Systems

This measuring system shall consist of one (1) or more of the following: wire, mirror and scale; surveyor's level and target road; or, as alternatives, electrical or optical levels.

(i) Wire, Mirror and Scale

Pile movement shall be determined by means of a single strand of wire drawn in front of graduated scale mounted on a mirror. This scale, at least 150mm long and machine-divided in graduations of 250µm, is mounted on a 75mm x 150mm mirror with metal and glass bonding adhesive or electrical tape. The mirror shall be attached directly to the pile oriented so that the mirror face is parallel to the reference beam. The mirror shall be mounted to the wire between the ends of the reference beam, with one (1) end fixed and the other is placed over a pulley with a weight in

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order to maintain tension. The wire shall be located so that it is level and within 20mm of the mirror face.

(ii) Surveyor's Level and Target Rod

Use a level and levelling rod with a Vernier target that can be read to 0.5mm. Determine deflections by readings on the two fixed independent benchmarks, and on an established scale or fixed point on the pile top.

(iii) Alternative Systems

Any other type of electrical or optical gauge yielding a precision equivalent to the primary system is acceptable as an alternative, provided prior written approval is obtained from the S.O..

5.10.4.7. Tell-tale Strain Measurements

(i) When specify, strain measurements on the pile to determine elastic shortening of the pile shall be obtained by tell-tale strain measuring devices.

(ii) Tell-tales extensometer or vibrating strain gauges or other suitable measuring system shall be installed according to the drawing shown or as directed by the S.O..

5.10.5. Testing Procedure

5.10.5.1. General

Prior to the performance of any load test, the Contractor shall submit to the S.O. for his approval, working Drawings showing the method and equipment he proposes to use in the performance of the load test and the measurement of settlements. Such submission shall include design calculations of lateral supports or other methods to be used in ensuring against buckling. Horizontal supports to ensure bucking stability shall be provided to the pile to be loaded whenever the ratio of the unsupported height to the least cross-sectional dimension is 20 or more. Horizontal supports shall provide full support without restraining the vertical movement of the pile in any way.

5.10.5.2. Maintained Load Test

The Maintained Load Test shall be carried out as follows:

(i) The Full Test Load (FTL) on a pile shall be twice the Working Load (WL) noted on the Drawings unless otherwise stated, or directed by S.O..

(ii) The test shall be carried out in two (2) cycles, with first cycle test up to working load and second cycle test up to full test load as specified in **Table C4** of this Specification.

(iii) The load shall be applied in increment of 25% of the working load. Each increment of load shall be applied as smoothly and as expeditiously as possible. Settlement readings and time observations shall be taken before and after each new

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load increment.

(iv) The minimum period for maintaining a load at each increment before reaching the working load or test load is 30 minutes. A further increment of load shall be applied when rate of settlement is less than 0.05mm in 15 minutes.

(v) Time-settlement readings shall be taken at 2, 8, 15 and 30 minutes, and at 15 minutes interval thereafter. A time-settlement graph shall be plotted to indicate when the rate of settlement of 0.05mm in 15 minutes is reached before load increment is applied.

(vi) The working load shall be decreased in two (2) equal stages, and time-settlement readings shall be as specified a foresaid, until the rate of settlement is less than 0.05mm in 15 minutes. At least 30 minutes interval shall be allowed between the unloading decrements while minimum one (1) hour shall be allowed when unloading to zero load.

(vii) The maximum working load in first cycle shall be maintained for a minimum of 6 hours and time-settlement readings shall be taken at regular intervals of every 15 minutes for the first two (2) hours and every hour thereafter.

(viii) The maximum test load shall then be maintained for a minimum of 24 hours, and time-settlement readings shall be taken at regular intervals for every 15 minutes for the first two (2) hours and every hour thereafter.

(ix) The maximum test load shall be decreased in four (4) equal stages, and time-settlement readings shall be as specified a foresaid, until the rate of settlement is less than 0.05mm in 15 minutes. At least 30 minutes interval shall be allowed between the unloading decrements while minimum one (1) hour shall be allowed when unloading to zero load.

(x) If large discrepancies occur between different measurement system in sub-section 5.10.4.5. and 5.10.4.6. the test shall be halted and the cause for the discrepancy corrected. The test shall be restarted from the beginning in this instance.

(xi) Settlement readings shall be taken immediately after and before every load increment is applied or removed.

Refer **Table C4** for Load Increments and Minimum Holding Time.

5.10.6. Submission of Results

Full test data, complete field test records and results from the readout unit shall be jointly signed by the S.O.'s representative and the Contractor's authorised agent and submit to the S.O. immediately upon completion of the load test. The submission shall also consist of the following:

(i) Stage of Loading

(ii) Period for which the load was held

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(iii) Final load and load increment

(iv) Maximum settlement

These are to be plotted as load versus settlement and load - settlement versus time graphs.

5.10.6.1. Interpretation of Test Results

The S.O.'s interpretation and conclusions on the test results shall be final. Unless otherwise specified, the pile so tested shall be deemed to have failed if:

(i) The total settlement under the Working Load exceeds 12.50mm; or

(ii) The total settlement under twice the Working Load exceeds 38.0mm, or 10% of pile diameter / width whichever is the lower value, or

(iii) The residual settlement after removal of the test load at working load exceeds [(diameter of pile or diagonal width for non-circular pile / 120) + 4]mm or 12.50mm whichever is the lower value; or

(iv) For pile longer than 30m, the limit for maximum allowable settlement (i) and (ii) above can be increased by 2.2% for every meter length of pile beyond 30m.

5.10.7. Completion of a Test

5.10.7.1. Removal of Test Equipment

(i) On completion of a test, all measuring equipment and load application devices shall be dismantled and checked. All other test equipment, including kentledge, beams and supporting structures shall be removed from the test pile location. Measuring and other demountable equipment shall be stored in a safe manner so that it is available for further tests, if required, or removed from site.

(ii) Temporary tension piles and ground anchorages shall be cut off below ground level and all cut-off materials removed from the site. The ground shall be made good to the original commencing surface level.

5.10.7.2. Preliminary Test Pile Head

Unless otherwise specified, the head of each preliminary test pile shall be cut off below ground level, and all cut-off materials removed from the site. The ground shall be made good to the original commencing surface level.

5.11. High Strain Dynamic Pile Testing

5.11.1. General

5.11.1.1. The Dynamic pile testing using Pile Driving Analyzer (PDA) equipment is a high strain non-destructive load test method which

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can be performed during initial pile driving and during pile restrike to provide dynamic analyses using Case Pile Wave Analysis Program (CAPWAP) or equivalent and Wave Equation analyses programs approved by S.O.. The analyses programs shall be performed for the purposes of obtaining ultimate pile bearing capacity, pile stresses, pile integrity, and pile driving system performance. PDA testing is undertaken in conformance with latest ASTM Standard D-4945.

5.11.1.2. The Contractor shall supply all material, equipment, and labour to perform the dynamic monitoring. The Contractor shall obtain the dynamic measurements with the PDA of monitor piles and furnish the necessary dynamic data to the S.O..

5.11.2. Construction of Pile Head to be Tested

5.11.2.1. Driven Concrete piles

For a concrete pile subjected to PDA testing, the original pile head is to be used. For a damaged pile head, it shall be cut off square at sound concrete, and all loose particles shall be removed by wire brushing, followed by washing with water. Care shall be exercised to ensure that the reinforcement in the pile head is not in any way damaged. Any damaged reinforcement shall be made good to the satisfaction of the S.O.. The head shall be replaced with concrete of similar grade or higher.

5.11.2.2. Cast In-Situ Piles

(i) For cast in-situ piles, a spiral welded steel casing of at least 6mm thickness, same diameter as the cast in-situ pile and one diameter in depth is used to prepare the pile head for testing. Concrete of the same quality or better is used to build up the pile head with the finished level just above the steel casing (with the steel casing forming part of the pile head). Care should be taken so that there is no cold joint between the build up pile head and the pile.

(ii) The completed pile surface shall be flat and perpendicular to the applied force.

5.11.2.3. Steel pile

The pile top shall be flat.

5.11.3. Method of Testing

5.11.3.1. Equipment and Personnel Qualification

(i) The dynamic monitoring shall be performed using a Pile Driving Analyzer (PDA) system or equivalent approved by S.O.. All equipment necessary for the dynamic monitoring such as sensors, cables or wireless transmitters, etc., shall be furnished by Contractor and well calibrated at the time of testing. The equipment shall conform to the requirements of the latest ASTM D-4945.

(ii) Dynamic testing shall be performed by an independent specialist firm approved by S.O..

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5.11.3.2. Preconstruction Wave Equation Analysis

(i) Wave Equation Analysis shall be carried out to access the ability of the proposed driving system to install the pile to the required capacity and desired penetration depth within the allowable driving stresses.

(ii) Ten working days prior to testing, the Contractor shall submit the Wave Equation Summary Report and the report shall be endorsed by Professional Engineer with Practicing Certificate and submitted to the S.O. for review and approval.

(iii) The output shall be:

a) In the form of a relationship between pile capacity and driving behaviour

b) An estimate of final set (mm/blow)

c) Relationship between driving stresses in the pile and penetration resistance.

(iv) Approval of the proposed driving system by the S.O. shall be based upon the wave equation analyses indicating that the proposed driving system can develop a pile capacity of twice the pile design load at driving resistance. The hammer should also be sized or adjustable such that the penetration per 10 blows at the required ultimate capacity does not exceed 25mm.

(v) A new pile driving system, modifications to existing system, or new pile installation procedures shall be proposed by the Contractor if the pile installation stresses calculated by Wave Equation Analysis or derived from the PDA measurements exceed the maximum values specified by the S.O. or shown in **Table C5.**

5.11.3.3. Apparatus for Applying Impact Force

(i) The driving apparatus shall be positioned so that the impact is applied axially to the head of the pile and concentric with the pile. The device used to apply the impact force should provide sufficient energy to cause pile penetration during the impact event adequate to mobilize the desired capacity.

(ii) Conventional pile driving hammer, drop weight, or similar impact device based on predictive dynamic analysis, experience, or both shall be approved by S.O.. The impact shall not result in dynamic stresses that will damage the pile. The S.O may require cushions, variable control of the impact energy (drop height, stroke, fuel settings, hydraulic pressure, etc.), or both, to prevent excessive stress in the pile during all phases of pile testing.

5.11.3.4. Gauges for Obtaining Dynamic Measurement

(i) Dynamic measurement shall be carried out by attaching at least two strain transducers and two accelerometers for pile sizes less than 1000mm and at least four strain transducers

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and four accelerometers for pile larger than 1000mm diameter.

(ii) Care shall be taken to ensure that the gauges are securely attached at least 1.5 pile diameter from the pile head for pile diameter less than 1000mm and at least 1 pile diameter for pile exceeding 1000mm. The gauges shall be attached above the existing ground level and at opposite sides for a pair of gauges and at every quarter of pile circumference for two (2) pairs of gauges.

(iii) The gauges shall be calibrated to an accuracy of 2% throughout the applicable measurement range. The frequency of calibration is as per stated in the latest ASTM D-4945. If damage is suspected during use, the gauges shall be replaced.

5.11.3.5. Apparatus for Recording, Processing and Displaying Data

(i) The Contractor shall provide apparatus for measuring the acceleration and strain of the pile head and the energy transferred to the pile. The signals from the transducers during the impact event, shall be transmitted to the PDA to allow determination of the force and velocity versus time.

(ii) A cable or wireless transmission which connects the sensors near the pile head with the PDA shall be located at safe distance from the pile, but not more than 100m from the pile.

(iii) The PDA shall include a screen for displaying the force and velocity, a hard disk for obtaining a record for future analysis, and a means to process the data.

(iv) The apparatus shall have the capability of making an internal calibration check of force, velocity and time scales. No error shall exceed 2% of the maximum signal expected.

5.11.4. Testing Procedures

5.11.4.1. General

(i) Dynamic Test shall be conducted on test piles as selected by the S.O.. The test shall be carried out in accordance with sub-section 5.11.4.2.

(ii) Prior to the performance of any dynamic test, the Contractor shall submit the specialist testing firm company profile and working drawings showing the method statement and equipment proposed to be used in the performance of conducting the test together with all relevant calibration certificates to the S.O. for approval. The S.O. may request additional piles to be dynamically tested if the hammer and/or driving system is replaced or modified, the pile type or installation procedures are modified, the pile capacity requirements are changed, unusual blow counts or penetrations are observed, or any other piling behaviour differing from normal installation. The Contractor shall bear the cost and time for all necessary additional test.

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5.11.4.2. Dynamic Load Test

The Dynamic Load Test shall be carried out as follows:

(i) Driven Piles

a) Continuous pile monitoring as indicated in the Drawing or as requested by the S.O..

b) Dynamic pile test shall be conducted on piled foundations at the end of driving or at restrike for selected piles.

c) The pile shall to be at least 3 diameters or 100mm above the ground level. The Contractor shall drill and prepare holes for sensor attachment near the pile top after the pile has been driven to the penetration depths as specified on Drawing.

d) The Contractor shall supply and operate the piling hammer to induce a driving force on to the pile. Dynamic measurement of force and velocity shall be processed by the PDA to give immediate visual and permanent record on-site.

(ii) Cast In-Situ Piles

a) Dynamic pile test shall be conducted on cast in-situ piles at 28 days after pile concreting. Piles which are to be tested prior the 28 days shall be proven that it has achieved the required concrete compressive strength and subjected to approval by the S.O.. However, no testing shall be allowed for piles less than 14 days after concreting.

b) The pile shall be casted so as to leave a height of at least one (1) diameter above the ground or excavated level.

c) Contractor shall supply and operate the drop hammer to induce a driving force on to the pile. Dynamic measurement of force and velocity shall be processed by the PDA to give immediate visual and permanent record on-site. The proposed hammer weight shall be at least 1% to 2% of the maximum test load.

5.11.5. Submission of Results

5.11.5.1. Full test data, complete field test records and results from the readout unit shall be jointly signed by the S.O.'s representative and the Contractor's authorised agent and submit to the S.O. immediately upon completion of the Dynamic Test.

5.11.5.2. The Contractor shall submit preliminary results within three (3) days after completion of the test to the S.O..

5.11.5.3. The Contractor shall also submit the raw data file (W01) or equivalent, upon completion of the test at the site.

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5.11.5.4. For all testing, CAPWAP analysis or equivalent shall be carried out. The S.O.'s acceptance of the interpretation and conclusion based on the results submitted shall be final.

5.11.6. CAPWAP Computer Analysis Programme and Final Report

5.11.6.1. The final analysis and report shall consist of matches of forces and velocities, resistance distribution, static simulation and complete tables of numeric values. The Final Report shall be submitted to the S.O. within at least 7 working days upon completion of field testing. The specialist Contractor shall complete and provide the following:

(i) Static Capacity of pile including the toe resistance and shaft friction

(ii) Hammer Efficiency

(iii) Integrity of Pile

(iv) Case Damping Factor

(v) Predicted Load Vs Settlement Plots

(vi) Match Quality

(vii) Slack Value, efficiency & location (if used)

(viii) Force Wave Traces of measured and computed

(ix) Shaft Resistance Distribution

5.11.6.2. A PDA plot indicating all the gauges used for the testing and all the output of the field results and the subsequent signal matching on the same blow for all the piles are to be included in the Test Report. These reports should only be prepared by an engineer who has achieved Advanced Level or higher.

5.11.6.3. The report shall contain complete analysis, results and their interpretation with Professional Engineer with Practicing Certificate’s endorsement.

5.11.7. Completion of a Test

5.11.7.1. On completion of a test, all measuring equipment and load application devices shall be dismantled and removed from the test pile.

5.11.7.2. Unless otherwise specified, the head of each test pile shall be cut off below ground level, and cut-off materials removed from the site. The ground shall be made good to the original commencing surface level.

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6. Subterranean Termites Treatment

6.1. The Contractor shall only appoint termite management company (TMC) that has adequate equipment, competency and skilled workers to perform expeditiously. The Contractor shall also ensure that the TMC engage workers who are licensed to apply the termiticide by the relevant authorities.

6.2. All methods of application and chemicals to be used for the treatment of subterranean termite infestation shall be in accordance to MS 8215: Protection of Buildings against Subterranean Termites - CP for Prevention, Detection and Treatment of Infestation.

6.3. The Contractor shall submit a termite management programme and provide the following in writing:

6.3.1. A termite infestation report;

6.3.2. Details of methods proposed and termiticides to be used.

6.4. The Contractor's termite management company shall submit the above proposal with the Material Safety Data Sheet, product label and brochure indicating the termiticide to be used to the S.O.'s for approval.

6.5. Termiticide chemicals shall be applied in accordance with the manufacturer's recommendation and label instructions prior to the pouring of concrete to construct the ground slab or for binding. Notwithstanding the manufacturer's recommendation, the minimum surface application rate shall be five (5) litres/m^2 on all ground floor built-up areas including apron areas, and also on all areas extending one (1) m beyond the perimeter drain all around the building. In addition, termiticide chemical shall be sprayed on interfaces between the concrete ground beam and the hardcore at a minimum rate of one (1) litre/m.

6.6. Treatment shall not be performed just before or after heavy rain, unless the area to be treated can be physically protected to avoid leaching and runoff before the termiticide chemical has bound to the soil.

6.7. Immediately after spraying the chemical, all surfaces exposed to direct sunlight or rain shall be covered with an impervious black PVC sheet of minimum thickness of 0.08 mm to reduce the loss of chemical by UV light, alkaline wet concrete, leaching and runoff caused by rain on exposed treated soil. In the case of areas receiving blinding, the coverings shall be removed immediately prior to the placement of the blinding concrete.

6.8. As soon as practicable after the completion of anti-termite treatment and prior to the issuance of the Certificate of Practical Completion, the Contractor shall submit to the S.O., the anti-termite treatment specialist's Guarantee against any termite attack to the Works which may arise during a period of two (2) years from the date of Practical Completion of Works due to any defect, fault or ineffective anti-termite treatment. The terms of the Guarantee shall be such as shall be approved by the S.O..

6.9. The Contractor shall verify the ground-water table before soil treatment. For this purpose, the Contractor shall excavate trial holes of not less than 0.5 meter deep measured from the level below the level of the soil to be treated. The restriction to soil treatment by virtue of this requirement shall not in any way affect or diminish the Contractor from any indemnity against termite attacks.

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7. Damp Proof Membrane (DPM)

7.1. DPM shall be installed below the ground concrete floor level or as shown on the Drawings to prevent the rise of moisture or damp through the structure flooring.

7.2. Unless otherwise specified in the Drawings, the DPM shall be extruded polythene film with a nominal thickness of 0.5mm and the tensile strength shall be not less than 15MPa as approved by the S.O.

7.3. Unless the application surface is smooth it shall be blinded with compacted soft sand to guarantee a soft bed, free from any objects that may puncture the membrane during the installation or when concrete is applied.

7.4. When laying two (2) sheets of DPM, a minimum of 150mm overlap shall be provided between each of the sheets and sealed with 100mm wide jointing tape.

7.5. Any punctures in the membrane shall be patched with sheets of identical thickness lapped at least 150mm away from the perforation edge and sealed with double sided pressure sensitive tape.

7.6. The DPM shall be covered with a protective layer or screed as soon as possible after the membrane has been installed. Care shall be taken when applying concrete or screed on top the DPM to avoid stretching or the DPM being displaced.

8. Damp Proof Course (DPC)

DPC shall comply with BS 8215: CP for design and installation of DPC in masonry construction and as specified in SECTION E: WALL SYSTEM.

9. Filling Under Floors, Aprons Etc.

Filling shall be provided and laid under floors, aprons, etc. where required. Filling shall be of suitable material as specified hereinbefore, deposited in layers not exceeding 155mm loose thickness, and each layer well watered where necessary, rammed and compacted. No clay shall be used for filling under floors and aprons.

10.Hardcore

Where shown and required, approved hardcore consisting of good, sound broken bricks or stones shall be provided and laid to the thickness shown on the Drawings, well rammed, compacted and blinded with sand. All hardcore shall be well watered immediately prior to the depositing of concrete thereon.

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Table C1. Plate Bearing Test – Load Increments and Minimum Holding Time

No.	Load (% of working load)	Time Interval (minute)
1.	20	15
2.	40	15
3.	60	15
4.	80	15
5.	100	120
6.	80	15
7.	60	15
8.	40	15
9.	20	15
10.	0	15
11.	20	15
12.	40	15
13.	60	15
14.	80	15
15.	100	15
16.	120	15
17.	140	15
18.	160	15
19.	180	15

No.	Load (% of working load)	Time Interval (minute)
20.	200	120
21.	160	15
22.	120	15
23.	80	15
24.	40	15
25.	0	15
26.	40	15
27.	80	15
28.	120	15
29.	160	15
30.	180	15
31.	240	15
32.	280	15
33.	300	120
34.	240	15
35.	160	15
36.	80	15
37.	0	15

Note: The rate of settlement for each load increment should be based on the preliminary test

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Table C2. Specification of Precast Concrete Piles (after MS1314)

Piles		Minimum Concrete Strength (N/mm^2)	Minimum Longitudinal Reinforcement	Minimum Cement Content (kg/m^3)	Method of Installation
Type	Class				
RC	M	45	1.2 % of cross sectional area	400	Hammer driven
	J	45	1.0 % of cross sectional area	400	Hammer driven
Spun pile	A	60	Minimum effective prestressed of 4 N/mm^2	420	Hammer driven
	B	60	Minimum effective prestressed of 5 N/mm^2	420	Hammer driven
	C	60	Minimum effective prestressed of 7 N/mm^2	420	Hammer driven
PC	X	60	Minimum effective prestressed of 5 N/mm^2	420	Hammer driven
	Y	60	Minimum effective prestressed of 7 N/mm^2	420	Hammer driven
PCS	1	60	Minimum effective prestressed of 3.5 N/mm^2	420	Hammer driven
	2	55	Minimum effective prestressed of 3.5 N/mm^2	420	Jacked-in
RCS	1	45	1.0 % of cross sectional area	400	Hammer driven
	2	45	0.8 % of cross sectional area	400	Jacked-in

NOTES:
Concrete strength means *characteristic compressive strength* at 28 days.
The nominal sizes and length for each class of piles are specified in Parts 3, 4, 5 or 6 of Malaysian Standard, whichever relevant.

Definitions:
Precast reinforced concrete square pile (RC pile)
A pile made of concrete cast in a uniform four-sided cross section before driving into the ground. It shall be suitably reinforced mainly with steel bars.
Precast prestressed concrete square pile (PC pile)
A pile described in definition No. 1 but suitably reinforced mainly with prestressing steel.
Precast pretensioned spun concrete pile (Spun pile)
A hollow cylindrical pile made of concrete cast by centrifugal spinning before driving into the ground. It shall be suitably reinforced mainly with pretensioned prestressing steel.
Small prestressed concrete square pile (PCS pile)
A small PC pile for sizes 200 mm and less.
Small reinforced concrete square pile (RCS pile)
A small RC pile for sizes less than 200 mm.

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Table C3. Slump Range for Typical Concreting Situations

Typical Conditions of Use	Slump Range (mm)
Placed into water-free unlined bore. Widely spaced reinforcement leaving room for free movement between bars.	75 to 125
Where reinforcement is not spaced widely enough to give free movement between bars. Where casting level of concrete is within the casing. Where pile diameter is less than 600 mm.	100 to 175
Where concrete is to be placed by tremie under water or drilling fluid.	150 to collapse

Table C4. Static Load Test – Load Increments and Minimum Holding Time

LOAD INCREMENTS AND MINIMUM PERIODS OF OBSERVATION		
Load Cycles	Load Increment (% WL)	Minimum Holding Time
1st cycle	0	
	25	30 minutes*
	50	30 minutes
	75	30 minutes
	100	6 Hours**
	50	30 minutes
	0	60 minutes
2nd cycle	25	30 minutes
	50	30 minutes
	75	30 minutes
	100	30 minutes
	125	30 minutes
	150	30 minutes
	175	30 minutes
	200	24 Hours***
	150	30 minutes
	100	30 minutes
	50	30 minutes
	0	60 minutes

NOTES
* Time-settlement readings shall be taken at 2, 8, 15 and 30 minutes, and at 15 minutes interval thereafter.
**Time-settlement readings shall be taken at regular intervals of every 15 minutes for the first 2 hours and every hour thereafter during load holding time at working load.
***Time-settlement readings shall be taken at regular intervals for every 15 minutes for the first 2 hours and every hour thereafter during load holding time at test load.

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Table C5. Typical Allowable Driving Stresses

Pile Material	Compression Stress	Tension Stress (psi)	Tension Stress (MPa)
Steel	0.9 F_y	0.9 F_y	0.9 F_y
Prestressed Concrete	0.85 f'_c - f_{pe}	3 $(f'_c)^{1/2}$ + f_{pe}	0.25 $(f'_c)^{1/2}$ + f_{pe}
Precast Concrete*	0.85 f'_c	0.70 f_y (A_s / A_c)	0.70 f_y (A_s / A_c)
Timber	3 σ_a	3 σ_a	3 σ_a

*Allows for tension cracks; for uncracked section allow prestressed concrete tension stress with f_{pe} = 0.

F_y = Steel Yield Strength
f'_c = Concrete Compressive Strength (MPa or psi)
f_{pe} = Effective Prestress (after losses) (MPa or psi)
A_s = Reinforcement Steel Cross Sectional Area
A_c = Concrete Cross Sectional Area
f_y = Reinforcement Steel Yield Strength
σ_a = Allowable Timber Design Stress

Table C6. Tests for Bentonite Drilling Fluids

Property	**Units**	**Stages**			**Test Equipment**
		Fresh	**Ready for re-use**	**Before concreting**	
Density	g/ml	< 1.10	< 1.25	< 1.15	Mud balance
Marsh viscosity (946 ml)	sec	32 to 50	32 to 60	32 to 50	Marsh funnel
Fluid loss (30 min)	ml	< 30	< 50	NA	Filter press
pH		7 to 11	7 to 12	NA	pH meter
Sand content	%	NA	NA	< 4	Sand content set
Filter Cake	mm	<3	<6	NA	Filter Press

Table C7. Tests for Polymer Drilling Fluids

Property	**Units**	**Stages**	**Test Equipment**
		Before concreting	
Density	g/ml	≤ 1.1	Mud balance
Marsh viscosity (946 ml)	sec	32 to 140	Marsh funnel
pH		7 to 12	pH meter
Sand content	%	≤ 1	Sand content set

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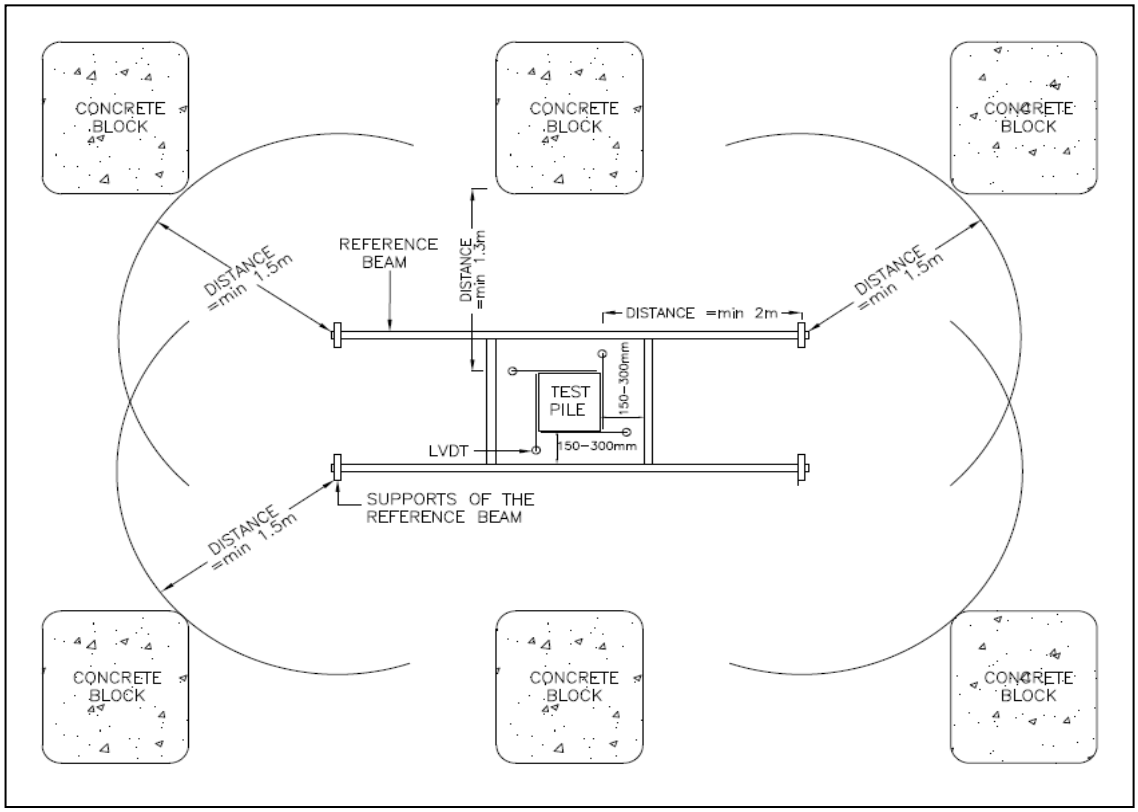
Figure C1. Plan View of Typical Pile Load Test Set Up



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APPENDIX C/1

Bending Strength for Precast Concrete Piles

Pile Body Strength Test

General

Bending strength test on the pile body shall be done to determine the ability of the pile to withstand the cracking bending moment (*M*c) and the ultimate bending strength (*M*u). The bending strength test of pile body shall be made by the application of vertical load *P* to the centre of the span, on the pile laid on two (2) supports which has a span equal to 3/5 of its length.

The applied bending moment shall be calculated from the following equation: -

Where,
$$M = \frac{1}{40}WL + \frac{P}{4}\left(\frac{3L}{5} - 1\right)$$

M is the applied bending moment (kNm);
W is the weight of pile (kN);
L is the length of pile (m); and
P is the applied load (kN)

The cracking bending moment (M_c)

The pile shall be designed to withstand the cracking bending moment calculated based on the maximum allowable crack width as shown in Table 1. The pile is considered to have passed the requirement to withstand the cracking bending moment if when subjected to a test load equal to the cracking load (P_c) corresponding to the appropriate M_c, no crack exceeding the values in Table 1 occurs. The calculated values of M_c are given in Table 2, Table 3 and Table 4.

Table 1: Maximum Allowable Crack Width

Types of pile	Maximum crack width (mm)
1 RC pile	0.20
2 Spun pile	0.05
3 PC and PCS pile	0.10
4 RCS pile	0.20

The ultimate bending moment (M_u)

The pile shall be tested to the largest applied load (P_{max}) until the pile failure occurs or until the applied load slightly exceeds the minimum ultimate load ($P_{min\text{-}u}$) which corresponds to the minimum ultimate bending strength, whichever comes first.

The minimum ultimate bending strength ($P_{min\text{-}u}$) is obtained by multiplying the cracking bending moment (M_c) by the factor *'f'* as given in.

The pile is considered to have passed the bend test if the pile does not fail when subjected to $P_{min\text{-}u}$ load.

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Testing

Apparatus setup

The pile manufacturer shall design and fabricate a suitable set-up for carrying out the bend test. The test shall be carried out using any suitable equipment of sufficient capacity and capable of applying the loads continuously and vertically.

The loading arrangement and the device for applying the loads shall consist of two supporting rollers and two load-applying rollers as in Figure 1.

All rollers shall be manufactured from steel and shall have a circular cross-section with a diameter of 20 mm to 120 mm; the rollers shall be at least 20 mm longer than the width of the test specimen. All rollers except one shall be capable of rotating around their axes and of being inclined in a plane normal to the longitudinal axis of the test specimen. All rollers shall be adjusted in their correct positions with all distances having an accuracy of ± 5 mm. Suitable safety precaution should be taken to ensure that the rollers do not fall off while adjustment is made and during the testing.

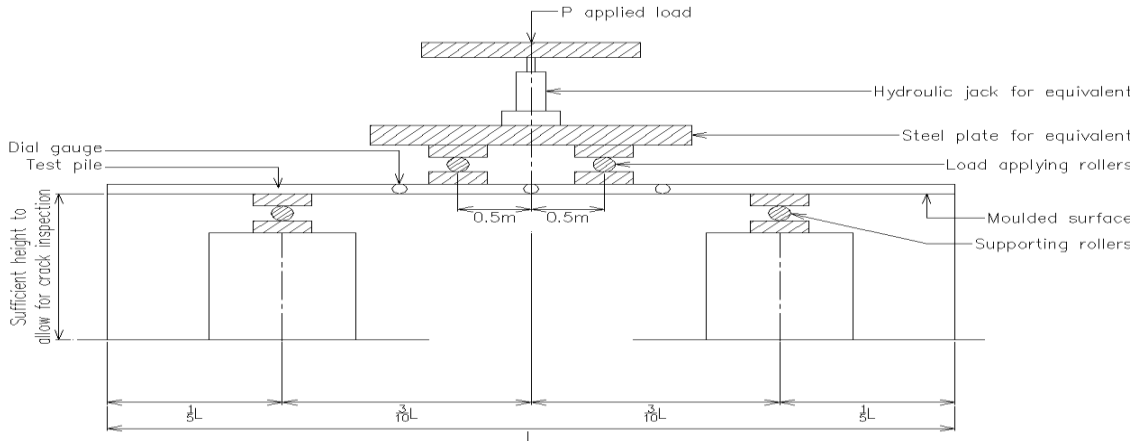

Figure 1- Loading Method

Rate of loading

The load shall be applied at the rate of (0.06 ± 0.04) N/mm2s using suitable equipment which shall be capable of applying the load uniformly without shock using manual or automatic control.

Load pacers

If the equipment is not equipped with a device to maintain, automatically, the specified rate of increase of load on the specimen, a load pacer shall be fitted or alternatively the control shall be done by manual method to ensure the rate of loading as described in the paragraph above is complied. If the pacer has a scale, this scale shall be basically linear such that 1 mm represents not more than 100 N/s. Over the operating range of the scale the accuracy shall be within ± 5 %.

NOTE. The pacer may incorporate a scale with an indicator or alternatively, it may be, for example, a marked disc or pointer, which rotates at the rate at which, the load pointer should move on the load scale being used. If the pacer is fitted with a variable speed control or has preset speeds, then once the variable speed control has been set, or preset speed has been chosen, the pacer speed shall remain within ± 5 % of the specified speed over the operating range. Alternatively if the rate of loading is controlled manually then the manufacturer shall prepare the table of loading application against time.

Load scale indicators or digital displays

The equipment shall be provided with either: -
a) Easily read dials or scales; or

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b) Electrical load indicators, which shall include a visual display.

These load scale indicators or digital displays shall be calibrated by an accredited laboratory.

Test specimens

Test specimens shall be selected randomly from piles casted and results shall be properly documented for inspection. The number of piles to be sampled is to be decided in accordance with the agreement between the parties concerned.

Procedure

1. Prior to testing, select a suitable load and time increment for a selected loading rate for particular hydraulic equipment such that it will facilitate inspection of the pile at the calculated crack load and at the required minimum ultimate load.

2. Check the specimens thoroughly for initial crack before testing. Wipe clean the bearing surfaces of the supporting and loading rollers.

3. Place the test specimen on the support rollers, correctly centred with the longitudinal axis of the specimen at right angles to the rollers. The trowelled surface direction shall be normal to the direction of loading and the moulded surface is in tension (see Figure 1). The moulded surface may not therefore be orientated with its position in the structure. For Spun piles, the test specimen can be placed at any surface position. Do not use packing between the specimen and the rollers.

4. Place the loading equipment and the load applying rollers correctly in the testing setup. Do not begin to apply the load until all loading and supporting rollers are in even contact with the test specimen.

5. Apply the load steadily and without shock at a rate of (0.06 ± 0.04) N/mm2s. Choose the lower loading rates for low strength concrete and the higher loading rates for high strength concrete (i.e. for RC Piles, *f*cu more than 45 N/mm2).

6. Once the loading rate has been adjusted, maintain the rate of loading without change until the applied crack load (*P*c) corresponding to crack moment (*M*c) from the respective tables 2, 3 and 4 as shown below is reached. Then hold the load for a sufficient time to inspect the pile for possible cracking. If crack is present, it shall be checked by means of the test crack measuring gauge and crack width and the location shall be recorded.

7. After step 5.6, continue the loading at the same uniform rate until failure occurs or when the applied load is slightly greater than the minimum ultimate load (*P*min-u), whichever comes first. The minimum ultimate load (*P*min-u) is a value corresponding to the value of *M*c multiplied by the factor *f* from the respective tables 2, 3 and 4 as shown below.

8. If pile failure comes first, the test specimen is considered fail. Record the maximum load (*P*max) applied. *P*max is the maximum applied load (kN), if and when pile failure occurs during the bend test.

9. If the pile does not fail, and when the applied load is slightly greater than *P*min-u is reached, then hold the load for sufficient time to allow for inspection of pile body for cracking. If crack is present, it shall be checked by means of the test crack-measuring gauge and crack width and location shall be recorded.

10. For record purposes, record all the deflection of test specimen shown by dial gauge during loading and unloading.

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Table 2 - Cracking Bending Moment (Mc) and Factor *'f'* for Precast Reinforced Concrete Square Piles (RC Piles)

Nominal Pile Size (mm x mm)	Cracking Bending Moment, Mc (kN-m)		*'f'*	
	Class M	Class J	Class M	Class J
200 x 200	8.3	7.3	1.5	
225 x 225	-	-		
250 x 250	13.1	11.6	1.8	
275 x 275	-	-		
300 x 300	22.1	19.6	2.0	
325 x 325	-	-		
350 x 350	33.7	29.8		
375 x 375	-	-		
400 x 400	47.9	42.5		
450 x 450	65.0	57.8		

Table 3 - Cracking Bending Moment (M_c) And Factor *'F'* For Precast Pretensioned Spun Concrete Piles (Spun Piles)

Nominal Diameter (mm)	Class	Minimum Concrete Strength (N/mm^2)	Cracking Bending Moment (M_c) (kNm)	Factor *'f'*	Effective Prestress (N/mm^2)
250	B	60	12	1.5	5.0
300	A	60	17	1.5	4.0
	B	60	20	1.5	5.0
350	A	60	26	1.5	4.0
	B	60	30	1.5	5.0
400	A	60	38	1.5	4.0
	B	60	43	1.5	5.0
	C	60	54	1.8	7.0
450	A	60	53	1.5	4.0
	B	60	60	1.5	5.0
	C	60	76	1.8	7.0
500	A	60	74	1.5	4.0
	B	60	84	1.5	5.0
	C	60	106	1.8	7.0
600	A	60	123	1.5	4.0
	B	60	141	1.5	5.0
	C	60	177	1.8	7.0
700	A	60	191	1.5	4.0
	B	60	218	1.5	5.0
	C	60	273	1.8	7.0
800	A	60	278	1.5	4.0
	B	60	318	1.5	5.0
	C	60	399	1.8	7.0
900	A	60	390	1.5	4.0
	B	60	445	1.5	5.0
	C	60	558	1.8	7.0
1000	A	60	527	1.5	4.0
	B	60	601	1.5	5.0
	C	60	755	1.8	7.0
1200	A	60	853	1.5	4.0
	B	60	973	1.5	5.0
	C	60	1217	1.8	7.0

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Table 4: Cracking Bending Moment (M_c) And Factor *'F'* For Precast Prestressed Concrete Square Piles –Class Pc-X, Class Pc-Y, Small Piles

Size (mm)	Class of Pile	Minimum Concrete Strength (N/mm^2)	Minimum Effective Prestress (N/mm^2)	Cracking Bending Moment, M_c (kNm)	Factor *'f'*
125	PCS-1	60	3.5	2.9	1.5
	PCS-2	55	3.5	2.9	1.5
150	PCS-1	60	3.5	4.9	1.5
	PCS-2	55	3.5	1.5	1.5
175	PCS-1	60	3.5	7.8	1.5
	PCS-2	55	3.5	7.8	1.5
200	PCS-2	55	3.5	11.7	1.5
	PC-X	60	5.0	13.7	1.5
	PC-Y	60	7.0	16.4	1.7
250	PC-X	60	5.0	26.5	1.5
	PC-Y	60	7.0	31.7	1.7
300	PC-X	60	5.0	45.2	1.5
	PC-Y	60	7.0	54.2	1.7
350	PC-X	60	5.0	70.9	1.5
	PC-Y	60	7.0	85.2	1.7
400	PC-X	60	5.0	104.5	1.5
	PC-Y	60	7.0	125.9	1.7
450	PC-X	60	5.0	147.0	1.5
	PC-Y	60	7.0	177.4	1.7

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TABLE OF CONTENT

SECTION E: WALL SYSTEM		PAGE
1.	General	E/1
2.	Products, components and proprietary systems	E/3
3.	Type of Finishes to Walls and Partitions	E/7
4.	Structural Wall (Blockwork System)	E/7
5.	Samples and Mock-up	E/9
6.	Walling / Construction	E/10

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1. General

1.1. Non-structural wall (NSW) system hereby refers to vertical building element designed as non-loadbearing internal wall which serve with functions as cited in Uniform Building By-Laws (UBBL), and not being a party wall inside a building.

1.2. Non-structural wall system shall refer to solid wall, lightweight drywall partition, pre-cast/pre-fabricated panels, etc.

1.3. Structural wall (SW) system hereby refers to vertical building element designed as loadbearing internal wall which serve with functions as cited in Uniform Building By-Laws (UBBL) and being a party wall inside a building.

1.4. Structural wall system shall refer to blockwork system stated in sub-section 4..

1.5. Unless otherwise specified, all non-structural walls or infill walls shall be constructed using proprietary blocks. Building materials considered for non-structural wall construction may refer to sub-section 2. below. Each material type shall comply with the respective standard or manufacturer's specification. Build-up or configuration of NSW shall be strictly based on recommendations or/and design by solution provider.

1.6. Unless otherwise specified, design considerations of NSW shall take into consideration the following functional features, any one or in combination, and comply with relevant parts of the current Building Code:

1.6.1. Structural stability. This includes consideration of external loadings, if any such as lateral wind or traffic pressure, heavy fixtures etc.;

1.6.2. Thermal & fire resistance;

1.6.3. Water resistance;

1.6.4. Acoustic performance; and

1.6.5. Impact resistance.

1.7. Design for Wall Performances

1.7.1. Loading

1.7.1.1. All NSW shall be constructed only for their intended purposes and any additional loadings shall be referred to the S.O. for approval.

1.7.1.2. Proprietary internal lightweight partition, including secondary framing shall be designed to meet specification requirement to ensure structural sufficiency and safety. The governing factor shall be based upon allowable deflection limit shall be of L/240 or L/360 @ 250Pa or equivalent design code. L refers to height of wall in metre (m). 250Pa refers to lateral uniform pressure applying perpendicular to wall surface.

1.7.2. Thermal and Fire Rating

1.7.2.1. Material used for wall construction shall be classified as Class O building material in accordance with BS 476 Part 4 (non-combustible) or Part 6 & 7 (limited combustible), or at least has an A2 rating in accordance with EN 13501 Part 1.

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1.7.2.2. Unless otherwise specified or shown on the Drawings, fire rated walls and partitions system shall be constructed and calculated according to requirements and approval of the DGFR and compliance to the Uniform Building By-Law (UBBL).

1.7.2.3. The glass wool, stone wool and cellulose insulation materials used shall comply with BS 476 - Fire tests on building materials and structures:

Part 4 : Non-combustibility test for materials;

Part 6 : Method of test for fire propagation for products; and

Part 7 : Method of test to determine the classification of the surface spread of flame of products.

1.7.3. Water proofing

Where necessary, NSW shall be properly treated with proprietary water proofing system as per respective manufacturer's recommendation, along with warranty coverage if applicable.

1.7.4. Acoustic rating

1.7.4.1. Where necessary, NSW shall be designed to have specific sound insulation rating in accordance with ISO or equivalent as below:

ISO 140-3 – Laboratory measurements of airborne sound insulation of building elements; and

ISO 717-1 – Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation.

1.7.4.2. Unless otherwise specified, designing architect shall determine the required acoustic performance for the wall structure based on intended usage.

1.7.5. Security and impact rating

1.7.5.1. Where applicable, wall shall be designed with some degree of security and impact resistance feature. While solid wall structure is naturally to have high impact resistance capability, for drywall partition this shall be evaluated in accordance with BS 5234: Partitions (including matching linings) – Part 2: Specification for performance requirements for strength and robustness including methods of test, or equivalent.

1.7.5.2. Where necessary, designing architect shall decide grade of duty rating for wall structure making reference to recommendation in Table 1 – Partition grades by categories of duty in BS 5324: Part 2.

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2. Products, components and proprietary systems

2.1. Cement

The cement, unless otherwise described, shall be CEM 1 complying with MS EN 197-1 and as specified under SECTION D: CONCRETING.

2.2. Sand

Sand for mortar shall comply with MS EN 12620 and as specified in SECTION D: CONCRETING.

2.3. Mortar

2.3.1. Mortar shall consist of one (1) part of cement to six (6) parts of sand, with the addition of an approved mortar plasticizer used strictly in accordance with manufacturer's recommendation. The ingredients for mortar shall be measured in proper gauge boxes and shall be mixed on a clean boarded platform or in an approved mechanical batch mixer.

2.3.2. All mortar shall be used within forty-five (45) minutes of mixing and no remaking up of mortar shall be permitted thereafter.

2.3.3. Mortar for brickwork below damp proof course or ground floor level shall be in the proportion of one part of cement and three parts of sand.

2.4. Damp Proof Course

2.4.1. Unless otherwise shown on the Drawings, bituminous damp proof courses shall comply with BS 8215: Code of practice for design and installation of damp-proof courses in masonry construction. The bitumen damp proof membrane shall be two (2) ply with a nominal mass of 1840g/m².

2.4.2. Bitumen damp proof course shall be in rolls to suit the thickness of walls or brickwork. The damp proof course shall be bedded on a level bed of cement mortar (1:1) and lapped at least 150mm or the width of the damp proof course at running joints and intersections.

2.4.3. In all cases of doubt as to the exact location of the damp proof course, the Contractor shall refer to the S.O. before laying the damp proof course. The damp proof course above ground shall be continuous for the whole length and thickness of the wall and be at least 150mm above finished ground level to prevent moisture from the ground rising through the foundation to the wall above ground, which otherwise would make wall surfaces damp and damage wall finishes.

2.5. Bricks and Blocks

2.5.1. General

All brick walls shall have G.I expanded/exmet mesh reinforcement with 750mm x 5mm diameter brickwork dowel bar complete with 75mm right angle bent to hook onto brickwork at every 4th course.

2.5.2. Samples

Separate samples of each type of bricks and blocks taken at random from the load, shall be submitted to the S.O. for approval before the bricks and blocks

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are used. All subsequent deliveries shall generally be up to the standard of the samples approved. No soft, broken, twisted or otherwise defective bricks and blocks will be permitted to be used.

2.5.3. Clay Bricks

All ordinary clay bricks shall be machine-made, wire cut and shall be hard, well burnt, sound, square and clean all in accordance with MS 76.

2.5.4. Cement Sand Bricks and Hollow Blocks

2.5.4.1. All cement sand bricks and hollow blocks shall comply with MS 27.

2.5.4.2. The dimensions of blocks shall comply with MS 1064.

2.5.4.3. Wherever blocks are used, a modular sized block shall be used and constructed in accordance with the manufacturer's standards, requirements and method statements.

2.5.4.4. The composition of cement sand bricks and hollow blocks shall consist of a uniform mixture of sand and cement. The sand cement shall be mixed in the ratio of six (6) parts of sand to one (1) part of cement by volume in a mechanical mixer capable of taking one (1) bag of cement (50 kg of cement shall be taken as 0.035 cube). The sand used shall be as described hereinbefore and the maximum size shall pass through a 4.8 mm mesh BS sieve. The cement used shall be CEM 1 as described under SECTION D: CONCRETING.

2.5.4.5. The Contractor shall only use cement sand bricks and hollow blocks supplied by approved manufacturer.

2.5.4.6. The minimum permissible average compressive strength shall be 5.2N/mm² for bricks and 2.8N/mm² for hollow blocks per 10 samples taken at random from the Contractor's stock pile of 1000 or part thereof. All rejected or condemned bricks shall be removed from site at the Contractor's expense.

2.5.5. Light Weight Concrete Block

2.5.5.1. Light weight concrete blocks shall comply with BS EN 6073-1 and shall be used and laid strictly in accordance with the manufacturer's instructions.

2.5.5.2. Light weight concrete blocks shall be free from asbestos or toxic substances.

2.5.5.3. Where light weight concrete blocks are used in lieu of clay bricks, a modular sized block shall be used according to manufacturer's standards, requirements and method statements.

2.5.5.4. The light weight concrete blocks shall have the following performance criteria:

Dry density of between 500kg/m³ and 1500kg/m³;

Dimensional accuracy of ± 1.5mm on all faces;

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The permissible compressive strength shall be not less than 7N/mm² per 10 samples taken at random from the contractor's stock pile of 1000 or part thereof and tested at certified lab;

Ultimate tensile strength shall be 0.44 - 0.55 Mpa;

Thermal resistance (R-value) of not less than 1*m²K/W;* and

Minimum working density for the blocks is 910kg/m³.

2.5.5.5. The infill wall thickness of light weight blocks shall be as follows:

100mm thickness for internal walls;

125mm thickness for external walls;

200mm thickness (fire rated) for party wall; and

Internal spaces with 24 hour air-condition should comply with the thermal resistance R-value of not less than 1*m²K/W.*

2.6. Patented and Proprietary Brick and Block

2.6.1. Patented bricks and blocks shall comply with MS 2282 and shall be used and laid strictly in accordance with the manufacturer's instructions.

2.6.2. Cement Brick (Patented or Proprietary)

2.6.2.1. The cement brick wall partition system shall satisfy the performance requirements specified in Clause 5 of BS 476: Part 22, for non-load bearing wall partition for the following periods:

Integrity : 130 minutes
Insulation : 130 minutes

2.6.2.2. Minimum compressive strength shall be not less than 7 N/mm².

2.6.3. All patented or proprietary brick and block wall installation works shall strictly adhere to the manufacturer's method statement for installation works and to S.O.'s approval.

2.7. Large Prefabricated Panels.

Large prefabricated panels when used shall conform to MS 1313 and shall be installed strictly in accordance with the manufacturer's recommendations.

2.8. Gypsum Plasterboard

2.8.1. Gypsum plasterboard sheeting shall be a complete proprietary system, in accordance with the Product Data, approved sample and the relevant Standards.

2.8.1.1. BS EN 15283 (Series): Gypsum boards with fibrous reinforcement - Definitions, requirements and test methods; dan

2.8.1.2. BS EN 520: Gypsum plasterboards - Definitions, requirements and test methods.

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2.8.2. Provide moisture-resistant, impact-resistant, fire-resistant and acoustic-rated plasterboard systems where indicated or required.

2.8.2.1. Moisture-resistant grade (MR) plasterboard shall be suitable proprietary products for use in moisture-resistant construction in wet areas where normal plasterboard would be unsuitable.

2.8.2.2. Fire-resistant grade (FR) plasterboard shall be suitable proprietary products for fire-resistant construction.

2.8.2.3. Impact-resistant grade (IR) plasterboard shall be suitable proprietary products for construction of system requiring robustness feature.

2.9. Fibre Cement Sheet

2.9.1. Fibre-cement (FC) sheeting shall be a complete proprietary system, asbestos-free, in accordance with the Product Data, approved samples, and the relevant Standards.

2.9.1.1. MS 1224: Specification for fibre cement symmetrically corrugated sheet and fittings - product specification and test method; and

2.9.1.2. MS 1296: Fibre-cement flat sheets- product specification and test methods.

2.10. Insulation (Acoustical and Thermal)

2.10.1. Unless otherwise specified or shown on the Drawings, acoustic wall panel and/or systems shall be constructed and calculated according to requirements of acoustic specialist and approved by S.O.'s approval.

2.10.2. Thermal insulation system shall comply with MS1020. Samples of the insulation material shall be submitted to the S.O. for approval before they are used and subsequent delivery shall be up to the standard of samples approved.

2.10.3. Unless otherwise shown in the Drawings, glass wool insulation shall be made in Malaysia 50mm thick. It shall have a conductive value of maximum 0.035 W/m²K (tested at a mean temperature of 20°C based MS1020 tested according to ASTM C518). Unless otherwise specified the size of the glass wool insulation shall be 600mm x 1200mm. Glass wool insulation shall be fixed in accordance with the manufacturer’s recommendation and to the approval of the S.O..

2.10.4. Where stone wool insulation is to be used, it shall be made in Malaysia 50mm thick. It shall have a conductive value of maximum 0.035 W/m²K (tested at a mean temperature of 20°C based MS1020 tested according to ASTM C518). Unless otherwise specified the size of the stone wool insulation shall be 600mm x 1200mm. Stone wool insulation shall be fixed in accordance with the manufacturer’s recommendation and to the approval of the S.O..

2.10.5. The contractor shall submit the COO (certificate of origin) confirming made in Malaysia from the supplier/manufacturer to the S.O for approval prior to the commencement of the works. No installation works shall commence until approval is given in writing by the S.O..

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2.10.6. Recommended type of spray applied cellulose insulation shall be:

2.10.6.1. Thickness - 30mm;

2.10.6.2. Thermal conductivity (k-value) = 0.0029 W/m·K tested to ASTM C-177;

2.10.6.3. Fire retardant Class "O" complying with BS476 Part 6 & 7 and endorsed by FRDM;

2.10.6.4. Average moisture absorption of not more than 15% as per ASTM C739;

2.10.6.5. Tested Noise Reduction Coefficient of NRC 0.75 at 30mm thickness; and

2.10.6.6. Tested to be non-toxic and asbestos free, contain no carcinogenic materials and shall not cause any skin irritation to humans.

3. Type of Finishes to Walls and Partitions

3.1. Unless otherwise shown in the Drawings, all plastering works for brick walls shall include the wall surface area above ceiling finish level.

3.2. Unless otherwise specified or shown on the drawings, the appropriate type of finishes for walls and partitions shall be as specified in the Schedule of Finishes. Unless otherwise shown on the Drawings or described in the B.Q., The finishes and their dimensions shall be as specified in SECTION K: PLASTERING, PAVING, TILING AND CARPET and SECTION O: PAINTING.

4. Structural Wall (Blockwork System)

This clause shall apply to the construction of all load bearing blockworks with or without steel reinforcement. All lines, levels, grades, dimensions and cross-sections shall be as shown on the Drawings and/or directed by the S.O.. The full requirement is outlined in the *Specification for Load Bearing Blockwork System (JKR 20601-0252-18)* or the latest edition published by JKR.

4.1. Material

The block shall comply with the requirements of MS 2282 Part 3.

4.2. Compressive Strength

For all block units intended to be used in elements subject to structural requirements, the mean compressive strength shall not be less than 7N/mm^2. The manufacturer shall also declare the normalised compressive strength when relevant.

4.3. Density

The net dry density of the units shall be declared in kilogram per cubic meters (kg/m^3) by the manufacturer in accordance with MS 1933 Part 13. The minimum dry density of unit shall not be less than 1500kg/m^3.

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4.4. Structural Mortar

4.4.1. Recommended minimum compressive strength for prescribed mortar shall be class M6. The proportion of materials by volume shall be referred to **TABLE E1**.

4.4.2. The compressive strength of masonry mortar shall be determined in accordance with BS EN 1015 Part 11. The adhesion between the mortar and the masonry units shall be adequate for the intended use. The ingredients for mortar shall be measured in proper gauge boxes and shall be mixed on a clean boarded platform or in an approved mechanical batch mixer.

4.4.3. The characteristic compressive strength of masonry bonded with thin layer mortar shall be taken as the values given for mortar strength class M12 (mortar designation (i) in **TABLE E1**. The contractor shall submit the manufacturer's specification and method statement to the S.O. for approval prior to the commencement of works.

4.5. Mortar Testing

The use of mortars shall be in accordance with the recommendation given in BS EN 1996. When samples are taken from a designed mortar in accordance with BS EN 1015 Part 2 and tested in accordance with BS EN 1015 Part 11, the compressive strength of the mortar shall not be less than the specified compressive strength. **TABLE E1** shows the relationship of compressive strength classes and the compressive strength of mortar at 28 days.

4.6. Concrete Infill

Concrete infill for reinforced masonry shall be of minimum grade C25/30 (designed mix) or 30P (prescribed) with 10mm nominal size aggregates and specified in accordance with MS 523 Part 2. The minimum cement content, maximum free water/cement ratio and the concrete cover shall conform to the requirement in **Table E2**.

4.7. Blocklaying

4.7.1. Unless otherwise specified, all blockworks shall be laid on a full bed of mortar, and vertical joints shall be filled up fully. The average thickness of the vertical and horizontal joints shall be 10mm, exclusive of any key in the jointing surfaces of the units.

4.7.2. Unless specified, as work proceeds do not rack back corners and other advanced work higher than 1.2m above the general level. For facing work complete the whole lift within one period of operation. Except where permitted by a proprietary system or by the designer, do not carry up any one leaf more than 1.5m height in one day.

4.8. Block Masonry Bonds

The running or stretcher bond of blocks are shown in **FIGURE E1** and **FIGURE E2**.

4.9. Services Holes and Chases

4.9.1. In order to eliminate unnecessary cutting away and making good, sleeves and chases should be provided during the erection of the masonry. In external walls, all sleeves and pipes should preferably be laid with a fall toward the

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outside. The installation of services should be completed before plastering or other finishing work is begun.

4.9.2. Where chases have to be cut, suitable power tools which do not operate by heavy impact should be used so that the recommended depth is not exceeded. Fixing units (blocks) where required, should be built into the wall or partition in the correct positions for skirting, rails and other items of joinery, fittings, etc.

4.9.3. In walls or leaves constructed of solid units, the depth of horizontal chases should not exceed one-sixth of the thickness of the single leaf at any point whilst the depth of the vertical chases should not normally exceed one-third of the thickness of the single leaf at any point.

4.9.4. The cutting of holes up to approximately 300mm square in the wall to accommodate items of equipment may be permitted.

4.9.5. Where heavy fittings are to be fixed to a wall, the effect on the stability of the masonry should be considered.

5. Samples and Mock-up

5.1. Samples and mock-up of wall construction shall be provided and approved by the S.O. prior to the commencement of the actual construction works. The size of the samples shall be determined by the S.O..

5.2. The samples and mock-up for walls and partitions shall include connections between the following components where applicable:

5.2.1. Floor to floor to a minimum of 5m length;

5.2.2. Wall corners;

5.2.3. Lintels;

5.2.4. Stiffeners;

5.2.5. Door and window frames; and

5.2.6. All other walls between different materials.

5.3. Sample and Mock-Up Panels for Structural Wall (Blockwork System)

5.3.1. The contractor shall construct a mock-up panel for the project with total build-up area more than 100m^2 using load bearing blockworks system.

5.3.2. Sample panels shall be built on site in a protected position to provide an agreed standard for the work and treatment of joints before the commencement of the works subjected to the S.O. approval. Such panels shall be maintained throughout the contract and removed on completion.

5.3.3. The mock-up panel needs to be constructed to expose not less than 2m length x 1m height, selected as follows:

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6. Walling / Construction

6.1. Brick Walling

6.1.1. Unless otherwise specified or shown on the Drawings, the whole of the brickwork shall be constructed with standard size clay bricks in mortar as described and the surface left ready for plastering.

6.1.2. All clay bricks shall be soaked in a suitable tank or pit to be provided by the Contractor for at least half an hour before being laid and shall be kept wet whilst being laid. The top of walls left off shall be thoroughly wet before work is resumed. All constructed walling must be left wet and properly protected from the direct sunlight during the following day. The Contractor shall provide sufficient means to ensure that this is done.

6.1.3. Cement sand bricks shall not be soaked but dipped in water before being laid and all constructed brickwork shall be protected from direct sunlight during the day on which it is laid and also during the following day and the contractor shall provide sufficient means to ensure that this is done.

6.1.4. All bricks shall be properly bedded in mortar and all joints shall be thoroughly flushed up and raked out to a depth of 13mm as the works proceeds. No joint shall exceed 10mm in thickness.

6.1.5. Brickwork shall be carried up perfectly true and plumb in a uniform manner. No one portion being raised more than 1m above another at one time. No overhand work shall be permitted, and scaffolding shall be carried up as the work proceeds. The vertical points of every alternate course shall be kept perpendicular over one another, and all perpends, quoins, et cetera shall be kept strictly true and square.

6.1.6. All intersections and angles of walls shall be properly bonded together, and all walls and piers of lengths not multiples of brick sizes shall be cut and bonded in the best approved manner. No broken bricks shall be used except where required to form bonds.

6.1.7. All half brick (113mm) walls shall be reinforced at every fourth course with approved reinforcement (for example exmet) commencing two courses above floor level. For block walling, reinforcement shall be at every second course commencing one course above floor level.

6.1.8. All brick walls shall be constructed on reinforced concrete beams in accordance with the Drawings. No brick walls except lightweight partitions are allowed to be constructed on reinforced concrete slabs.

6.1.9. Unless otherwise specified, all toilet perimeter walls shall be constructed using clay bricks. Cement sand bricks shall not be used for toilet walls.

6.1.10. All half brick walls shall be built in Stretcher Bond.

6.1.11. All other brickwork shall be built in English Bond or as shown on the Drawings.

6.2. Facing Brickwork

6.2.1. All facing brickwork shall be executed in first quality approved facing bricks in Stretcher or Flemish Bond as shown on the Drawings, properly bonded into any backing walls, piers, et cetera. Joints shall be racked out to a depth of 13

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mm and point up in coloured cement mortar to approved tints, finished with a neat struck weathered joint.

6.2.2. Facing brickwork shall be kept perfectly clean and no rubbing down of brickwork will be allowed.

6.3. Stonework

6.3.1. Unless otherwise shown on the Drawings or described in the B.Q., all stone blocks used shall be of limestone or granite whichever is more readily available within the locality of the Site and shall be free from cracks, fissures or other defects to the approval of the S.O.. The stone blocks shall in general, have their largest faces parallel. Unless otherwise required, the maximum thickness of the stone blocks shall in no case exceed the thickness of the wall or portion of the structure into which it is being built.

6.3.2. Stone walling shall be laid random un-coursed or random coursed as shown on the Drawings. Through or bonded stones shall be used at one stone per meter square for random coursed. Where backing brick wall is shown, the through stone shall be properly bonded in such brick wall.

6.3.3. Unless otherwise shown on the Drawings, all stonework shall be bedded in cement and sand mortar (1:3) mix and finished with a flushed joint rubbed down with sacking. All interstices between individual stones shall be filled with mortar. Finish to exposed surfaces or random walling shall be hammer-dressed.

6.4. Hollow Block Walling

The cement sand block wall shall be laid in the manner specified for brick wall. The hollow block shall not be soaked but dipped in water before laying. The hollow block wall shall be reinforced at every second course with reinforcement commencing one course above floor level.

6.5. Autoclaved Aerated Concrete (AAC) Block Walling

6.5.1. Where shown on the Drawings and/or described in the B.Q. or as an alternative to clay bricks, the Contractor may use AAC blocks for non-load bearing walls and partitions. The AAC block work shall be constructed strictly in accordance with the manufacturer's recommendations. Any extra cost in connection therewith shall be borne by the Contractor.

6.5.2. Only proprietary thin bed adhesive shall be used assembling AAC block wall. The AAC block work shall be installed using an approved thin layer of proprietary thin bed adhesive mortar with minimum flexural strength of 0.44 MPa to all horizontals and perpends. The first course must be made true and level using a normal layer of mortar with thin layer of adhesive to fully seal the perpends. The thin layer of proprietary adhesive shall be applied using notched trowel to obtain an even distribution of adhesive to achieve joint thickness of 2mm to 3mm.

6.5.3. A damp-proof course slip-joint membrane shall be laid on top of the floor slab or beams before receiving the mortar bedding to allow for differential movement between the blocks and the supporting structure.

6.5.4. The AAC block work shall be laid in a manner that the vertical joint of the lower course shall be staggered at least 100mm relative to the vertical joint of the overlaying course.

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6.5.5. Unless otherwise directed and/or shown, where concrete block walls abut concrete faces, the face shall be flushed.

6.5.6. Control joints should be built into walls at spacing not greater than 8m centres, and at locations in accordance with manufacturer's recommendation.

6.5.7. Care must be taken to keep the walls clean, strictly in accordance with the manufacturer's recommendation. Excess adhesive must be removed progressively.

6.5.8. The wall surfaces may be finished with suitable surface coating that has the dual properties of being waterproof and water vapour permeable and shall be applied in accordance with the manufacturer's recommendation.

6.5.9. Only proprietary cement plaster of the same AAC block shall be used for external rendering of an external wall. The minimum thickness for the rendering of the external wall shall be 12mm thick.

6.5.10. Only proprietary skim coat base and skim coat finish of the same AAC block shall be used for internal wall application. The recommended thickness of the skim coat base shall be between 2 - 4mm thickness and the skim coat finish of an internal wall shall be of 1 - 2mm thickness. Both are coatings shall be applied as a two-coat system and applied according to manufacturer's instruction and to the S.O's approval.

6.5.11. All AAC block wall installation works shall strictly adhere to the manufacturer's method statement for installation works and to S.O.'s approval.

6.6. Parapet and Freestanding Wall

6.6.1. Any parapet and freestanding wall consisting of 155mm thick brick wall including plastering on both sides shall only be constructed to a maximum height of 900mm.

6.6.2. Where shown on the Drawings, freestanding walls above 900mm in height shall be constructed as per the engineer's detail Drawings or to the S.O.'s approval.

6.6.3. Precast reinforced concrete copings shall be constructed on all external parapet and free-standing walls. The reinforced concrete coping shall be laid to fall, complete with 12mm half round throating.

6.6.4. Freestanding walls more than 3m length vertically and horizontally shall be constructed with reinforced concrete stiffeners to engineer's detail and with the S.O.'s approval.

6.7. Lintel and Stiffener

6.7.1. Unless otherwise specified or shown on the Drawings, lintels shall be provided to all openings and to be sized accordingly by the Contractor to the S.O.'s approval.

6.7.2. Reinforced concrete stiffeners shall be constructed at every minimum of 3m vertically and horizontally to strengthen brick and block wall system construction according to engineer's detail.

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6.7.3. Alternatively, prefabricated lintel and stiffener may be installed to the manufacturer's details and as approved by the S.O.

6.8. Fasteners

Unless otherwise shown on the Drawings, fasteners or cramps for frames, metal windows and precast units shall be built in at 1m centres on the vertical side of the frame. Mild steel cramps shall be 25mm x 3mm x 225mm long for fixing wooden frames, etc. One end of the cramp shall be turned up and screwed to back of the frame and the other end shall be split and fish-tailed for building in. Cramps which are to be fixed to concrete shall be embedded in concrete and built into brickwork as the work proceeds.

6.9. Cutting

All cuttings such as arches, sinks, setbacks, and projections shall be properly formed. Chases and holes through walls and slabs for the passage of pipes, wiring and the like shall be neatly cut or formed. Upon the installation of the services pipes, the chases and holes through walls shall be properly sealed (Fire Stop) to prevent fire spread as required by the DGFR and UBBL. Where plastering works are done on the cuttings, the surface shall be smooth and seamless.

6.10. Partitioning

6.10.1. Timber Framed Partition

6.10.1.1. All timber used for the timber stud framings for partition walls shall be as specified in SECTION H: TIMBER, JOINERY AND IRONMONGERY.

6.10.1.2. Wall partition consisting of timber frames shall consist of vertical and horizontal studs. The studs shall consist of approved timber hardwood with a minimum size of 50mm x 50mm unless otherwise specified. All horizontal and vertical studs shall be constructed at a maximum nominal spacing of 610mm centres.

6.10.1.3. The top most horizontal frame, referred to as the top plate shall be bolted or nailed to the ceiling and continuously erected using timber or metal stiffener securely fixed to the slab to the S.O.'s approval. The timber and metal stiffeners shall be spaced at 1220mm centres maximum.

6.10.1.4. The lowest horizontal frame, referred to as the bottom plate, shall be securely fixed using bolts or nails. Unless otherwise advised, all fixing to slabs, M12 expansion bolts shall be used at 1220mm centres maximum with galvanized mild steel strap, or equivalent, to the floor to the S.O.'s approval. All fixings to timber slabs shall be fixed at 600mm centres maximum.

6.10.1.5. Unless otherwise specified, dimension for timber panels shall comply with MS 1064.

6.10.1.6. Where proprietary timber partitions are used, they shall be constructed in accordance with the manufacturer's recommendations and to the S.O.'s approval.

6.10.1.7. Partitions, screens and vent panels, shall be constructed as detailed in the Drawings. Where shown, galvanized welded wire mesh or expanded metal of the required sizes and patterns shall

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be fixed to vent panels and window openings. The mesh shall be secured in position using rebated and mitred timber battens and screws.

6.10.2. Metal Framed Partition

6.10.2.1. Steel sections such as, but not limited to metal framing and studs shall comply with ASTM C645, BS EN 14195, BS 7364 or other approved equivalent standards as appropriate, and to the approval of the S.O..

6.10.2.2. Unless otherwise specified, all metal framing for partitions shall be either galvanized or zinc alum coated steel 62mm C-Studs (vertical) and 64mm U-tracks (horizontal) of 0.5mm base metal thickness. The steel stud shall be manufactured from mild steel strip, with material specification complying to either one of the following:

Steel grade Z2 with minimum yield strength of 210N/mm² and zinc coating type Z275 minimum, complying with BS EN 10143;

Steel grade G300, with minimum yield strength of 300N/mm^2 and zinc-alum coating type AZ150 minimum, complying with AS 1397.

6.10.2.3. The stud which is to support a joint shall have a minimum fixing face width of 32mm for screw fixing and all other framing members shall not be less than 30mm. Drywall screws shall be at least 10mm longer than total thickness of plasterboards on each side of the partition wall. The plasterboards are laid staggered and fixed to the metal frames using drywall screws not exceeding 300mm centres.

6.10.2.4. The top most U-track (horizontal) shall be screwed to the ceiling and continuously erected using metal stiffener securely fixed to the slab. The metal studs directly supporting plasterboard sheets shall be spaced at 610mm centres maximum. The bottom U-track (horizontal) shall be securely fixed to the floor slab using bolts or screws. Unless otherwise advised, all fixing to slabs, M12 expansion bolts shall be used at 1200mm centres maximum with galvanized mild steel strap to the floor and to the S.O.'s approval.

6.10.2.5. Unless otherwise shown on the Drawings, the partitions shall not be erected more than 3000mm height. Partitions which are more than 3000mm height shall be supported by additional structural members, to structural engineer's detail and S.O.'s approval.

6.10.2.6. Partition above ceiling shall allow for cut out opening for service ducts or trunks and cable trays. The contractor shall coordinate with all subcontractors on the exact location and size of the openings. For fire rated partition, any gaps around any pipe ducts through the partition shall be properly sealed with approved fire/smoke stop system by the fire stopping specialist.

6.10.2.7. If full height partition has to be terminated below ventilation duct route parallel to the partitions, the stud of the partition shall be secured to the support frame of the duct or extended secondary frame support. In such cases, space between the duct and reinforced concrete soffit need not be sealed up, unless it is of fire rated type of partition.

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6.10.2.8. The deflection of the metal frame partition system under service condition shall be controlled by the limit for the calculated deflection of the element chosen for the system and its intended use. The deflection shall not exceed L/240 or L/360 subject to the finishing material attached to the partition. Any system wall partition selected shall be installed strictly according to the manufacturer's specifications and details to the S.O.'s approval.

6.10.3. Plasterboard lining

6.10.3.1. The type of plasterboard used shall comply with BS EN 520. The specified plasterboard shall carry class 'O' approval from DGFR. Unless otherwise specified the plasterboards used for the works shall be minimum 12.5mm thick with standard length of 2440mm and shall be free of defects.

6.10.3.2. The deviations and tolerances shall be in accordance with BS 8212. When required, the deflection under load shall be determined in accordance with BS EN 520.

6.10.3.3. The appropriate type of sealant shall be used for the required type of plasterboard. Elastomeric sealants shall be used at the perimeter of the dry lining or partitioning to provide an airtight construction and to the approval of the S.O..

6.10.3.4. Jointing compound shall be of air drying or setting type, in accordance with BS EN 13963, and to the approval of the S.O.. Jointing compound shall be applied as per manufacturer's recommendation and S.O.'s approval. The use of any additives to modify any of the properties of compounds shall not be permitted.

6.10.3.5. Jointing tape for plasterboards shall not be less than 48mm wide and not exceeding 60mm in accordance with ASTM C475 or equivalent, and the approval of the S.O..

6.10.3.6. Control joints shall be provided for a long continuous run of plasterboard wall spaced at not more than 10m apart.

6.10.3.7. Corner beads shall be provided as reinforcement to permit construction of true, concealed angles with gypsum base and panels.

6.10.3.8. Provision shall be allowed for the plasterboard partition system to support surface mounted fixtures by incorporating independent support framing hidden behind or exposed on the partition surface to provide adequate and appropriate support and to the approval of the S.O..

6.10.3.9. Wherever possible, full length plasterboard sheets shall be used to eliminate the need for sheet end butt joints. Where possible, joints on opposite sides of framing should be arranged to occur between different framing members.

6.10.3.10. Plasterboard sheets shall be laid out to minimize butt joints and waste. Butt joints on adjoining sheets shall be staggered. Butt joints on opposite sides of the wall shall be staggered. The sheet shall

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be laid so that the vertical joints fall a minimum of 200mm from the edge of the opening.

6.10.3.11. Fire resisting systems comprising of more than one layer of plasterboards, the joints in successive layers should be staggered. In the case of walls sheeted on both sides' joints should be staggered on opposite sides of the wall.

6.10.3.12. Penetrations in the system shall only be allowed if installed in accordance to manufacturer's recommendation and tested at the Contractor's expenses. Penetration shall be strictly carried out in accordance with the requirements of the DGFR and to the approval of the S.O..

6.10.3.13. Fasteners shall have a corrosion-resistant finish and be appropriate for intended use, also in accordance with BS EN 14566 and BS 8212, or any relevant standards. The heads of fasteners shall be shaped so that they can be driven slightly below the surface of the plasterboard without punching through the paper liner.

6.10.3.14. Impact resistance of a partition system including gypsum plasterboard shall be determined in accordance with ISO 7892 and BS 5234-2.

6.10.3.15. The Contractor shall submit to the S.O., a manufacturer's warranty against any defect or damage to the proprietary plasterboard partition system which may arise during the period of five (5) years from the date of Certificate of Practical Completion. Terms of the warranty shall be such as shall be approved by the S.O..

6.11. Insulation Installation

6.11.1. Where necessary, insulation shall be installed so that:

6.11.1.1. It abuts or overlaps adjoining insulation other than at supporting members such as studs, noggings, joists, furring channels and the like where the insulation must butt against the member;

6.11.1.2. It forms a continuous barrier with ceilings, walls, bulkheads, floors or the like that inherently contribute to the thermal barrier; and

6.11.1.3. It does not affect the safe or effective operation of a service or fitting.

6.11.2. Reflective insulation shall be installed so that:

6.11.2.1. The necessary airspace to achieve the required R-value between a reflective side of the reflective insulation and a building lining or cladding;

6.11.2.2. The reflective insulation closely fitted against any penetration, door or window opening;

6.11.2.3. The reflective insulation adequately supported by framing members; and

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6.11.2.4. Each adjoining sheet of roll membrane being overlapped not less than 50mm; or taped together.

6.11.3. Bulk insulation shall be installed so that:

6.11.3.1. It maintains its position and thickness, other than where it crosses roof battens, water pipes, electrical cabling or the like; and

6.11.3.2. In a ceiling, where there is no bulk insulation or reflective insulation in the wall beneath, it overlaps the wall by not less than 50mm.

6.11.4. Fixing methods of insulation material shall be as below, or as recommendation of manufacturer:

6.11.4.1. Use proprietary fixing methods which prevent long term sag, collapse or dislodgement; and

6.11.4.2. Fasteners shall be suitable non-corrosive types.

6.12. Glass Partitions

6.12.1. Unless otherwise specified or shown on the Drawing, all fixed glass wall systems shall be 8mm thick minimum, erected with stainless steel framing system for sizes up to 1200mm x 4800mm maximum installed to manufacturer's recommendation and to S.O.'s approval. For sizes more than 4800mm, the panels shall be constructed according to manufacturer's recommendation and the installation shall be certified by a P.E.

6.12.2. Glass doors shall be installed complete with accessories as recommended by the manufacturer and to the S.O.'s approval.

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TABLE E1 – MASONRY MORTARS

	Mortar designation	Compressive strength class	Prescribed mortars (proportion of materials by volume) (see notes 1 and 2)		Compressive strength at 28 days N/mm^2
			Cement **(a)**: sand with or without air entrainment	masonry cement **(b)**: sand	
↓ Increasing ability to accommodate movement, e.g. due to settlement, temperature and moisture changes	(i)	M12	-	-	12
	(ii)	M6	1 : 3 to 4	1 : 2½ to 3½	6

a. Cement, or combination of cements except masonry cements.

i) Combinations produced in the mortar mixer from Portland cement CEM I conforming to MS EN 197 Part 1 and ground granulated blastfurnace slag conforming to MS EN 15167 Part 1 where the proportions and properties conform to CEM II/A-S or CEM II/B-S of MS EN 197 Part 1, except Clause 9 of that standard.

ii) Combinations produced in the mortar mixer from Portland cement CEM I conforming to MS EN 197 Part 1 where the proportions and properties conform to CEM II/A-L or CEM II/A-LL of MS EN 197 Part 1, except Clause 9 of that standard.

iii) Combinations produced in the mortar mixer from Portland cement CEM I conforming to MS EN 197 Part 1 and pulverized fuel ash conforming to MS EN 450 Part 1, where the proportions and properties conform to CEM II/A-V or CEM II/B-V of MS EN 197 Part 1, except Clause 9 of that standard.

b. Masonry cement (inorganic filler other than lime)

NOTE 1 Proportioning by mass will give more accurate batching than proportioning by volume, provided that the bulk densities of the materials are checked on site.

NOTE 2 When the sand portion is given as, for example, 5 to 6, the lower figure should be used with sands containing a higher proportion of fines whilst the higher figure should be used with sands containing a lower proportion of fines.

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TABLE E2 - MINIMUM CONCRETE COVER FOR CARBON STEEL REINFORCEMENT

Exposure situations	*Concrete grade in MS EN 206 and MS 523 Part 2 & MS 523 Part 3*				
	C25/30	C28/35	C32/40	C35/45	C40/50
	Minimum cement content (kg/m^3)				
	300	320	340	360	380
	Maximum free water/cement ratio				
	0.65	0.6	0.55	0.50	0.45
	Thickness of concrete cover				
	mm	mm	mm	mm	mm
E1[a]	20	20	20[b]	20[b]	20[b]
E2	—	35	30	25	20
E3	—	—	40	30	25
E4	—	—	—	60	50

Exposure situation E1. Internal work and the inner skin of ungrouted external cavity walls and behind surfaces protected by an impervious coating that can readily be inspected, or external parts built.

Exposure situation E2. Buried masonry and masonry continually submerged in fresh water or external parts built.

Exposure situation E3. Masonry exposed to freezing whilst wet, subjected to heavy condensation oe exposed to cycles of wetting by fresh water and drying out or external parts built.

Exposure situation E4. Masonry exposed to salt or moorland water, corrosive fumes, abrasion or the salt used for de-icing.

a Alternatively, 1: 0 to ¼ : 3: 2 cement: lime : sand: 10 mm nominal aggregate mix may be used to meet exposure situation E1 when the cover to reinforcement is 15 mm minimum.

b These covers may be reduced to 15 mm minimum provided that the nominal maximum size of aggregate does not exceed 10mm.

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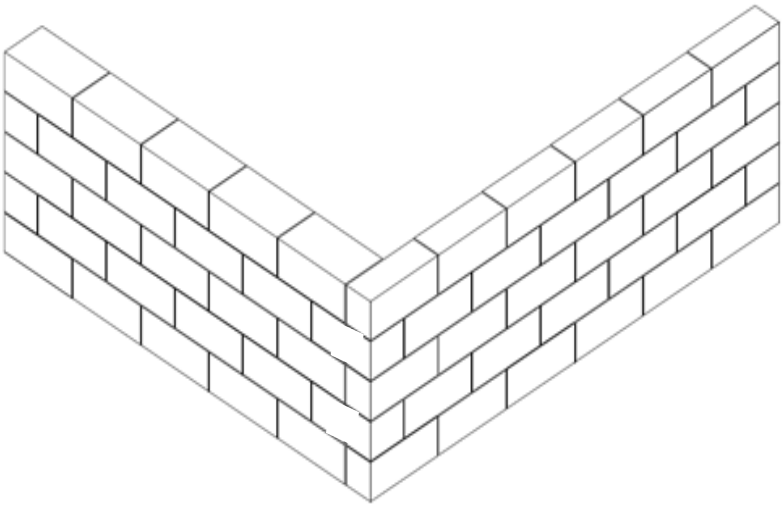

FIGURE E1: RUNNING OR STRETCHER BOND

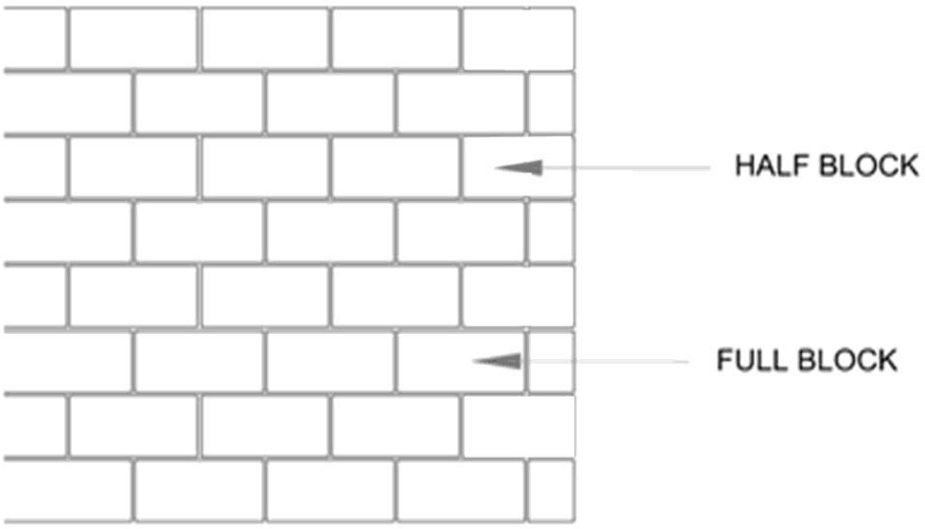

FIGURE E2: RUNNING OR STRETCHER BOND

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TABLE OF CONTENTS

SECTION F: SEWERAGE		PAGE
1.	General	F/1
2.	Material	F/1
3.	Layout	F/1
4.	Excavation	F/1
5.	Pipes and Fittings	F/3
6.	Joint for Sewer Pipes	F/3
7.	Pipe Laying	F/4
8.	Bedding, Haunching And Surround	F/5
9.	Connections	F/5
10.	Manholes, Inspection Chambers and Valve Chambers	F/5
11.	Septic Tank, Small Sewage Treatment System (SSTS) and Sewage Treatment Plant (STP)	F/7
12.	Connections to the Public Sewerage Line	F/8
13.	Testing for Sewer Pipes Installation	F/8
14.	Backfilling	F/11

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1. General

1.1. This section shall comply with the latest Suruhanjaya Perkhidmatan Air Negara (SPAN) requirement, Malaysian Sewerage Industry Guideline (MSIG), MS 1228 or any other relevant standards approved by the Government.

1.2. This section of the Works shall be carried out strictly with the provisions of all legislation, regulations and by-laws currently in force with regard to and in connection with the works as specified in Section A.

1.3. The Works to be done under this section unless otherwise shown or described in the B.Q. shall consist of the supply, delivery, construction, and testing of all sewerage works and ancillary works, and all necessary works up to the point of final discharge of the effluent. In the case of discharge into the public sewer or the package sewage treatment plant, the Works shall terminate up to and including the last manhole or intercepting trap of the system. This section of the Works shall be carried out strictly in accordance with the appropriate by-laws and to the approval of the S.O.

1.4. The Contractor is responsible to ensure that all works are carried out by a competent person and any submission for approval to the Certifying Agency appointed by Suruhanjaya Perkhidmatan Air Negara (SPAN).

2. Material

2.1. Cement, Sand, Aggregates and Bricks

2.1.1. Cement, sand and aggregates shall be as specified in SECTION D: CONCRETING. All bricks used unless otherwise shown on the Drawings or described in the B.Q. shall be clay bricks as specified in SECTION E: WALL SYSTEM.

2.2. Sewerage Pipe

2.2.1. The Contractor shall use sewer pipes from suppliers approved by the relevant authorities and the S.O. before being installed.

2.2.2. The Contractor shall submit the certificate and test report of sewer pipe to the S.O. for approval.

2.2.3. The Contractor shall make sure the sewer pipe is stored and/or stacked in such manner to prevent breakage.

3. Layout

The whole sewerage work shall be carried out according to the layout as shown on the Drawings unless otherwise instructed by the S.O.

4. Excavation

4.1. Generally, all excavation works in this section unless otherwise specified hereunder shall be as specified in SECTION B: EXCAVATION AND EARTHWORKS.

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4.2. The Contractor shall carry out survey works and any other necessary preliminary work to determine the sewer pipe alignment, method of excavation and protection and all related works. Excavation works clearance from the building/ road shall be 1 meter. The pipe alignment shall be approved by the S.O. before the Contractor starts the excavation works.

4.3. The trench shall be excavated to the depths intended or as shown on the Drawings and shall be finished and trimmed to the correct level and grade. Unless indicated otherwise, the bottom of the trench shall be graded so that the pipe invert slopes evenly between the appropriate outlet invert of the preceding manhole and the inlet invert of the next manhole.

4.4. The trench shall be excavated to such width so as to ensure that a minimum working space of 300mm will be available on each side of the pipe when properly aligned. At all joints, the trench shall be excavated to give a minimum working space of not less than 300mm all-round the joint.

4.5. The sides of all excavation unless otherwise approved by the S.O. shall be cut vertical and where necessary shall be protected against caving in by timbering or other temporary shoring to the approval of the S.O. If the trench is more than 1.5m, the Contractor shall provide support for the trench to avoid collapse, settlement or movement of the banks.

4.6. The trench excavation shall not advance more than 100m ahead of the completed backfilled pipeline. Pipe shall be laid in all trenches that have been excavated at the end of each day's work, unless the Contractor get approval from the S.O. to do otherwise.

4.7. It shall be the responsibility of the Contractor to identify, protect and support all existing service utilities within 3 meters of excavation or work to be performed and to arrange with the services owner or authority for the temporary closure, removal and subsequent replacement or relocation as approved by the S.O.

4.8. The trench should be excavated precisely to ensure the sewer pipe will be in the centre of the trench. The bottoms of the trenches for all sewers shall be carefully and truly graded, formed and lined according to the grades and dimensions as shown on the Drawings.

4.9. Should the ground be so wet or soft and does not form a firm base for the pipe, and if it is deemed necessary in the opinion of the S.O. then the trench shall be excavated 225mm below the intended level or shown on the Drawings and then brought to the correct level with good selected earth, quarry dust or sand well rammed into place. Such deepening of pipe trench and filling back shall be treated as a variation under the terms of the Contract. Should the bottom of the trench be inadvertently excavated below the specified level, it shall be brought back at the Contractor's expense to the correct level with good selected earth, quarry dust or sand carefully rammed into place.

4.10. The Contractor shall remove any water that collects in the trenches while sewer pipes are being laid. Water encountered shall be disposed of by the Contractor in a manner satisfactory to the S.O.

4.11. Excess material from the trench excavation shall be located 600mm (minimum) away from the trench.

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4.12. When excavating pipe trenches in roadway or other paved surfaces, the Contractor shall first remove all metal, slabs or bricks forming the existing pavement to the width of the trenches and reinstate to the approval of the S.O. after the trenches have been backfilled. The Contractor must make sure that not more than half of the width of a roadway shall be disrupted at any one time during the sewerage work.

4.13. Generally, where rock is encountered in the trench excavation, it shall be removed to the approval of the S.O. Where layer of rock is encountered along the bottom of the excavation, it shall be cut and trimmed to the required level of the trench. All voids formed at the bottom of the trench by the removal of rocks shall be back filled to the required level with concrete strength class of C20/25 or other suitable materials well rammed and compacted to the approval of the S.O. Uneven surfaces of rocks at the bottom of the excavation due to the trimming shall be levelled and smoothen with sand blinding to the approval of the S.O.

4.14. If the works required pipe jacking, the Contractor shall provide method statement for S.O.'s review and approval.

4.15. The Contractor shall ensure that the work performed is safe and in compliance with Occupational Safety and Health Act (OSHA).

4.16. The Contractor shall halt the excavation works once the medium of protection and signage of existing utilities area is visible. The Contractor shall use suitable tools and method as approved by the S.O. to further excavate the particular area.

4.17. Existing drains, gutters and channels shall not be obstructed. Existing drains affected by the works shall be realigned to ensure continual operation.

5. Pipes and Fittings

5.1. Generally, all sewer pipes and fittings shall comply with the relevant authorities' guidelines.

5.2. Sewer pipes used for gravity types of sewer shall be a minimum size of 150mm for service connection and 225mm for public sewer.

5.3. Sewer pipes for force mains (which require pump) shall comply with the relevant authorities' guidelines.

6. Joint for Sewer Pipes

6.1. Generally, all joints shall comply with the relevant authorities' guidelines.

6.2. Unless otherwise approved by the S.O., joints of flexible and watertight type shall be used on all sewer pipes. The spigot and socket of each pipe shall be cleaned and lubricated before the running of each joint.

6.3. Couplings shall be made either of the same materials as the pipe or other material to the approval of the S.O. The pipes and coupling shall have accurately machined or moulded tapered ends, the internal taper of the couplings matching the external taper of the pipes.

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7. Pipe Laying

7.1. All pipes shall be laid in compliance with the relevant authorities' guidelines and in accordance with the sizes, locations, dimensions, grades and other particulars as shown on the Drawings. Each pipe shall be carefully inspected upon arrival at site. Sewer pipes shall be carefully stored. Defective pipes shall be marked and removed from the site forthwith.

7.2. Prior to fixing or laying all pipes and fittings shall again be carefully inspecting for damage and only those found to be sound in every aspect shall be fixed or laid. Any pipes, specials, et cetera found to be damaged in any way shall be clearly marked, set aside and removed from the site.

7.3. No pipe shall be laid until the trench has been inspected and approved by the S.O.

7.4. The pipes shall be gently lowered into the trench by means approved by the S.O. No pipes shall be rolled or dropped into the trench. The pipe shall be laid true to alignment as shown on the Drawings or as instructed by the S.O. Interior and exterior of each pipe at the joint shall be thoroughly cleaned before the joint is made. Pipes shall be laid from the downstream end towards the upstream end.

7.5. To prevent the entry of earth and other materials into the pipes, the Contractor shall provide and fix suitable stops for efficiently closing all open ends of pipes in the trench while work is not actually being carried out at such open ends.

7.6. Socketed pipes shall be laid with the sockets laid against the direction of flow. At every position of pipe joint's, the bedding shall be recessed sufficiently.

7.7. Where sewer pipes are to be laid on concrete bed, hunched or encased in concrete surrounds, these shall be as shown on the Drawings.

7.8. The gravity sewer pipes shall be laid to the gradients as shown on the Drawings. Where the gradients are not shown on the Drawings, the pipe shall be laid to the following gradients as shown in the **Table F1**.

7.9. The invert level of each pipe laid shall be checked during laying and immediately after laying as shown on the Drawings.

7.10. Where sewer pipes are laid above ground, they shall be supported at intervals to the details as shown on the Drawings or to the approval of the S.O.

7.11. Minimum depth of cover from crown of pipe to the finish road or ground level shall be minimum of 450mm unless shown otherwise on the Drawings or instructed by the S.O.

7.12. Sewers pipes shall not be laid above the water pipes. A minimum vertical clearance of 1.0m shall be provided between the crown of a sewer pipe and the bottom of a water pipe. The horizontal clearance between sewer and water pipelines shall be 3.0m where applicable unless otherwise shown on the Drawings.

7.13. Sewerline shall not be constructed under buildings, permanent structures or private lots and stagnant water bodies unless otherwise approved by the S.O.

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7.14. Other requirements

For easy identification of underground forced sewer mains, the layout shall be planted with marker posts at every 200m length and at every change of pipe direction. Valve chambers provided shall have adequate access for operations and maintenance.

8. Bedding, Haunching and Surround

8.1. Concrete bed, haunching and surround shall be of concrete strength class of C20/25.

8.2. Typical bedding is to be used for all pipes under normal site condition unless directed by the S.O.

8.3. Only approved materials are allowed to be used for pipe embedment.

8.4. The bedding material shall be placed as soon as possible after the base of the trench is prepared and excess water has been removed.

8.5. Whenever the bedding is disturbed, the pipe shall be raised to allow for repair works to be done.

8.6. Any pegs or other temporary aids for levelling works shall be removed before any pipe being laid.

8.7. All bedding shall comply with the relevant authorities' guidelines and in accordance with the sizes, locations, dimensions, grades and other particular as shown on the Drawings.

9. Connections

9.1. The Contractor shall allow and provide for all bends, junctions, traps, gullies as shown on the Drawings or where necessary. If a gully is used, it shall be of the inlet type, and shall be set level on a concrete base, with a riser to finish 50mm above the surrounding surface level, complete with concrete surrounds rendered on all sides and galvanized iron grating. Bends turned up to receive various stacks shall be set on concrete bases to the approval of the S.O. The bends at the foot of vertical stacks shall be of gentle radius type.

9.2. All underground fittings shall be completely surrounded in concrete and the Contractor shall allow for any additional excavation and jointing of pipes.

10. Manholes, Inspection Chambers and Valve Chambers

10.1. Manholes, inspection chambers and valve chambers shall be constructed with the sizes, locations, spacing between manholes, and details shown on the Drawings and the relevant authorities' guidelines. Unless otherwise shown or specified, all dimensions on the plan shall be the inside measurement.

10.2. Manholes and inspection chambers shall be protected by lining/ coating to prevent corrosion of the concrete due to sulphide attack. Internal walls shall be either rendered with minimum 20mm thick sulphate resistant cement mortar or lined with PVC, HDPE or epoxy coating.

10.3. Manholes

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10.3.1. Manhole Covers and Frames

10.3.1.1. No manhole shall be constructed on the road and hard standing unless otherwise shown on the Drawings.

10.3.1.2. Manhole covers, and frames shall comply with the relevant authorities' guidelines and be equipped with safety features such as locking device, and hinge to prevent rocking due to traffic and to provide a theft proof design.

10.3.1.3. All surfaces of manhole's covers and frames supplied shall be coated as stated in the relevant authorities' guidelines with either:

(i) Hot applied bituminous material complying with BS EN 10300 (Steel tubes and fittings for onshore and offshore pipelines. Bitumen hot applied materials for external coating).

(ii) Cold applied bituminous material complying with BS 3416 (Specification for bitumen-based coatings for cold application, suitable for use in contact with potable water)

10.3.2. Manhole Testing (Before Backfilling)

10.3.2.1. Water-tightness test shall be conducted where no visible leakage shall occur between the manhole cover and its seating in the frame when tested in accordance with the relevant authorities' guidelines.

10.3.2.2. A visual inspection shall be conducted on all the external and internal section of each manhole in accordance with the relevant authorities' guidelines. Particular attention shall be given to:

(i) The slope of benching.

(ii) Joints to pipes.

(iii) Transitions at entry and exits.

(iv) Joints in the structure.

(v) Quality of concrete finish.

(vi) Water-tightness of manhole covers and surround.

10.4. Inspection Chambers

10.4.1. Unless otherwise shown on the Drawings, inspection chambers shall be constructed using clay bricks on concrete foundation with strength class of C20/25. The dimensions shall be as shown on the Drawings.

10.4.2. Each inspection chamber shall have channels and open channel junctions of sizes as shown on the Drawings.

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10.4.3. Concrete benching shall be to a gradient of 1:6 and shall be with strength class of C20/25 concrete finished with 19mm steel trowelled water proofed cement and sand (1:3) rendering.

10.4.4. The internal sides of the inspection chambers shall be lined with 20mm thick high alumina cement mortar or minimum of two (2) layers coal tar epoxy as approved by the S.O.

10.4.5. Externally, the exposed concrete or brick surfaces shall be rendered with 12mm cement and sand mortar (1:3) and terminated 150mm below the finished ground level. All internal angles shall be rounded off.

10.4.6. Inspection chambers shall be provided with covers and unless specified or as shown on the Drawings, covers shall be of medium duty 450mm x 600mm cast iron covers with air tight frames.

10.4.7. The usage of inspection chamber shall be restricted for internal sanitary uses only and shall not be located on the carriageway/ vehicle routes.

11. Septic Tank, Small Sewage Treatment System (SSTS) and Sewage Treatment Plant (STP)

11.1. Septic tank, SSTS and STP shall be constructed as shown on the Drawings complying to the relevant authorities' guidelines and to the approval of the S.O.

11.2. All septic tank, SSTS and STP shall be approved only by SPAN. The material shall be supplied by the supplier listed by SPAN.

11.3. The quality limit for sewage effluent at the discharge point shall comply with *Environmental Quality Act (EQA) 1974* or latest. The limit for sewage effluent at the discharge point shall comply with Standard A of *EQA* as in **Appendix F/1.**

11.4. Prior to the installation of the sewage treatment system, the Contractor shall submit to the S.O. the approved drawings duly endorsed by the authority, system design, method statement including structural, foundation, external work and M & E work duly certified by a Competent Person.

11.5. The procedures for certification of sewerage services are given in the relevant authorities' guidelines. Sewage treatment system shall be approved by the Local Authority/ Certifying Agency before installation at site. The submission approval to the Local Authority/ Certifying Agency is as per **Appendix F/1.**

11.6. The S.P. shall provide specification on construction and installation of the system and during these periods, the Local Authority/ Certifying Agency will carry out inspection to ensure the compliance of their requirements. The S.P. shall adhere to the certification procedures for planning, system and design approval until the approval of final inspection prior to handing over.

11.7. Upon the completion of the installation of the sewage treatment system and prior to the issuance of the Certificate of Practical Completion, the Contractor shall submit the following documents to the S.O. for information and record:

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11.7.1. S.P.'s Guarantee against any defects or damages during a period of five (5) years from the date of Certificate of Practical Completion due to any defect, fault or insufficiency in design, material or workmanship or against any other failure which an experienced Contractor may reasonably contemplate but shall not include normal replacement and maintenance. The terms of the Guarantee shall be such as approved by the S.O.

11.7.2. As-built drawings and *Operation Manual and Maintenance (OMM)* of the sewage treatment system certified by a Professional Engineer with Practicing Certificate (PEPC) registered with the Board of Engineers Malaysia.

12. Connections to the Public Sewerage Line

12.1. Connections to the public sewerage line, if any, shall be strictly carried out in accordance with requirements of the relevant authorities' guidelines and to the approval of the S.O.

12.2. Connection to public sewerage line can only be carried out by licensed Contractor upon approval by the Local Authorities/ Certifying Agency.

12.3. The type and location of connections shall be determined by the Local Authorities/ Certifying Agency. Examples of the type of connections are connection to a manhole or a connection to a sewer through junction or saddle fittings.

12.4. For direct connection to existing public sewer of diameter 375 mm or less, the connection shall be made using a proper Y-junction fitting. The typical connection configuration of junction is shown on the Drawing.

12.5. Saddle connections may only be permitted where the existing sewer is at least two pipe sizes greater than the proposed connection pipe. Only saddles specifically designed for the type and size of the sewer to be connected to shall be used.

13. Testing for Sewer Pipes Installation

13.1. The Contractor shall carry out tests to the sewer pipes installation in accordance with the method of statement and requirements as described hereinafter. The Contractor shall give reasonable notice in writing to the S.O. before such tests to be carried out.

13.2. Testing of pipework shall be carried out and wherever possible, such testing shall be carried out from manhole to manhole. Short branch pipes connected to a main sewer between manholes shall be tested as one system with the main sewer. Long branches and manholes shall be separately tested.

13.3. Subject to type of pipe and size, pipes shall be subjected to either low water pressure tests, CCTV test or any other test required by the relevant authorities' guidelines and to the approval of the S.O.

13.4. Low water pressure test

13.4.1. The low water pressure test is commonly used for checking the water tightness of the joints and the integrity of the sewer pipes.

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13.4.2. For the water test, the pipe shall be subjected to an internal test pressure of 2m head of water above the crown of the pipe at the higher end but not more than 7m at the lower end. Steeply graded pipe shall be tested in such a manner that the above maximum heads are not exceeded.

13.4.3. The test shall be carried out by filling the sewer with water slowly to the required head and bleed air from behind the upstream plugs. Maintain the water head for two (2) hours. Top up the water as required.

13.4.4. Check the leakage at the plugs and the test apparatus during the pressurizing period and the constant pressure holding period. Release the water pressure if leakage occurs. Make the necessary repairs and adjustments before pressurizing again.

13.4.5. Commence the test immediately after the last adjustment of water head in the preceding two (2) hours period.

13.4.6. Add water to maintain the starting water head every five (5) minutes during the test period of 30 minutes. Record the total amount of water required for readjustment.

13.4.7. The test is considered pass when:

13.4.7.1. The loss of water does not exceed 1 litre per hour linear meter per meter internal diameter for VCP and reinforced concrete pipes.

13.4.7.2. There shall be no loss of water for pipe other than VCP and reinforced concrete pipes.

13.4.7.3. There is no visible leakage at the joints for all pipe types.

13.5. Closed-circuit Television (CCTV) Testing (if required)

13.5.1. General

CCTV inspection where required shall be carried out in accordance with the relevant authorities' guidelines to enable detection of sewer defects such as cracks, deformations, collapse, dislocation et cetera which are not detected by normal means.

13.5.2. Inspection Requirements

13.5.2.1. A CCTV Inspection Contractor with Permit Holder Class D registered with the relevant authorities shall be appointed to carry out the inspection works and the inspection work shall be witnessed by the S.O.

13.5.2.2. General Inspection Coverage

Initial CCTV testing and inspection shall be conducted for a minimum 10% random selection of sewer pipes including all manholes and connections in accordance with the relevant authorities' guidelines.

13.5.2.3. High Risk Areas

100% CCTV inspection shall be conducted for sewer pipes including manholes laid in the ground with high risk of failure

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and having the following characteristics:

a) Average depth of 6 m or more

b) Pipe diameter above 600 mm.

c) Areas that have restricted vehicular access for repair (e.g. central business district).

d) Crossing under buildings, roads, railway, rivers and lakes including their reserve.

e) Ground slopes greater than 30° inclination.

f) All sewers installed using pipe jacking method and horizontal drilling method.

g) All diversion or re-alignment of existing sewer networks.

h) All single private developments (with PE > 30) connecting to existing main sewer.

13.5.3. Witness

Representative from Certifying Agency, S.O., consultant representative and Contractor responsible for the construction of sewer shall be present at the onset for CCTV inspection at each project site.

13.5.4. Documentation

13.5.4.1. Within 7 days after completion of the inspection, the Contractor shall submit to the Certifying Agency and S.O. the following:

(i) Two (2) copies of digital records; and

(i) One (1) copy of hardcopy report and recommendation

13.5.4.2. The format of the report and documentation shall be in accordance with the relevant authorities' guidelines. All documents shall be certified and duly signed by the qualified person responsible for the CCTV inspection declaring the authenticity of the recording submitted and done in accordance with the procedure stated in the relevant authorities' guidelines.

13.5.4.3. Documents shall be submitted to S.O. for the acceptance of completion of works.

(i) Photographs showing sewer pipe laying during and after construction.

(ii) Testing certificates.

(iii) Supervision report.

(iv) As–built drawings.

13.5.4.4. During Defects Liability Period

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If any blockages, damages, seepages occur to the sewer networks during the Defects Liability Period, the S.O. may require the Contractor to carry out further CCTV inspection to determine the cause within 24 hours.

14. Backfilling

14.1. After the pipes have been tested and approved, the trench shall be backfilled with approved fill material, free from rock and other hard material, well compacted around the pipes up to a level of at least 300mm above the top of the pipes. After this has been approved, the remaining excavation shall be backfilled in 300mm layers, each layer being well compacted. The bedding details and the types of fill material shall in accordance with Drawings and the relevant authorities' guidelines.

14.2. Trench support shall be progressively removed during the backfill work.

14.3. There shall be at least 300mm of cover over the sewer pipe before light mechanical compaction can commence.

14.4. There shall be at least 1000mm of cover (depth of backfill) over the sewer before heavy mechanical compaction can commence.

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APPENDIX F/1

Table F1. Gradient of Sewer Pipes

Size diameter (mm)	Gradient
100	1 : 60
150	1 : 80
225	1 : 110
250	1 : 120
300	1 : 140
375	1 : 170
450	1 : 200

NOTE: Not applicable for force mains.

Table F2. Parameter Limits for Sewage and Industrial Effluents

Parameter	Effluent discharge to rivers/stream				Effluent discharge to stagnant water bodies*			
	Standard A		Standard B		Standard A		Standard B	
	Absolute	Design	Absolute	Design	Absolute	Design	Absolute	Design
BOD5	20	10	50	20	20	10	50	20
SS	50	20	100	40	50	20	100	40
COD	120	60	200	100	120	60	200	100
AMN	10	5	20	10	5	2	5	2
Nitrate Nitrogen	20	10	50	20	10	5	10	5
Total Phosphorus	N/A	N/A	N/A	N/A	5	2	10	5
O&G	5	2	10	5	5	2	10	5

NOTES 1) N/A = not applicable.
2) All values in mg/l unless otherwise stated.
3) *Stagnant water bodies refer to enclosed water bodies such as lakes, ponds and slow-moving watercourses where dead zone occurs.
4) A: Discharge upstream of water supply sources.
5) B: Discharge downstream of water supply sources.

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Table F3. Sewerage Work Submission

No.	Type of System	Allowable Population Equivalent (PE)	Document Requirement
1.	Individual Septic Tank (IST)	6 - 30	Pre-Tender Sewerage Works Application (SWA) Post-Tender Sewerage Works Completion (SWC)
	Network Connection (Single Manhole directly connected to Existing Manhole)	No limit	
2.	Small Sewage Treatment System (SSTS)	31 - 149	SWA (Pre-Tender) SWC (Post-Tender)
3.	Sewage Treatment Plant (STP)	150 – 5,000	Refer Table F4

NOTE : 1) The submission procedure might change due to authority requirement.
2) Only for single manhole (outside property boundary) connected direct to existing manhole (public sewer) – fall under low risk category (submit SWA and SWC)

Table F4. Sewerage Work Submission for STP

No.	Item	Description	Submitting Person / Person in Charge
1.	PDC 1	Planning Approval	HODT
2.	PDC 2	(i) Sewer pipe reticulation (ii) SSTS/STP Detail Design	(i) HODT (ii) S.O./Contractor
3.	PDC 3	Detail for Structural Plans and Design Calculations	S.O./Contractor
4.	PDC 4	Detail for Electrical Design and Drawing	S.O./Contractor
5.	PDC 5	Details for Equipment and Material Data Sheets (EMDS)	S.O./Contractor
6.	PDC 6	Notice of Commencement Sewerage Works/Septic Tank Works	S.O./Contractor
7.	PDC 7	Notice of Intermediate Inspection of Sewerage Works	S.O./Contractor
8.	PDC 8	Notice of Final Inspection	S.O./Contractor
9.	PDC 9	Declaration by Competent Person Who Supervised the Septic Tank Works.	S.O./Contractor

NOTES 1) PDC – Planning, Design and Construction
2) The submission procedure might change due to authority requirement.

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TABLE OF CONTENTS

SECTION J : STRUCTURAL STEEL AND METAL WORKS		PAGE
1.	General	J/1
2.	Hot Rolled Structural Steelworks	J/1
3.	Prefabricated Cold Formed Steel Roof Trusses	J/2
4.	Metal Frames for Doors and Windows	J/5
5.	Collapsible Gates, Roller Shutters And Et Cetera	J/7
6.	Sundries	J/7

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1 General

This section provides the generally applicable requirements for steel and metal for the construction of structures, building components and other related works. All materials shall conform to the relevant Malaysian or British or European Standards or other internationally recognised standards with the approval of the S.O.

2 Hot Rolled Structural Steelworks

2.1 All hot rolled structural steelworks design, materials, drawings, workmanship (welding, bolting, fabrication and erection), protective treatment (corrosion and fire), Quality Assurance and Quality Control shall be in accordance with the *JKR Specification for Structural Steelworks (No. JKR 20601-0272-22)* and its latest amendments.

2.2 The contractors shall procure all steel products or components from manufacturers/ suppliers with *Perakuan Pematuhan Standard* (PPS) as specified in SECTION A: PRELIMINARIES AND GENERAL CONDITIONS.

2.3 The Contractors are reminded to employ certified skilled construction workers with *Sijil Kemahiran Kompetensi Pembinaan* (SKKP) as specified in SECTION A: PRELIMINARIES AND GENERAL CONDITIONS.

2.4 Quality Assurance and Quality Control (QA & QC)

The Contractor shall submit a Quality Assurance and Quality Control programme as specified in the *JKR Specification for Structural Steelworks (No. JKR 20601-0272-22)* and its latest amendments.

2.5 Drawings and Design Reports

2.5.1 The Drawings to be submitted by the Contractor shall be endorsed by Professional Engineer with Practicing Certificate (P.E.P.C.) based on construction drawings are as follows:

2.5.1.1 Shop drawings:
- Fabrication drawings;
- Erection drawings.

2.5.1.2 As-built drawings.

2.5.2 Where the Contractor provides the design, the Contractor shall prepare design reports and Drawings with details in accordance with *MS EN 1993* or other relevant standards. The Drawings and design reports shall be endorsed by a P.E.P.C.. The Contractor shall also prepare Drawings of temporary restraints and/ or works for all construction stages in compliance with the requirements specified in the *JKR Specification for Structural Steelworks (No. JKR 20601-0272-22)* and its latest amendments.

2.6 The Contractor shall refer to the list provided in the *JKR Specification for Structural Steelworks (No. JKR 20601-0272-22)* as in **Appendix 1** (but not limited) for design, workmanship, erection, protective treatment and construction work programme.

2.7 Records

2.7.1 All records related to the works shall be made available to the S.O. throughout the contract period.

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2.7.2 The Contractor shall submit to the S.O. document and records for approval which shall include but not limited to:

2.7.2.1 Drawings as in Item 2.5. and documentation register;

2.7.2.2 Mill certificates for materials and certification for welding consumables;

2.7.2.3 Calibration of equipment;

2.7.2.4 Welding Procedure Specification (WPS);

2.7.2.5 Inspection, laboratory test reports and valid test certificates;

2.7.2.6 Type of protective treatment system for corrosion and fire including technical data sheet and method statement;

2.7.2.7 Delivery schedules and method statements for fabrication, erection and installation;

2.7.2.8 Construction works sequences;

2.7.2.9 Surveys and final inspection results;

2.7.2.10 Completion of erection and hand over certification.

3 Prefabricated Cold Formed Steel Roof Trusses

3.1 All prefabricated components shall be manufactured only by reputable licensed truss suppliers listed in *J-TRUSS system online (Application and Approval of Truss System Provider)* and approved by the S.O.. This supplier duly termed as 'System Provider' is responsible for the analysis, design, detailing, drawing, manufacture, material, handling and erection of the roof members, and their ancillary fixing components. The full requirement is outlined in the *JKR Specification for Prefabricated Cold Formed Steel Roof Trusses (No. JKR 20601-0270-22)* and its latest amendments.

3.2 System Provider (S.P.)

The System Provider (S.P.) is a manufacturer and a supplier of a proprietary roof truss system, approved by Jabatan Kerja Raya (JKR) which employs quality assurance procedures in the supply of material, design with detailing and trusses component manufacturing. The S.P. shall be responsible to fabricate, deliver and install the cold formed steel roof trusses system. The S.P. shall guarantee the due performance of the entire roofing system.

3.3 Duties of P.E.P.C.

3.3.1 The P.E.P.C. shall sign-off and endorse every process of the truss system delivery that includes:

3.3.1.1 Roof truss analysis and design;

3.3.1.2 Construction drawings;

3.3.1.3 Fabrication drawings;

3.3.1.4 Design changes document in every stage of works;

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3.3.1.5 Roof truss installation completion document, prior to issuance of Certificate of Practical Completion (CPC) by the S.O.;

3.3.1.6 As Built Drawings; and

3.3.1.7 Defect report prior to issuance of Certificate of Making Good Defect (CMGD) by the S.O..

3.4 Fabricator

All trusses may be assembled and installed either by S.P. or licensed company appointed by the S.P. and registered with Construction Industries Development Board (CIDB) under Class B02 IBS: *Sistem Kerangka Keluli.* A copy of CIDB registration certificate shall be submitted to the S.O. for verification.

3.5 Installer

All fabrication and installation works shall be executed and supervised by skilled construction worker accredited and certified by CIDB. The S.O. may verify the identification and qualification of the installer prior to the installation.

3.6 General Truss Limitation

3.6.1 Prior to any prefabricated cold formed steel roof trusses works, the following general limitation shall be applied:

3.6.1.1 Maximum truss span or unsupported truss length 12.00 metres with permitted deviation of ± 0.05 metres unless otherwise instructed by the S.O.;

3.6.1.2 Maximum truss spacing of 1.20 metres with permitted deviation of +0.025 metres;

3.6.1.3 The minimum basic wind speed shall be 35.0 m/s;

3.6.1.4 Minimum base steel thickness for main truss member shall be;

a) 1.0 mm for unsymmetrical section or open cross section; or

b) 0.6 mm for symmetrical machine-manufactured box or closed cross section.

3.6.1.5 Minimum base steel thickness for other truss element shall be;

a) 0.5 mm for batten or purlin;

b) 1.2 mm for wall plate; and

c) 1.0 mm for bracing.

3.6.1.6 Minimum section depth shall be 75.0 mm in the direction of local major axis of truss member section;

3.6.1.7 Minimum section flange shall be 35.0 mm in the direction of local minor axis of truss member section;

3.6.1.8 Minimum section lip shall be 7.0 mm in the direction of local major axis of truss member section;

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3.6.1.9 Minimum section batten or purlin shall be proposed and endorsed by P.E.P.C. according to the design; and

3.6.1.10 Connector shall only be of hexagon head/wafer-head self-drilling screw or bolt. Welding is not allowed as fastener.

3.7 Analysis, Design Report and Drawings Submission

3.7.1 The S.P. shall propose a roof truss system which is safe, functional and conforming to design standard. Submission of proposal shall include truss analysis, design report, and construction drawings. The truss analysis and design shall indicate all design parameters including but not limited to loads, load combinations, connections criteria, bracings and tie-downs of the truss. Design output of the truss members, battens, connections, tie-downs and wall plates, anchors, bracings, truss accessories, splicing and stiffeners whereby related to the analysis shall be included in the design report. Refer to **Appendix 3** of *JKR Specification for Prefabricated Cold Formed Steel Roof Trusses (No. JKR 20601-0270-22)* and its latest amendments.

3.7.2 All details in the construction drawing shall be sufficient as such to enable checking against the analysis and design report, by specifying and providing not limited to; the truss layout and configuration, steel grades, section properties of members, length of members in each truss configuration, properties of truss accessories, specification of corrosion protection, specification of fastener and anchor, tie-down and anchoring details and all type of connection details including the connection of all attachments to the trusses.

3.7.3 Technical specifications or mill certificates for base steel, fastener and anchor of which the designs refer to shall also be included in the submission. Verification test certificate from an approved accredited laboratory on the technical parameter specified in the technical specifications or mill certificates shall be submitted upon request by the S.O..

3.8 Warranty

3.8.1 When a prefabricated cold formed steel roof truss system is used, the Contractor shall submit to the S.O. a warranty from the S.P. with the following provisions:

3.8.1.1 The products used are genuine and free from manufacturing defects;

3.8.1.2 The prefabricated cold formed steel roof truss system is installed in accordance with the S.P.'s instructions, guidance and specifications that will deliver the specified level of performance; and

3.8.1.3 The warranty certificate shall cover a period of ten (10) years from the date of Certificate of Practical Completion against any defect or failure due to the installation and workmanship by the S.P.'s registered panel installer.

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4 Metal Frames for Doors and Windows

4.1 Steel Frames

4.1.1 The Contractor shall supply, assemble and fix steel frames for doors and windows as shown on the Drawings. The steel frames shall comply with *BS 6510*, and shall be from an approved source and shop-primed with two coats of red lead oxide or other approved rust resisting primer.

4.1.2 The steel frames shall be manufactured from sections rolled from good commercial grade galvanized mild steel in single sections, mechanically straightened with all corners pre-cut with a 45 degrees mitre joint giving a snug and accurate fit, fully electrically welded, and carefully ground and cleaned, or shall be mechanically jointed by an approved method.

4.1.3 All screws, nuts, bolts and washers shall be of stainless steel.

4.1.4 Steel frames shall be painted as specified in SECTION O: PAINTING WORKS.

4.2 Aluminium Frames

4.2.1 The Contractor shall supply, assemble and fix aluminium frames for doors and windows as shown on the Drawings. Unless otherwise specified, all aluminium frames for windows shall be fabricated from sections extruded from aluminium alloy conforming to *MS 832*. All aluminium frames for glass sliding doors shall be fabricated from sections extruded from aluminium alloy and in compliance with *MS 1017*.

4.2.2 Unless otherwise shown on the Drawings or described in the Bills of Quantities, aluminium surfaces shall be natural anodised finish, free from alloy defects, dye marks, scratches and other surface blemishes in accordance with *BS 3987* with an anodic coating of 15µ minimum thickness complying with *BS EN 12373-1*.

4.2.3 All coloured anodized finish to aluminium exposed surfaces shall be subject to the S.O.'s approval.

4.2.4 All aluminium extrusion or sheet exposed surfaces after anodizing and after colouring, if required by the S.O., shall be sealed, and the adequacy of the sealing shall be given special emphasis.

4.2.5 All fasteners such as bolts and screws shall be of stainless steel type A2-70 (minimum) in compliance with *ISO 3506* or other suitable materials as specified on the Drawings. Rivets shall be stainless steel or aluminium alloy appropriate to the applications.

4.2.6 Extruded aluminium framing members shall be fabricated from designated alloys complying with *MS 2289*. Ancillary members such as sills, couplings and the like formed from sheet materials, they shall be fabricated from designated alloys complying with *MS 2040*.

4.2.7 Where friction stays and hinges are fastened onto the framing section, the portion that receives the fastener shall not be less than 2.5 mm thick.

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4.3 Frames for Adjustable Louvre Windows

4.3.1 The Contractor shall supply, assemble and fix frames for adjustable louvre windows as shown on the Drawings in compliance with *MS 1057*.

4.3.2 Unless otherwise specified, the frames shall be of approved manufacture. The frames shall be supplied complete with weather seal and non-ferrous bearings, spring clips, locking device and weather stripping with all necessary spacing pieces. The frames, coupling mullions and spacer brackets shall be minimum 1.2 mm thick (18 SWG) or otherwise specified cold-rolled steel strip galvanised with hot-dipped process. Unless otherwise specified on the Drawings, the clips and pivots to receive the louvres shall be of durable nylon material and sample submitted shall be to S.O.'s approval.

4.3.3 The operating rods shall be 2.13 mm thick (14 SWG). The handle and lock shall be 2.642 mm thick (12 SWG) steel.

4.3.4 Unless otherwise specified, the finish shall be anodized coating of 15 µ (average) minimum complying with *BS EN 12373-1*.

4.4 Accessories

4.4.1 Accessories for each steel or aluminium frame for doors and windows shall be supplied complete with:

4.4.1.1 Sufficient number of built-in stainless steel hinges as per Schedule of Ironmongery under SECTION H: TIMBER, JOINERY AND IRONMONGERY WORKS;

4.4.1.2 Two (2) rubber buffers per closing jamb, to reduce noise and vibration;

4.4.1.3 Welded mortar guard; Adjustable stainless steel striker plate with a gently curved lead-in edge;

4.4.1.4 Removable spreader bars, to ensure a perfect square during transportation and installation; and

4.4.1.5 Minimum of eight (8) pieces of 4 mm brick ties, to ensure a tight permanent fit.

4.5 Samples

Samples of steel or aluminium sections with complete accessories for the doors and windows, together with complete set of shop drawings of all works shall be submitted to the S.O's for approval prior to the commencement of any work.

4.6 Installation

4.6.1 Unless otherwise specified or shown on the Drawings, all types of window and door frames shall be fixed or installed using the sub-frame method in accordance with the manufacturer's recommendation and to the S.O.'s approval.

4.6.2 All joints on the window and door frames shall be sealed using polyurethane (PU) type joint sealant.

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4.6.3 Where buildings are located near to the coastal area, the bolts, nuts and screws used shall be of stainless steel unless otherwise specified.

4.6.4 Unless otherwise specified on the Drawings, the adjustable louvre side frames shall fix to the aluminium frames and shall be installed using the sub-frame method in accordance with the manufacturer's recommendation and to the S.O.'s approval.

5 Collapsible Gates, Roller Shutters and Et Cetera

The Contractor shall provide and fix approved collapsible steel gates, folding shutters, roller shutters and et cetera complete with all necessary accessories as approved by the S.O. to the sizes and positions as shown on the Drawings. Unless otherwise specified on the Drawings, they shall be galvanised and fixed in accordance with the manufacturer's instructions.

6 Sundries

6.1 Unless otherwise specified on the Drawings, mild steel shall be used for balustrades to staircases, verandahs, balconies, et cetera and shall be fixed as shown on the Drawings.

6.2 All iron and steel for the sundries shall be of the quality approved by the S.O. Screws and bolts shall have washers where appropriate. Hooks for carrying ceiling fans shall be formed from 13 mm diameter mild steel rods bolted to timber ceiling members or ragged into concrete.

6.3 Welded mesh, expanded metal, aluminium sheets et cetera shall be provided and fixed as shown on the Drawings.

6.4 Mild steel grilles, drain cover gratings shall be provided and fixed as shown on the Drawings. Unless otherwise stated, all steelworks shall be joined by continuous welding.

6.5 Ant caps shall be of 16 gauge galvanised iron sheets formed to shape as shown on the Drawing. The caps shall be fixed between concrete stumps/brick piers or walls and timber posts or plates as required. The caps shall project 60 mm and inclined at 45^0 from the surface.

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TABLE OF CONTENT

SECTION L: WATER RETICULATION		PAGE
1.	General	L/1
2.	Local Authority's Approval, Fees and Deposit	L/1
3.	Products and Materials	L/1
4.	Inspection	L/1
5.	Water Reticulation	L/2

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1. General

1.1. The Works in this section shall comply with the latest regulations of Suruhanjaya Perkhidmatan Air Negara (SPAN), Uniform Technical Guideline (UTG) and any other relevant standards approved by the Government. The Works in Sabah and Sarawak shall comply with the relevant State Water Authority's (SWA) regulations and guidelines.

1.2. The water reticulation and internal cold water plumbing works shall be executed by personnel with valid permits issued by the relevant authorities as stipulated under Water Service Industry Act 2006. The Contractor shall be responsible for employing such personnel and all the works performed by them.

2. Local Authority's Approval, Fees and Deposit

The Contractor shall comply with the Local Authority's requirements to obtain the necessary approval for storage of materials along the road shoulders and work permit to cut across the metal road. All necessary fees and deposit for obtaining approvals from the Local Authority's to execute the works shall be borne by the Contractor. The Contractor shall liaise with the Local Authority's before commencement of work, regarding trenching work crossing metaled road and along road shoulder.

3. Products and Materials

3.1. All products and materials to be incorporated in the work shall be new and unused. Materials to be used within the scope of work shall be those approved the relevant authorities. When the quality of a material or process is not specifically set forth in the approved products and materials list, the drawings, or the specifications, the best available quality of the material or process shall be provided, subject to the approval of the S.O. The pipe material from the tapping point to the bulk meter that will be handed over shall be inspected by the Water Service Provider.

3.2. All products and materials shall be supplied by suppliers registered with the relevant authorities. The Contractor shall provide proof to the S.O. in the form of a valid Confirmation Letter or Certificate of Registration issued by the relevant authorities to the supplier. The products and materials shall also be subjected to other terms and conditions mentioned in these specifications.

3.3. All products and materials shall be of makes and models tested and approved for use. It is the Contractor's responsibility to verify that products and materials received for the Works conform to the current approved products and materials supplied by the relevant authorities' registered suppliers.

3.4. All products and materials shall be transported, handled and stored in such a manner as to prevent damage or deterioration.

3.5. All products and materials furnished shall be subject to inspection for compliance with these specifications and all other appropriate specifications. The Contractor shall make an application to the S.O. for inspection at least five (5) days in advance of starting any work.

4. Inspection

The S.O. shall at all times have access to the work wherever it is in preparation or progress and the Contractor shall provide proper facilities for such access and for

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inspection. The Contractor shall provide safe means to inspect the work. Failure or oversight of the S.O. or his representative to reject defective materials at the time of use, or to reject improper work at the time it is performed, shall not diminish the Contractor's obligations to comply with Drawings and Specifications. The Contractor shall remove and replace any faulty materials and work at no additional cost to the Government upon discovery of the defects or upon receipt of notice from the S.O. to do so.

5. Water Reticulation

5.1. Setting Out

All settings out for pipe laying works shall be performed by the Contractor's surveyor. Generally, stakes for alignment and grade shall be set at 10m intervals. The survey shall conform to the lines, grades, and dimensions shown on the Drawings. The Contractor shall preserve all monuments, benchmarks, survey markers and stakes. In case of their removal or destruction by the Contractor or his employees, agents or subcontractors, the Contractor shall be liable for the cost of their replacement. The pipeline from the tapping point to the bulk meter that will be handed over shall be inspected by the Water Service Provider.

5.2. Excavation

5.2.1. General

All general excavation works shall be as specified in SECTION B: EXCAVATION AND EARTHWORKS.

5.2.2. Excavation for Pipe Trenches

5.2.2.1. Before commencing the excavation of pipe trenches, the routes of the pipelines shall be pegged out accurately. Strong sight rails shall be fixed and maintained at each change of gradient, and at as many intermediate points as may be necessary but not exceeding 100m apart. On these rails shall be marked the center line and level to which the pipes are to be laid, and such rails shall be maintained in position and at the correct level from the time the excavation commences until backfilling is completed. The run of pipe trenches opened up ahead of pipe laying operations at any one time shall not be more than:

(i) 100m if the pipe laying operations are in an urban area,

(ii) 300m if the pipe laying operations are in the side tables of a trunk road, or

(iii) 600m if the pipe laying operations are in unoccupied land schemes or housing estates under development or are in the side tables of minor rural roads.

5.2.2.2. The S.O. may, at his absolute discretion, vary the distances stated above if he considers that traffic, road, weather or physical conditions warrant the variation.

5.2.2.3. Unless the S.O. permits otherwise, the trenches shall be excavated to the widths given in **TABLE L1**.

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5.2.2.4. Where pipes are to be laid on a concrete bed, the width of the excavation at the bottom of the trench shall be the width of the underside of the concrete bed. At all joints, the trench shall be so excavated as to give a working space of not less than 300mm all around the joint. Where bends are made by deflecting pipes at joints the trench shall be widened to permit this operation. The sides of the trench shall be cut vertically, and where necessary, shall be protected against caving in by timbering to the approval of the S.O.

5.2.2.5. The trench shall be excavated to the intended depths or shown on the drawings and shall be finished and trimmed accurately to level and grade.

5.2.2.6. Should the ground be so wet or soft that, in the opinion of the S.O., it does not form a firm base for the pipe, or should rock be encountered at the bottom of the trench, the trench shall be excavated 250mm below the level intended or shown on the drawings and then brought back to the correct level with good selected earth or sand well rammed into place. Such deepening of the pipe trench and filling back shall be treated as a variation under the terms of the Contract. Should the bottom of the trench be inadvertently excavated below the specified level, it shall be brought back, at the Contractor's expense, to the correct level with good selected earth or sand carefully rammed into place.

5.2.3. Excavation of Road Crossings

5.2.3.1. No trench is to be excavated in the carriageway unless specific approval has been given by the relevant road authority. The whole operation of excavation and reinstatement of the trench shall be completed as quickly as possible. The Contractor shall ensure that minimum interference to traffic flow is maintained at all times.

5.2.3.2. A joint site inspection shall be arranged by the Contractor before the commencement of work if requested by the road authority. After pegging out, the Contractor shall inform the road authority and the police of the actual date of commencement at least one week in advance of and on the day of commencement.

5.2.3.3. If specific approval has been given to lay services across the road by open excavation, proper cutting of the metalled pavement shall be done and the Contractor shall ensure that the top edges of the excavation are neat and straight.

5.2.3.4. All materials from the excavation, if accepted for backfilling shall be neatly stacked outside the carriageway. Where there is no place to stack the excavated materials outside the carriageway, the excavated materials shall be removed from the work site immediately after excavation.

5.2.3.5. Where specific approval has been given by the road authority for half-width construction, the traffic lanes may be reduced to not less than 5.0m wide, and where necessary, the shoulder should be strengthened to accommodate traffic load to the satisfaction of the S.O. by the Contractor and at the Contractor's expenses.

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5.2.3.6. Trenches shall be provided with adequate shuttering, walling and struts to prevent the adjoining road pavement from cracking and subsiding.

5.2.3.7. If a road diversion is required, the Contractor shall build it to the specifications of the road authority. It shall be maintained in good motorable condition until the reinstatement is completed.

5.2.3.8. Carriageway excavation across important and busy roads and junctions shall be carried out during off-peak hours. The S.O. shall specify the appropriate times based on the merits of each case and such conditions shall be strictly adhered to by the Contractor.

5.2.4. Excavation of Rock in Trench

Rock shall mean those geological strata of hard material which necessitates the use of blasting or approved pneumatic tools for their removal. Solid boulders found in trench excavations and foundation pits shall be considered as rock if such boulders are of size each exceeding 0.08m³. Shale and clay boulders shall not be classified as rock. The S.O.'s decision as to whether or not the material of the excavation is to be classified as rock shall be final. The Contractor shall be entitled to extra payment for rock excavation only if reasonable notice is given to the S.O. to examine and measure such material prior to breaking up. The volume of rock excavated shall be taken as its volume in-situ before it is broken up.

5.2.5. Pipe Bedding

The pipe bedding and foundation shall be prepared according to the Drawings. No pipes shall be laid until the S.O. has inspected and approved the pipe bedding and foundation. Any work that has been carried out without the approval of the S.O. shall, on the instructions of the S.O., be uncovered or removed by the Contractor and reinstated to the S.O‘s approval at the Contractor's own expense

5.2.6. Crossing Water Courses

Where the pipeline crosses underneath streams, culverts and other water courses, the Contractor shall be deemed to have allowed for all additional measures necessary for the proper construction of the pipeline especially maintaining the flow of water.

5.2.7. Backfilling of Pipe Trenches

5.2.7.1. After the pipe laying has been approved by the S.O. and before the pipelines are tested, sufficient backfilling of the trenches will be permitted to prevent "snaking" and to maintain the pipes in position, but all joints shall be left exposed. In any other locality where the trench may be filled with water and cause flotation of the pipes, or elsewhere as may be decided by the S.O. the backfilling shall follow the pipe alignment as closely as possible.

5.2.7.2. In backfilling pipe trenches, only approved materials free from stones or rocks or other hard materials shall be carefully spread along the trench bottom between the pipes and the trench walls to a depth of about 150mm and shall be hand-rammed. Further layers each of about 150mm thick of the same materials shall

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then be spread and rammed in the same manner up to the top of the pipes. The remainder of the backfilling may consist of coarse materials free from boulders and large earth clods. It shall be placed in layers each of 150mm thickness and hand or mechanically rammed until the backfill is 300mm above the top of the pipes. The rest of the trench backfill shall be in layers each of 300mm thickness and compacted by a mechanical vibrating tamper to finish off slightly proud of the surrounding ground. The degree of compaction of each layer shall not be less than 95 % of the dry density obtainable using the BS 1377 Compaction Test. The Contractor shall make good any settlement to avoid the formation of drains or gullies within the refilled trenches.

5.2.7.3. Approved fill material to be used as backfill to the top of the pipes shall be uniform low plasticity granular material. The material shall be free from all organic or other materials subject to decay. Highly plastic or expansive soils or clay shall not be used. The filling material shall be readily compactable to its maximum density and must not form mud, or otherwise breakdown when wet.

5.2.7.4. Should the material being placed as fill or backfill while acceptable at the time of selection, become unacceptable to the S.O. due to exposure to weather conditions or due to flooding or have become puddled, soft or segregated during the progress of the works, the Contractor shall, at his own expense, remove such damaged, softened or segregated material and replaced it with fresh approved material.

5.2.7.5. Where the pipeline crosses a road, approved sand shall be used as fill material up to the road formation level.

5.2.8. Backfilling of Excavations Other Than Pipe Trenches

5.2.8.1. Backfilling of all excavations shall not be carried out until the Works therein have been inspected and approved by the S.O. In backfilling excavations other than pipe trench excavations, portions of the excavated materials may be used with the approval of the S.O. Where required, approved materials shall be brought to the site for backfilling works. The materials shall be deposited and spread in layers not more than 300mm deep, and each layer shall be thoroughly rammed by a mechanical vibrating tamper or smooth wheel roller and watered if required.

5.2.8.2. If directed by the S.O, the backfilling shall be finished off slightly proud of the surrounding ground to allow for settlement, but the Contractor shall make good any settlement which may occur during the construction of the Works and during the Defects Liability Period of the Contract at his own expense.

5.2.9. Road Reinstatement

5.2.9.1. Road reinstatement works shall be carried out by the Contractor to a standard equivalent or superior to the road condition existing prior to excavation and to the requirements of the relevant road authority and approval of the S.O.

5.2.9.2. All backfilling shall be done by the Contractor with approved sand. No organic soil, broken premix or stones are to be used. The sand shall be compacted in 225mm layers. The degree of

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compaction of each layer below the pavement course shall not be less than 95% of the dry density obtainable using the BS 1377 Compaction Test. The Contractor shall bear the cost of such tests and shall make good any works which are found to be unsatisfactory.

5.2.9.3. Sand material shall be deposited in layers on both sides of the pipe simultaneously and thoroughly compacted and around the pipe working alternately on either side of the pipe until the trench has been filled up to the base course formation level.

5.2.9.4. The Contractor shall reinstate the road pavement by replacing, in the proper sequence, any block or metaling removed to the requirements of the relevant road authority and the approval of the S.O. The road surface shall be reinstated with new materials of the type existing on site. Edges of the reinstated road pavement shall be straight and neatly finished to match the existing road to the satisfaction of the S.O.

5.2.9.5. In the absence of any written requirement, all reinstatement works shall be carried out within 24 hours after backfilling.

5.2.9.6. If the Contractor fails to carry out the reinstatement to the requirements of the relevant road authority and the satisfaction of the S.O., the S.O. or the relevant authority may proceed with such repairs and the cost of such reinstatement shall be recouped by the S.O. from the Contractor

5.3. Pipeworks

5.3.1. Handling and Laying Pipelines

5.3.1.1. All handling, laying and testing of pipelines shall comply to the latest technical specifications from the relevant authorities or other relevant standards and also to the manufacturer's requirements:

(i) The minimum cover for main pipelines shall be 1m. Under roads and hard standing the cover shall be 1.2m. Otherwise the pipes shall be encased with concrete strength class C20/25 with minimum thickness of 150mm or as approved by the S.O.

(ii) The section of pipeline that runs across roads and culverts shall be made from Ductile Iron pipe (D.I) or mild steel pipe approved by the relevant authorities.

5.3.2. Testing of Pipelines

5.3.2.1. The Contractor shall provide all water required for filling, testing and retesting the pipelines, and any pumps, pipework fittings and pressure gauges required for the purpose. The testing of pipeline from the tapping point to the bulk meter shall be witnessed and handed over to the Water Service Provider.

5.3.2.2. Whenever a section (which shall not exceed 1000m long in or adjacent to roads, or not exceeding 2000m long in open ground) of any pipeline has been laid, jointed and part backfilled as specified, it shall be prepared for testing by sealing the open ends

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temporarily with stop ends. The stop ends shall be of cast iron or steel. The stop end at the lower end of the section of the pipeline shall be fitted with a valved inlet pipe for use to fill the section of the pipeline with water and the stop end at the higher end of the section of the pipeline shall be fitted with a valved air release vent pipe. A pressure gauge shall be connected to the valved inlet pipe. The pressure gauge shall have a dial of not less than 150mm dia. and graduate to read up to 15 bars with 0.25 bar graduations. All pressure gauges shall be tested by the S.O. before use, and provisions shall be made for connecting the pressure gauge, if the S.O. so elects, to the valved inlet pipe.

5.3.2.3. The stop ends shall be braced to the satisfaction of the S.O. to withstand the end thrust which develops from water pressure. All weight, thrust and anchor blocks intended to prevent the vertical and lateral displacement of the pipes and specials shall have been properly completed and have attained an adequate strength before the tests are carried out. When gentle curves are affected by deflection pipes, these pipes shall be securely packed with backfill to prevent movement.

5.3.2.4. The section of the pipeline to be tested shall be filled with water of fair quality, free from sediment and from a source approved by the S.O. The water shall be introduced into the section of the pipeline through the valved inlet in the stop end at the lower end of the section. During filling, provision shall be made for the air to escape from all high spots in the section by properly installing all air valves and from the air-released vent pipe in the stop end at the higher end of the section. The pressure/strength test shall be carried out first. Each section of the pipelines shall be tested to a minimum pressure of 16.0 bars head of water and shall comply with the technical specifications from the relevant authorities or other relevant standards and to the manufacturer’s requirements.

5.3.2.5. After the section of the pipeline has been filled with water for a period of not less than seven (7) days, more water shall be pumped into the section to raise the pressure slowly in increments of 10m head of water with a pause of one minute between each increment.

5.3.2.6. Should any appreciable drop in pressure be noted during one of these pauses the test shall be stopped until the cause of the pressure drop has been investigated and rectified. An engine-driven pump may be used until 55m head pressure is attained, and thereafter only a hand-operated pump shall be used.

5.3.2.7. The pressure/strength test shall be considered to have been passed when the pressure gauge shows no reduction in pressure during the specified one-minute pause and also during the period of ten (10) minutes after full test pressure has been attained. If these conditions are not satisfied a thorough inspection of the section of the pipeline shall be made. All defects shall be repaired and the test shall be repeated.

5.3.2.8. The leakage test shall then follow. The pressure shall be reduced to 10.5 bars head of water and shall be maintained as constant as possible for a period of 24 hours. Make-up water shall be pumped into the section of the pipeline from time to time to maintain this pressure. The leakage test shall be considered to

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have been passed if the make-up water pumped into the section of the pipeline does not exceed the allowable leakage calculated as: 0.05l/mm of internal diameter per kilometer of pipe per 24 hours. If this specified rate of leakage is exceeded a thorough inspection of the section of the pipeline shall be made. All leaks discovered shall be repaired and the section shall be tested again.

5.3.2.9. Every section pipeline shall be tested as described above in the presence of the S.O. Testing may be carried out between sluice valves but not against the gates of the sluice valves.

5.3.2.10. All permanent thrust block provided at tees/bends shall be concreted and sufficiently cured prior to permission being given for testing. No temporary strutting or temporary bracing will be permitted in lieu of the permanent thrust blocks as the tests are also to subject these blocks to the transmitted pressures.

5.3.3. Flushing and Disinfecting Pipelines

When the final connections have been made and the pipeline has been tested to the satisfaction of the S.O. it shall be thoroughly cleaned, disinfected and flushed in sections by the Contractor. Water for this purpose shall be obtained from the Water Service Provider's sources and the Contractor shall pay all the charges incurred in connection therewith.

5.3.4. Non-Precast Valve chambers

5.3.4.1. Valve chambers shall be constructed to the size shown on the Drawings. Unless otherwise specified, all dimensions on plan shall be inside measurement. Manhole covers shall comply with BS EN 124.

5.3.4.2. Unless otherwise shown on the drawings all manholes and chambers shall be of brickwork in cement mortar 1:2. The brickwork foundation shall be constructed with concrete strength class C20/25 unless shown otherwise. The thicknesses and sizes shall be as shown on the Drawings. The inside of the chambers and manholes shall be lined with 12mm thick cement plaster (1:2). Externally, the exposed concrete or block brick surfaces shall be plastered with 12mm cement mortar (1:2) and terminated 150mm below the finished ground level. All internal angles shall be rounded off. Manholes and chambers shall provide with precast concrete cover unless otherwise specified on the Drawings. Approved typed wrought iron steps shall be built into the brick wall of all manholes and chambers of depth 2.0m or more and they shall be spaced not more than 300mm apart projecting 100mm over face of wall.

5.3.5. Precast Chambers

Precast valve chambers shall be as shown on the Drawings and in accordance with SECTION D: CONCRETING. Chamber covers shall comply with BS EN 124.

5.3.6. Washout (Scour Valves Location)

Washouts shall be constructed at locations specified on the drawings or as may be directed by the S.O. The washout branches shall be connected to

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the pipeline by special washout tees and sluice valves. From the washout sluice valves, HDPE or mild steel pipes shall be laid to the nearest drain or stream. The discharge point shall be downstream.

5.3.7. Indicator Post (Pipe and Valve Markers)

The Contractor shall provide and fix indicator posts close to the centre line of pipes, at valves, washout and other points as directed by the S.O. The details of indicator posts are as shown on the Drawings

5.3.8. Hot Tapping

5.3.8.1. The Contractor shall submit a method statement as how to conduct the hot tap that has been approved by the State Water Authorities to the S.O. prior to commencement of the works.

5.3.8.2. Hot tapping shall only be done in the presence of the Water Service Provider's representative. The tapping mechanism shall be of the self-purging type so that cutting chips are removed from the tapping machine and do not enter the pipeline.

5.3.8.3. All hot tap connections to existing pipelines, whether for mainline extension or service laterals, shall be performed by an authorized and qualified person.

5.3.8.4. The tapping machine shall be cleaned and disinfected prior to attachment to the tapping valve and saddle.

5.3.9. Pipe Jacking

5.3.9.1. Placement of pipe by boring or jacking methods requires special S.O.'s approval for each instance. The methods and equipment used in boring and jacking operations shall be optional to the contractor, provided that the S.O. reviews them prior to any work.

5.3.9.2. The Contractor shall submit to the S.O. the method statement on how to conduct the pipe jacking operation prior to commencement of the works.

5.4. External Water Storage Tanks (Factory Fabricated Tanks)

5.4.1. The Contractor shall supply a new tank reservoir and water tanks from suppliers with valid product listing and registration with the relevant authorities. All materials shall comply with the relevant authorities' guidelines and approved by the S.O. before being installed. The type of tanks that may be supplied and installed shall be only as shown in **Table L2.**

5.4.2. The tank shown on the Drawings and specified herein shall be fabricated, supplied and installed by a manufacturer with valid registration with the relevant authorities' guidelines.

5.4.3. Construction shall be governed by the Contract Drawings and specifications showing general dimensions

5.4.4. The water tank inclusive of all associated pipe works shall be cleaned upon completion, tested for water tightness and disinfected and approved by the S.O. before it is commissioned.

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5.4.5. The test for the water tightness, strength, etc. shall be in accordance with the requirement as set out by the relevant authorities. The method of testing and test approval certificate shall be submitted to the S.O. Water tightness testing results for water tanks and components that will be handed over shall be witnessed by the Water Service Provider.

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Table L1. Width of Pipe Trenches

External Pipe Diameter (D)	Width of Trench
Not exceeding 460mm	D+300mm
460mm and above	D+600mm

Table L2. Type of Water Storage Tank

No	Product Name	Specified conditions/ Requirements
1	Steel Tank with Lining or Coating (Non-Corrugated Type) (Glass Fused/Glass Coated/Epoxy Lining/HDPE) Lining	Maximum capacity allowed for elevated tanks is 2.3ML (500,000 UK gallons) and for ground storage tanks is 3.4ML (750,000 UK gallons). Maximum height allowed is 5m or 4 panels high whichever is lower. The minimum warranty period for the tank and sealant/lining shall be 10 years. The minimum thickness of PE/HDPE lining shall be 2.0mm.
2	Cylindrical Steel Tank - Double Fold System	Maximum capacity allowed is 4.5ML (1,000,000 UK gallons). Maximum height allowed is 5m. The minimum warranty period for the tank and sealant/lining shall be ten (10) years.
3	Polyethylene Storage Tanks (PE Storage Tanks)	Tanks shall have interlocking mechanisms. Tanks shall only be allowed up to 4,546L (1,000 UK gallons) capacity only. Multiple tanks on one tower structure shall be strictly not allowed.

Note: The use of other types of tanks are subjected to approval of SPAN and the S.O.

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TABLE OF CONTENTS

SECTION P: ROADS AND HARDSTANDING		PAGE
1.	General	P/1
2.	Flexible Pavement	P/1
3.	Horizontal Alignment, Surface Levels and Surface Regularity Of Pavement Courses	P/7
4.	Shoulders	P/8
5.	Concrete Pavement	P/9
6.	Road Furniture	P/9
7.	Street Lighting	P/10
8.	Traffic Signal System	P/10

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1. General

1.1. The construction of roads and hardstanding shall generally be carried out only after completion of all drainage systems, services and ducts which may affect the Works, unless otherwise agreed by the S.O.

2. Flexible Pavement

2.1. Subgrade

2.1.1. Subgrade means that part of the embankment or existing ground in cutting which is immediately below the sub-base or lower sub-base of the road pavement and shoulders.

2.1.2. Material for the top 300mm of subgrade shall have a minimum soaked laboratory California Bearing Ratio (CBR) as shown on the Drawing when compacted to 95% of the maximum dry density determined in the *MS 1056* Compaction Test (4.5kg Rammer Method). In the event CBR value not mentioned on the Drawing, a minimum CBR value of 10% shall be adopted.

2.1.3. Throughout the top 300mm of subgrade, the materials shall be compacted to not less than 95% of the maximum dry density determined in the *MS 1056* Compaction Test (4.5kg Rammer Method).

2.1.4. In cut area, the top 300mm of the subgrade shall be scarified and recompacted to 95% of the maximum dry density determined in the *MS 1056* Compaction Test (4.5kg Rammer Method). If the S.O. is fully satisfied that the subgrade in its natural state possesses a density exceeding the requirements, then the surface of the subgrade shall be trimmed and rolled to obtain a smooth finish.

2.1.5. Where the material in cut area is found to be unsuitable for use in the top 300mm of subgrade or to a suitable level to be determined by the S.O., it shall be removed and replaced with suitable material which shall be compacted as indicated above. Alternatively, stabilizing agent may be used subject to the S.O.'s approval.

2.1.6. The subgrade shall be finished in a neat and workmanlike manner, and the widths of embankments and cuts shall be everywhere at least of those specified or shown on the Drawings on both sides of the centre line. The top surface of the subgrade shall have the required shape, superelevation, levels and grades and shall be finished everywhere to within + 10mm and - 30mm of the required level.

2.1.7. Where subgrade construction encounters rock surfaces:

2.1.7.1. Rock surfaces extend over the whole width of the formation:

The rock surface shall be trimmed to a free draining profile, at or below formation levels. No high spot shall protrude above the formation level. Any voids or cavities more than 0.5m below the formation level shall be filled up with approved crusher run, gravel or lean concrete having strength class of C12/15. The rock surface shall then be brought up to the formation levels with approved crushed rock or gravel, regulated and blinded.

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2.1.7.2. Rock outcrop occurs over part of the formation only:

The rock outcrop shall be cut down to a level not less than 300mm below the formation level. The surface shall then be brought up to level with suitable subgrade material.

2.2. Drainage Layer

2.2.1. This work shall consist of furnishing, placing, compacting and shaping drainage layer on a prepared and accepted subgrade in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O.

2.2.2. Coarse aggregate shall be screened crushed hard rock and fine aggregate shall be screened quarry dust or sand. The aggregate shall be well graded and lie within the limits as shown in **Table P1.**

2.2.3. Notwithstanding any earlier approval of finished subgrade, the surface of the subgrade shall be, on completion of compaction and immediately before placing drainage layer, well closed and free from movement under the compaction plant and from ridges, cracks, loose material, potholes, ruts or other defects. Any damage to or deterioration of the subgrade shall be made good in accordance with sub-section 2.1.

2.2.4. The material shall be transported, laid and compacted at a moisture content within the range + 1% to - 2% of the optimum moisture content determined in compliance with *BS 5835* and without drying out or segregation.

2.2.5. The drainage layer shall be placed and compacted to the required width and thickness as shown on the Drawings, in one single layer.

2.2.6. The material shall be spread and lightly compacted with tracked spreading plant or other approved equipment with consideration given to the protection of the subgrade.

2.3. Sub-base

2.3.1. This work shall consist of furnishing, placing, compacting and shaping sub-base material on a prepared and accepted subgrade in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O.

2.3.2. Sub-base shall be a natural or artificial mixture of locally available materials such as sand, gravel, crushed aggregate, et cetera, free from organic matter, clay lumps and other deleterious materials. It shall be well graded and conform to **Table P2** and the following quality requirements:

2.3.2.1. The CBR of the sub-base shall not be less than 30% or as shown on the Drawings when compacted to 95% of the maximum dry density determined in the *BS 1377* Compaction Test (4.5kg rammer method) and soaked for 4 days under a surcharge of 4.5kg. This shall involve carrying out a series of CBR tests at various dry densities, using the field moisture content. The field density must then be measured at a number of points using the sand replacement method and the CBR deduced from the mean of the field density measurements.

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2.3.2.2. If more than 10% of the material is retained on the BS Sieve Size 20.0mm, the whole material can be assumed without test to have a CBR value of 30% or more.

2.3.2.3. The plasticity index when tested in accordance with *BS 1377* shall be not more than 12.

2.3.2.4. The 10% fines value when tested in accordance with *MS EN 933* shall be not less than 30kN.

2.3.2.5. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with *ASTM D 2419* shall be not less than 45%.

2.3.3. Prior to placing any sub-base material, the underlying subgrade (particularly the top 300mm of the subgrade) shall have been shaped and compacted in accordance with the provisions of sub-section 2.1. or sub-section 2.2. as appropriate. Notwithstanding any earlier approval of finished subgrade, the surface of the subgrade shall be, on completion of compaction and immediately before placing sub-base layer, well closed and free from movement under the compaction plant and from ridges, cracks, loose material, potholes, ruts or other defects. Any damage to or deterioration of the subgrade shall be made good in accordance with sub-section 2.1.

2.3.4. Sub-base material shall be transported, laid and compacted at a moisture content within the range + 1% to - 2% of the optimum moisture content without drying out or segregation.

2.3.5. Sub-base material shall be placed over the full width of the formation to the required thickness as shown on the Drawings or directed by the S.O. in one layer or more, each layer not exceeding 200mm compacted thickness. Where two or more layers are required, they shall be of approximately equal thickness and none shall be less than 100mm compacted thickness.

2.3.6. Each layer of sub-base shall be processed as necessary to bring its moisture content to a uniform level throughout the material suitable for compaction and shall then be compacted using suitable compaction equipment approved by the S.O. to not less than 95% of the maximum dry density determined in the *BS 1377* Compaction Test (4.5kg rammer method). Compaction shall be carried out in a longitudinal direction along the roadbed, and shall generally begin at the outer edge and progress uniformly towards the crown on each side in such a manner that each section receives equal compaction effort, all to the satisfaction of the S.O.

2.3.7. All loose, segregated or other defective areas shall be removed to the full thickness of the layer, and new sub-base material laid and compacted.

2.3.8. The sub-base shall be finished in a neat and workmanlike manner and shall have an average thickness over any 100m length not less than the required thickness. The top surface of the sub-base shall have the required shape, superelevation, levels and grades, and shall be everywhere within the tolerances as specified in sub-section 3.2.

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2.4. Crushed Aggregate Road Base

2.4.1. This work shall consist of furnishing, placing, compacting and shaping crushed aggregate road base material on a prepared and accepted subgrade or sub-base in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O.

2.4.2. Crushed aggregate road base material shall be crushed rock, crushed gravel or a mixture of crushed rock and gravel, which shall be hard, durable, clean and essentially free from clay and other deleterious materials. The material shall conform to the following physical and mechanical quality requirements:

2.4.2.1. The plasticity index when tested in accordance with *BS 1377* shall be not more than 6.

2.4.2.2. The aggregate crushing value when tested in accordance with *MS 30* shall be not more than 25%.

2.4.2.3. The flakiness index when tested in accordance with *MS 30* shall be not more than 25%.

2.4.2.4. The weighted average loss of weight in the magnesium sulphate soundness test (5 cycles) when tested in accordance with *AASHTO Test Method T 104* shall be not more than 18%.

2.4.2.5. The material shall have a CBR value of not less than 80% when compacted to 95% of the maximum dry density determined in the *BS 1377* Compaction Test (4.5kg rammer method) and soaked for 4 days under a surcharge of 4.5kg.

2.4.2.6. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with *ASTM D 2419* shall be not less than 45%.

2.4.2.7. The gradation shall comply with the envelope as shown in **Table P3.**

2.4.3. Prior to placing any crushed aggregate road base material, the sub base shall have been constructed in accordance with the provisions of sub-section 2.3.

2.4.4. Crushed aggregate road base shall be placed to the required width and thickness as shown on the Drawings or directed by the S.O. in one layer or more, each layer not exceeding 200mm compacted thickness.

2.4.5. Where two or more layers are required, each layer shall be of approximately equal thickness and none shall be less than 100mm compacted thickness.

2.4.6. The material shall be spread using a motor grader of sufficient capacity or other approved mechanical spreader, at the optimum moisture content ± 1%.

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2.4.7. Compaction shall be carried out using suitable approved equipment, in a longitudinal direction, and begin at the lower edges and progress towards the crown, or in the case of superelevation towards the upper edge, in such a manner that each section receives equal compaction effort, sufficient to produce a density of not less than 95% of the maximum dry density as determined by *BS 1377: Test 13*.

2.4.8. Throughout the placing, adjustment of moisture content and compaction of crushed aggregate road base material, care shall be taken to maintain a uniform gradation of the material and prevent its separation into coarse and fine parts, all to the satisfaction of the S.O.

2.4.9. The crushed aggregate road base width shall be everywhere at least that specified or shown on the Drawings on both sides of the centre-line; and its average thickness over any 100m length shall be not less than the required thickness.

2.4.10. The surface of the road base shall on completion of compaction and immediately before placing bituminous surfacing be well closed and free from movement under the compaction plant and from ridges, cracks, loose material, potholes, ruts other defects.

2.4.11. All loose, segregated or otherwise defective areas shall be removed to the full thickness of the layer, and new material laid and compacted. The addition of fine material will not be permitted.

2.4.12. The surface shall be to the required level and grade and comply with the tolerances as specified in sub-section 3.2.

2.5. Wet-Mix Road Base

2.5.1. This works shall consist of furnishing, placing, compacting wet-mix road base on a prepared and accepted sub-base in accordance with this Specification and the lines and levels as shown on the Drawings and/or as directed by the S.O.

2.5.2. Aggregate for wet-mix road base shall be crushed rock, crushed gravel or a mixture of crushed rock and gravel, which shall be hard, durable, clean and essentially free from clay and other deleterious materials.

2.5.3. The aggregate shall conform to the following physical and mechanical quality requirements:

2.5.3.1. The flakiness index when tested in accordance with *MS EN 933* shall be not more than 25%.

2.5.3.2. The aggregate crushing value when tested in accordance with *MS 30* shall be not more than 25%.

2.5.3.3. The weighted average loss of weight in the magnesium sulphate soundness test (5 cycles) when tested in accordance with *AASHTO Test Method T 104* shall be not more than 18%.

2.5.3.4. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with *ASTM D 2419* shall be not less than 45%.

2.5.3.5. The gradation shall comply with the limits shown in **Table P4.**

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2.5.4. Notwithstanding any earlier approval of finished sub-base, prior to placing wet-mix road base material, any damage to or deterioration of the sub-base shall be made good in accordance with sub-section 2.3.

2.5.5. Wet-mix road base material shall be placed to the required width and thickness as shown on the Drawings or as directed by the S.O. in one layer or more, each layer not exceeding 200mm compacted thickness. Where two or more layers are required, they shall be of approximately equal thickness and none shall be less than 100mm compacted thickness.

2.5.6. The material shall be laid using a paving machine at moisture content + 0.5% of the optimum which shall be maintained during the compaction operation.

2.5.7. Compaction shall be carried out using suitable approved equipment in a longitudinal direction, and begin at the lower edges and progress towards the crown, or in the case of superelevation towards the upper edge, in such a manner that each section receives equal compaction effort, sufficient to produce a density of not less than 95% of the maximum dry density as determined by *BS 1377: Test 13.*

2.5.8. Throughout the placing, and compaction of wet-mix road base material, care shall be taken to maintain a uniform gradation of the material and prevent its separation into coarse and fine parts.

2.5.9. All loose, segregated or otherwise defective areas shall be removed to the full thickness of the layer, and new wet-mix road base material laid and compacted, the addition of fine aggregate only shall not be permitted.

2.5.10. The wet-mix road base width shall be everywhere at least that specified or shown on the Drawings on both sides of the centre-line. The average thickness measured over any 100m length shall be not less than shown on the Drawings or specified and the minimum thickness measured at any one point shall be not less than the thickness shown on the drawing or specified **Table P5.**

2.5.11. The surface of the wet-mix road base shall, on completion of compaction and immediately before placing bituminous surfacing, be well closed and free from movement under the compaction plant and from ridges, cracks, loose material, potholes, ruts or other defects.

2.5.12. The surface shall be to the required level and grade and comply with the tolerances specified in sub-section 3.2.

2.6. Bituminous Pavement Courses

2.6.1. Bituminous Prime Coat

2.6.1.1. This work shall consist of the careful and thorough cleaning of the surface of a prepared and accepted unbound road base and cement-treated base (CTB), and the furnishing and application to the cleaned road base and CTB surface of a bituminous prime coat, all in accordance with this Specification and the lines, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O.

2.6.1.2. The materials, equipment and construction methods shall be in accordance with *Standard Specification for Roadworks Section*

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4: Flexible Pavement JKR Specification No. JKR/SPJ/2008-S4.

2.6.2. Bituminous Tack Coat

2.6.2.1. This work shall consist of the careful and thorough cleaning of the surface of a prepared and accepted bituminous or bitumen primed pavement course, and the furnishing and application to the cleaned surface of a bituminous tack coat prior to the construction of an overlying bituminous pavement course, all in accordance with this Specification and the lines, dimensions and cross-sections as shown on the Drawings and/or as required by the S.O.

2.6.2.2. The materials, equipment and construction methods shall be in accordance with *Standard Specification for Roadworks Section 4: Flexible Pavement JKR Specification No. JKR/SPJ/2008-S4.*

2.6.3. Asphaltic Concrete

2.6.3.1. This work shall consist of furnishing, placing, shaping and compacting asphaltic concrete binder course and/or wearing course on a prepared and accepted bituminous or bitumen primed pavement course, and shall include the careful and thorough cleaning of surfaces which are to be covered prior to the application of bituminous prime coat and tack coat. The work shall be carried out all in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as required by the S.O.

2.6.3.2. The materials, mix design, equipment and construction methods shall be in accordance with JKR Specification No. *JKR/SPJ/2008-S4*.

3. Horizontal Alignment, Surface Levels and Surface Regularity of Pavement Courses

3.1. Horizontal Alignment

3.1.1. The horizontal alignment shall be determined from the center-line of the pavement surface shown on the Drawings. The edges of the pavement as constructed and all other parallel construction lines shall be correct within a tolerance of + 50mm and - 0mm from the centre-line, except for kerbs, channel blocks and edge lines which shall be laid with a smooth alignment within a tolerance of + 25mm and - 0mm from the centre-line.

3.2. Surface Levels of Pavement Courses

3.2.1. The design levels of pavement courses shall be calculated from the vertical profile, crossfall and pavement course thicknesses shown on the Drawings. Crossfall for hardstanding shall be constructed at a minimum of 2.5% gradient from the highest point of the area or as approved by S.O. The level of any point on the constructed surface of a pavement course shall be the design level subject to the appropriate tolerances given in **Table P5.**

3.2.2. The combination of permitted tolerances in the levels of different pavement courses shall not result in a pavement thickness less than that

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shown on the Drawings. Each pavement course shall have an average thickness not less than that shown on the Drawings.

4. Shoulders

4.1. This work shall consist of furnishing, compacting and shaping earth, gravel or paved shoulder material on a prepared and accepted sub-base or subgrade, all in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as required by the S.O.

4.2. Materials

4.2.1. Paved Shoulders

The bituminous surfacing and underlying pavement courses shall be constructed as described in the appropriate sections of this Specification.

4.2.2. Gravel Shoulders

Gravel shoulder material shall conform to the requirements for gravel surfacing material set forth in *Standard Specification for Roadworks Section 4: Flexible Pavement JKR Specification No. JKR/SPJ/2008-S4.*

4.2.3. Earth Shoulders

Earth shoulder material shall be suitable material as described in *Standard Specification for Roadworks Section 2: Earthworks JKR Specification No. JKR/SPJ/2020-S2.*

4.2.4. Construction

4.2.4.1. Shoulders shall be constructed in stages or in one operation as directed or approved by the S.O., but in no instance shall a shoulder be built up to a level higher than that part of the abutting carriageway structure which has been completed and accepted.

4.2.4.2. Prior to placing any shoulder material, the underlying sub-base or subgrade shall have been shaped and compacted in accordance with the provisions of *Standard Specification for Roadworks Section 2: Earthworks JKR Specification No. JKR/SPJ/2020-S2*. respectively, and the abutting carriageway structure course or courses shall likewise have been shaped and compacted in accordance with the provisions of the appropriate sub-sections of this Specification. Notwithstanding any earlier approval of the underlying and abutting pavement courses, any damage to or deterioration of these underlying and abutting pavement courses shall be made good to the satisfaction of the S.O. before shoulder construction proceeds.

4.2.4.3. Shoulders shall be placed to the required width and thickness as shown on the Drawings or as directed by the S.O. in one layer or more, each layer not exceeding 200mm compacted thickness at the point of maximum thickness. Where two or more layers are required, they shall be of approximately equal shape and thickness, and none shall be less than 100mm compacted thickness at the point of maximum thickness.

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4.2.4.4. Each layer of shoulder material shall be processed as necessary to bring its moisture content to a uniform level throughout the material suitable for compaction and shall then be compacted using suitable compaction equipment approved by the S.O. to not less than 95% of the maximum dry density determined in the *BS 1377* Compaction Test (4.5kg rammer method). Compaction shall be carried out in a longitudinal direction along the shoulder and shall generally begin at the outer edge and progress uniformly towards the carriageway, except on super-elevated curves where rolling shall begin at lower edge and progress uniformly towards the higher edge. In all cases, compaction shall be carried out in such a manner that each section receives compaction effort appropriate to its thickness, all to the satisfaction of the S.O.

4.2.4.5. Throughout the placing, adjustment of moisture content and compaction of shoulder material, care shall be taken to maintain a uniform gradation of the material and prevent its separation into coarse and separate parts, all to the satisfaction of the S.O.

4.2.4.6. Where shown on the Drawings or directed by the S.O., earth shoulders shall be turfed in accordance with *Standard Specification for Roadworks Section 2: Earthworks JKR Specification No. JKR/SPJ/2013-S2.*

4.2.4.7. Shoulders shall be finished in a neat and workmanlike manner. The total width of carriageway and shoulder shall throughout be at least as specified or shown on the Drawings on both sides of the centre-line. The top surface of each shoulder shall throughout have the required shape, super-elevation, levels and grades, within 10mm of the required plane, and shall provide a flush joint with the carriageway surface and shall be uniformly free draining away from the carriageway, all to the satisfaction of the S.O.

5. Concrete Pavement

Concrete Pavement works shall be in accordance with Standard Specification for Road Works JKR Specification No. JKR/SPJ/2020 Section 5: Portland Cement Concrete Pavement.

6. Road Furniture

6.1. Corrugated Sheet Steel Beam Guardrail

The supply and method of installation of guardrails shall be in accordance with Standard Specification for Road Works Section 6: Road Furniture JKR Specification No. JKR/SPJ/2017-S6.

6.2. Traffic Signs

The supply and method of installation of traffic signs shall be in accordance with *Standard Specification for Road Works Section 6: Road Furniture JKR Specification No. JKR/SPJ/2017-S6.*

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6.3. Road Markings

The supply and application of road markings shall be in accordance with *Standard Specification for Road Works Section 6: Road Furniture JKR Specification No. JKR/SPJ/2017-S6.*

6.4. Concrete Kerb

The supply and installation of concrete kerb shall be in accordance with *Standard Specification for Road Works Section 6: Road Furniture JKR Specification No. JKR/SPJ/2017-S6.*

7. Street Lighting

The supply and installation of street lighting shall be in accordance with *Standard Specification for Road Works Section 7: Street Lighting JKR Specification No. JKR/SPJ/2011-S7.*

8. Traffic Signal System

The *supply* and installation of traffic signal system shall be in accordance with *Standard Specification for Road Works Section 8: Traffic Signal System JKR Specification No. JKR/SPJ/2008-S8.*

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Table P1. Gradation Limits for Drainage Layer

B.S. Sieve Size (mm)	Percentage Passing by Weight
75.0	100
37.5	75 - 100
20.0	60 - 90
10.0	25 - 75
5.0	10 - 45
2.00	0 - 20
1.18	0 - 10

Table P2. Gradation Limits for Sub-Base

BS Sieve Size (mm)	Percentage Passing by Weight
75.0	100
37.5	85 - 100
20.0	65 - 100
10.0	45 - 100
5.0	25 - 85
0.600	8 - 45
0.075	0 - 10
The particle size shall be determined by the washing and sieving method of *BS 1377*.	

Table P3. Gradation Limits for Crushed Aggregate Road Base

B.S. Sieve Size (mm)	Percentage Passing by Weight
50.0	100
37.5	85 - 100
28.0	70 - 100
20.0	60 - 90
10.0	40 - 65
5.0	30 - 55
2.00	20 - 40
0.425	10 - 25
0.075	2 - 10
The particle size shall be determined by the washing and sieving method of *BS 1377*.	

Table P4. Gradation Limit for Wet-Mix Road Base

B.S. Sieve Size (mm)	Percentage by Weight Passing
50.0	100
37.5	95 - 100
20.0	60 - 80
10.0	40 - 60
5.0	25 - 40
2.36	15 - 30
0.060	8 - 22
0.075	0 - 8
The particle size shall be determined by the washing and sieving method of *BS 1377*.	

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Table P5. Tolerances in Surface Levels of Pavement Courses

Pavement Course	Tolerance
Wearing Course	± 5mm
Binder Course	± 5mm
Roadbase	+ 0mm to - 20mm
Sub-base	+ 10mm to - 20mm

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TABLE OF CONTENTS

SECTION S : DRAINAGE **PAGE**

1.	General	S/1
2.	Excavation And Backfilling	S/1
3.	Materials	S/3
4.	Surface Drainage	S/5
5.	Subsoil Drain	S/6
6.	Sumps	S/7
7.	Piling Works	S/7
8.	Culverts	S/7
9.	On-Site Detention	S/9
10.	Stormwater Pumping	S/10
11.	Bio-Ecological Drainage System (BIOECODS)	S/10
12.	Types Of Lining	S/11
13.	Brickwork	S/12

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1. General

1.1. All drainage works shall conform to the latest requirements of the *Urban Stormwater Management Manual for Malaysia (MSMA)/* MS 2526 and for Works in Sarawak shall comply with *Sarawak Urban Stormwater Management (SUStoM).*

1.2. The works shall include the construction of surface drains, sumps, culverts, subsoil drains, and other drainage structures in accordance with the above requirements or as directed by the S.O.

1.3. Drainage works shall be constructed to the lines, levels, grades and cross-sections shown on the Drawings or to suit the site as approved by the S.O.

1.4. The site drainage system shall be constructed to direct the runoff from the entire site to the storage area. There shall be no flooding, ponding, silting-up either during construction or after completion of the works. The quantity and quality of runoff from post development area shall be maintained to be the same or less than pre-development condition.

1.5. Final discharge point shall be identified and approved by the relevant local Authority. Where necessary, the existing drainage system shall be upgraded in order to ensure they are fully functional.

2. Excavation and Backfilling

2.1. All general excavation works shall be as specified in SECTION B: EXCAVATION AND EARTHWORKS.

2.2. The Contractor shall notify the S.O. sufficiently in advance of the beginning of any excavation so that cross-section elevations and measurements shall be taken of undisturbed ground. The natural ground adjacent to the structure shall not be disturbed without permission of the S.O. The excavation works shall be carried out so as not to cause any danger or obstruction to the traffic or public.

2.3. All excavation shall be inspected and approved by the S.O. prior to further work being carried out.

2.3.1. Excavation of Hard Materials/Rock

2.3.1.1. Hard materials/rock encountered in the trench excavation shall be removed to the approval of the S.O. Layer of rock encountered along the bottom of the excavation shall be cut and trimmed to the required level.

2.3.1.2. Voids formed at bottom of the trench due to the removal of rocks shall be backfilled to the required level with 20mm concrete strength class C16/20 or other suitable materials, well rammed and compacted all to the approval of the S.O.

2.3.1.3. Jagged surfaces of rocks at the bottom of the excavation due to the trimming shall be levelled and smoothened with sand blinding to the approval of the S.O.

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2.3.2. Excavation of Soft Materials

When, in the opinion of the S.O., the foundation material is soft or otherwise unsuitable, the Contractor shall remove and insert foundation fill material or concrete as specified or shown on the Drawings or directed by the S.O. It shall be placed and compacted in layers not more than 150mm thick or as directed by the S.O.

2.4. Excavation for Drain Trenches

2.4.1. The trench shall be excavated to a depth intended or shown on the Drawings. The blinding material shall be laid immediately after the excavation.

2.4.2. Should the bottom of the trench be inadvertently excavated below the specified level, it should be brought back at the Contractor's expense to the correct level with good selected earth or sand, carefully rammed into place.

2.4.3. The trench bottom shall be of sufficient width to allow adequate working space for the pipe workers. Trenches deeper than 1.5 m shall be provided with any trench support method, approved by the S.O. The Contractor at all time shall ensure the excavated trench is in the safe working condition for the workers.

2.4.4. Unless otherwise specified, excavated material shall not be deposited at the edges of the trench.

2.5. Excavation for Culvert

2.5.1. The earthworks at the required location shall be constructed to a level at least 600mm above the top of culverts design levels or to the top of subgrade levels, whichever is lower. The culverts specified to be constructed in trench conditions shall be excavated in accordance with sub-section 2.6.

2.5.2. Where drainage conditions or other circumstances so require, the S.O. shall direct the Contractor to construct the culvert without first constructing the earthworks to the level specified above, in which case excavation, and foundation preparation shall be in accordance with sub-section 2.7.

2.6. Trench Method

2.6.1. The trench to receive culvert shall have sufficient width and depth to enable the placing of bedding material. The bottom of the trench shall be trimmed to suitably smooth plane surface which shall be kept free from water, all to the satisfaction of the S.O.

2.6.2. Rock or other hard material encountered shall be excavated to a depth as directed by S.O. The excavated hard material shall be replaced with suitable material uniformly compacted in layers of not more than 150mm compacted thickness to provide satisfactory support for the culvert, all to the satisfaction of the S.O.

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2.7. Open Ground Method

2.7.1. Where existing ground levels are above top bedding material design levels and firm foundation materials are encountered, excavation and foundation preparation shall be similar to the described in trench method above. Otherwise, a firm foundation plane shall be prepared, which shall be essentially free draining along the line of the culvert by trimming the existing ground, or such fill as it is necessary to place and compact, over a width sufficient to permit satisfactory construction of the pipe bedding, all to the satisfaction of the S.O.

2.7.2. Where soft or unstable soil is encountered in the foundation, it shall be excavated over a width of at least 1.5 times the outside of each side of the culvert centre-line to the depth directed by the S.O., and replaced with suitable material uniformly compacted in layers of not more than 150mm compacted thickness to provide satisfactory support for the pipe, all to the satisfaction of the S.O.

2.8. Backfilling

2.8.1. Drainage trenches shall be backfilled immediately after completion of drain laying or installation of culverts and as soon as the S.O. has inspected and given his approval.

2.8.2. Backfilling with approved fill materials shall be placed evenly in layers not exceeding 150mm. To provide uniform support, loose thickness of fill materials on both sides of the drain shall be thoroughly compacted with mechanical rammers. This procedure shall be followed for the whole depth of drain section.

2.8.3. All spaces excavated under this Specification and not occupied by a permanent structure shall be backfilled with material free from large lumps, wood and extraneous material.

2.8.4. Backfill shall be in layers not more than 150mm compacted thickness. Each layer of backfill shall be wetted uniformly as necessary and compacted to the same requirements as the adjacent undisturbed material. Unless otherwise approved by the S.O., hand tamping shall not be permitted.

2.8.5. In placing the backfill, the material shall be to the same height on both sides of the structure. If conditions require backfilling appreciably higher on one side, the additional material on the higher side shall not be placed until the S.O. is satisfied that the structure has enough strength to withstand any pressure created.

3. Materials

3.1. Basic construction materials shall comprise the following;

3.1.1. Granular Bedding Material

The foundations shall be of granular bedding material suitably graded broken rubble, crushed stone, crushed gravel, sand or other material as shown on the Drawings or as directed by the S.O.

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3.1.2. Concrete Bedding

3.1.2.1. Concrete for blinding, bedding and cast-in-situ drains shall be as shown on the Drawings and as specified in SECTION D: CONCRETING.

3.1.2.2. Unless otherwise shown on the Drawings, concrete bedding shall be of concrete strength class C20/25 and blinding for the foundations of structure such as drains, sumps and culvert shall be of concrete strength class C12/15 or as directed by the S.O.

3.1.3. Cement Mortar

3.1.3.1. Cement mortar, unless otherwise specified, shall contain 1 part ordinary Portland cement to 3 parts fine aggregate by volume. Water shall be added to the mix to produce a suitable consistency for the intended use, all to the approval of the S.O.

3.1.3.2. The ingredients for mortar shall be measured in proper gauge boxes and mixed on a clean boarded platform or in an approved mechanical batch mixer.

3.1.3.3. All mortar shall be used within 45 minutes of mixing and no reworking of mortar shall be permitted thereafter.

3.1.4. Ordinary Backfill Material

3.1.4.1. Ordinary backfill material shall be of suitable material as defined in SECTION B: EXCAVATION & EARTHWORK.

3.1.4.2. Materials from swamps, peats or top soils and other highly organic clay or silt, materials containing logs, stumps or boulders, which are susceptible to combustion, and any other materials which, by virtue of their physical or chemical composition or at their moisture content will not compact properly, shall not be used for filling.

3.1.5. Granular Backfill Material

3.1.5.1. Granular backfill material shall be sand, crushed stone, crushed gravel or a mixture of crushed and natural aggregates, shall be essentially free from vegetative and other organic matter and clay, and shall not contain lateritic or concretionary materials. The material shall conform to the following physical and mechanical quality requirements:

i) The fines shall be non-plastic;

ii) Sand shall have a gradation conforming to the envelope shown in **Table S1**;

iii) Material other than sand shall have a gradation conforming to one of the envelopes shown in **Table S2**.

3.1.5.2. The granular backfill shall be placed in layers not to exceed 150mm in depth and each layer shall be thoroughly compacted

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by means of packers or mechanical tampers to a relative compaction of not less than 95% Standard Proctor Density for the backfill material at optimum moisture content.

4. Surface Drainage

4.1. Surface drains shall be constructed with regard to both operation and ease of maintenance and adequate gradient shall be provided to enable self-cleansing flow.

4.2. Where gradient designed is not practical or above the finished level, the Contractor shall submit their proposal for the approval of the S.O.

4.3. Reinforced concrete struts shall be provided for all drain side walls exceeding 0.9m height. Handrails shall be provided for open drains more than 1.2m width and / or maximum depth as specified in **Table S3**.

4.4. Types of Surface Drains

4.4.1. Surface drains of all types shown on the Drawings shall be constructed either unlined or lined using cast in situ concrete, precast or porous concrete drain sections or stone pitching.

4.4.2. Unlined (Earth) Drains

4.4.2.1. The Contractor shall refer to approved plans for location, extent and construction details as shown on the Drawing, or otherwise directed by the S.O. Clearing shall be done only when is necessary to provide access for personnel and equipment installation. Roots, stumps and other debris shall be removed and disposed off properly and not be used to build the bank.

4.4.2.2. Excavation for unlined/ earth drains shall be trimmed to form a smooth, firm surface to the required lines, levels, grades and cross-sections as shown on the Drawings or as directed by the S.O.

4.4.2.3. Any areas of over excavation shall be made good to the satisfaction of the S.O., all at the contractor's expenses.

4.4.2.4. The sides of cut drain shall not be steeper than 1:1.5 (V:H), while fill slopes shall not be steeper than 1:2 (V:H). The surface water shall be discharged to a stable outlet such that soil erosion is prevented from occurring.

4.4.3. Lined Drain

4.4.3.1. Lined drains shall be constructed from material proven to be structurally sound and durable and have satisfactory jointing systems. Unless otherwise stated on the Drawings, the maximum steepness of the side slopes for lined open drains shall be as indicated in **Table S4**.

4.4.3.2. All concrete works shall conform to the requirement in SECTION D: CONCRETING of this Specification or unless otherwise specified.

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4.4.3.3. Lined drains shall be constructed by the following means;

i) Cast In Situ Concrete Drains

a) Cast in-situ concrete drains shall be concrete strength class C20/25 unless otherwise stated. Weep holes shall be cast in-situ as shown on the Drawings or as directed by the S.O.

b) Where the concrete grade is found to be of the lower grade, the S.O. shall request the Contractor to do the rectification work according to the requested proper method.

ii) Precast Concrete Drain

a) Precast concrete block inverts shall be of the shapes and dimensions as shown on the Drawing and shall be of concrete strength class C20/25 or unless otherwise specified.

b) The joint shall be grouted with cement mortar (1:3) and weep holes shall be provided as shown on the Drawing or as directed by the S.O.

c) The S.O. shall have access to the casting yards where the proprietary precast concrete product are being utilized. A copy of the manufacturer's test certificate shall be provided to the S.O.

d) All inspections shall be conducted in the present of the S.O. and any rectification works shall be carried out any accordance to the method as approved by the S.O.

iii) Cascade Drains

a) Cascade drains shall be constructed from precast concrete drain units and laid stepping on a 150mm thick bed of mass concrete of concrete strength class C20/25 or as shown on the Drawings or as approved by the S.O.

5. Subsoil Drain

5.1. This work shall include supply and installation of subsoil drains, constructed in accordance with these Specifications at locations and in accordance with the lines, levels and grades as shown on the Drawing and/or to suit the site as approved by the S.O.

5.2. Minimum gradient of 1:200 shall be provided for the drain to discharge into existing stormwater system, open drain, creek or pond in the area unless otherwise stated on the Drawings. The discharge shall not create an unwanted bog.

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5.3. Unless otherwise shown on the Drawings, lateral drains shall have a minimum slope of 1: 200 to ensure water always flowing even though there are undulations and laid at minimum 2m spacing at 45° to the main pipes/ collector drain.

5.4. The pipes for subsoil drains shall be made up preferably of the materials/ system as stated below or as approved by the S.O.:

i) Perforated Corrugated Double Wall HDPE pipe

ii) Porous concrete pipes comply to MS 525

iii) Proprietary System

All proposed materials shall be approved by the S.O.

5.5. Filter Material

5.5.1. Filter material shall consist of hard, clean, sand conforming to the grading limits given in Table S5. The material passing the 425µm sieve shall be non-plastic when tested in accordance with BS 1377.

5.5.2. Geotextile shall be of non-woven type thermally bonded as approved by the S.O. Trenches shall be lined with geotextile filter fabric as shown on the Standard Drawings, or otherwise approved by the S.O. Where fabric requires jointing, it shall be stitched and overlapped with a minimum of 500 mm at transverse joints and the full trench width at the top shall be provided. Subsoil drains shall be laid, bedded and jointed as detailed on the Drawings.

6. Sumps

6.1. Sumps shall be constructed as accordance to the Drawing or as directed by the S.O. to facilitate changes in level and flow within a drainage system. All sumps shall be covered either by concrete slab or galvanized steel grating hinged to the seating frame on the sumps for safety purposes.

6.2. Unless otherwise as shown on the Drawings, sumps of depth less than 1.5m (internal depth) shall be made up of brickwalls of minimum 225mm thickness. Sump of depth (internal depth) more than 1.5m shall use reinforced concrete strength class C20/25 or otherwise specified on the Drawings.

6.3. The invert levels of pipe/ drain to the sump inlet as shown on the Drawing(s).

7. Piling Works

7.1. Wherever applicable, all piling works shall comply with the requirements as specified in SECTION C: FOUNDATION WORKS AND WORKS BELOW LOWEST FLOOR LEVEL.

8. Culverts

8.1. The work shall comprise of supply and installation of either reinforced concrete pipe culverts or precast box culverts, including the end treatment components such as

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headwall, wingwalls, aprons and sumps and channel protection works, all in accordance with these Specifications and details as shown on the Drawings.

8.2. Culvert Bedding

8.2.1. Type A bedding material shall consist of concrete strength class C20/25, complying with SECTION D: CONCRETING unless otherwise stated on the Drawings.

8.2.2. Type B bedding shall consist of clean, natural sand or gravelly sand of suitable gradation and quality with maximum particle size of not more than 20mm.

8.3. Culvert Components

8.3.1. Culvert shall be constructed with barrel and end treatments including headwalls, endwalls, wingwalls, outlet protection, inlet improvement and debris control structures.

8.4. In each culvert, the following markings shall be clearly shown:

i) Size

ii) Date of manufacture

iii) Name and trademark of the manufacturer

8.5. Pipe Culverts

8.5.1. Reinforced concrete pipes shall conform to the requirement of *MS EN 1916* and shall be approved by the S.O.

8.5.2. Minimum cover to concrete pipe culvert shall be 600mm to avoid undesirable load action. Where the minimum cover cannot be achieved, the concrete pipe shall be surrounded in concrete.

8.5.3. Installation of Pipe Culverts

8.5.3.1. Culverts shall not be installed at any location until the type of pipe, the exact location, the lines, levels and grades, the length of pipe and details of inlet and outlet structures have been confirmed and approved by the S.O.

8.5.3.2. Special requirements recommended by the manufacturer with respect to assembly and installation shall be complied. Where elliptically reinforced pipe sections are used, care shall be taken to ensure that the loading axes are positioned exactly vertically.

8.6. Precast Box Culverts

8.6.1. Precast box culverts shall conform to the requirement of *MS 1293-1* and shall be approved by the S.O.

8.6.2. Unless otherwise shown on the Drawings, the precast box culvert shall be capable of withstanding a proof load test of 112.5kN applied over an area of 320mm x 320mm at any position on the cover slab.

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8.6.3. Precast box culverts shall be laid on Type B bedding with layer of crushed aggregate of maximum particle size not exceeding 50mm as shown on the Drawings or directed by the S.O.

8.6.4. The maximum gap between each culvert shall not be more than 13mm and the difference in level shall less than 3mm. The gap shall be filled with cement mortar (1:3) with smooth finished.

8.6.5. To ensure uniform bearing, a layer of cement grout shall be spread along the top of the walls of the invert where the lid shall sit.

8.7. The S.O. reserves the right to request for test certificates and further tests to be carried out on samples, all at the Contractor's expenses.

8.8. An individual section of culvert shall be rejected due to any of the following:

i) Fractures or cracks passing through the wall, except for a single end crack that does not exceed the depth of the joint.
ii) Defects that indicate imperfect proportioning, mixing and moulding.

iii) Surface defects indicating honeycombed or open texture.

iv) Damaged ends where such damage would prevent making a satisfactory joint.

8.9. All culverts damaged during laying, handling, transporting, or any other time shall be replaced, all at the Contractor’s expenses. Rejected culverts shall be marked and removed from the site.

8.10. Extension of Existing Culverts

8.10.1. Existing structures

8.10.1.1. The existing wing walls, aprons and concrete bedding shall be demolished wherever indicated on the Drawings to expose the existing culvert on the side(s) to be extended. The end of the existing culvert to be extended shall then be wire-brushed or some other means to give a clean end.

8.10.2. Extension joints

8.10.2.1. Extension joints shall be formed as shown on the drawings and such material to be of a type approved by the S.O. and in accordance with the manufacturer’s specification or otherwise specified on the Drawing.

9. On-Site Detention

9.1. On-site detention (OSD) facilities shall be constructed in accordance with the Drawings and conform to the relevant authorities requirements.

9.2. The construction of OSD facilities shall include the system components at the inlet, storage and outlet zone to cater outflow discharges without causing adverse effects on downstream properties. Fencing and warning signs shall be provided as shown on the Drawings.

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9.3. Maintenance shall be done periodically or as and when the silt has accumulated to 0.3m thick. The desilted material shall be transported to disposal site approved by S.O.

10. Stormwater Pumping

10.1. Wherever applicable, all works involving stormwater pumping shall comply with the requirements as specified in Mechanical and Electrical works specification.

11. Bio-Ecological Drainage System (BIOECODS)

11.1. All BIOECODS works shall comply with the requirements as specified in Bio-Ecological Drainage System (BIOECODS) Specification (JKR 20601-0266-21).

11.1.1. The work shall include the supply and installation of the ecological drainage system in accordance with project specifications and Drawings, or as directed by the S.O.

11.1.2. Unless otherwise shown on the Drawings, drain reserves for ecological drainage system shall be at least 5 meters from the side of the road pavement.

11.1.3. Materials

11.1.3.1. All Subsurface ecological drainage products used shall comply with the specifications and requirements of the manufacturer.

i) The material shall be resistant to chemical and bacterial attack.

ii) Unless otherwise shown on the Drawings, all soil and subsurface product interface shall have a layer of geotextile to prevent fine particles from entering the drainage system.

iii) If damage occurs to one of the geotextile fabric during installation, repairs shall be carried out by placing new material over the damaged area by allowing 300 mm excess on all sides and then fixing with silicon adhesive.

11.1.4. Filter Materials

11.1.4.1. Filter material shall be of hard and clean river sand normally used in construction of subsoil drains to give better infiltration rates.

11.1.4.2. The material passing the 0.425 mm sieve shall be non-plastic when tested in accordance with BS 1377.

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12. Types of Lining

12.1. Stone Pitching

12.1.1. Construction

12.1.1.1. This work shall consist of the construction of all structures or part of structures to be composed of stone pitching either grouted or ungrouted as shown on the Drawings or as directed by the S.O. including erosion protection pavements and aprons, drain linings, culvert inlets and outlets, etc.

12.1.1.2. The work shall be carried out to the lines, levels, grades, dimensions and cross-sections shown on the Drawings and as approved by the S.O.

12.1.2. Stone

12.1.2.1. Stone shall be clean roughly quarry stone, or pit or river cobbles, or a mixture of any of these materials, and shall be essentially free from dust, clay, vegetative matter and other deleterious materials.

12.1.2.2. Unless otherwise specified, individual pieces of stone shall be approximately cubical or spherical and shall have a minimum dimension of 100mm and a maximum dimension of 250mm. The stone shall be hard, tough, durable and dense. They shall be resistant to the action of air and water, and suitable in all respects for the purpose intended.

12.1.3. Grouted Stone Pitching

12.1.3.1. Prior to construction grouted stone pitching, the surfaces against which it is to be placed shall have been finished to the satisfaction of the S.O. Notwithstanding any earlier approval of these finished surfaces, any damage to or deterioration of them shall be made good to the satisfaction of the S.O. before grouted stone pitching is placed.

12.1.3.2. Construction of grouted stone pitching shall commence at the lowest part of each structure or section of a structure and continue progressively upward. Long structures such as drain linings and slope protection pavements shall be constructed in sections of practicable lengths, to the approval of the S.O.

12.1.3.3. Stones shall then be firmly set by hand into the mortar, densely packed against adjacent stones and built up to form a stone structure of more or less uniform thickness which shall nowhere be less than 150 mm (measured perpendicularly to the surface covered).

12.1.3.4. All voids in the structure shall be packed solidly with mortar and stone spalls; however, the surfaces of stones in the exposed faces and edges shall not be covered with mortar.

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12.1.3.5. The exposed surfaces and edges of the structure shall be constructed such that they have as large a proportion as practicable composed of stone faces. Weep holes shall be provided as shown on the Drawings or as directed by the S.O.

12.1.3.6. Mortar which has been mixed for more than 45 minutes shall not be used in the works. The work shall be carried out and finished all to the approval of the S.O.

12.1.4. Ungrouted Stone Pitching

12.1.4.1. Where shown on the Drawings, ungrouted stone pitching shall be hand set to provide maximum interlocking effect. The stones, the largest of which shall be used at the bottom, shall be well bedded on a 75 mm layer of gravel or aggregate rammed to an even surface. The whole work shall be finished to the approval of the S.O.

13. Brickwork

13.1. The bricks shall comply with the requirements of MS 76 and as specified in SECTION E: WALL SYSTEM of this specification. All bricks shall be clean, sound, hard, well burnt, proper size and shall give a clear ring when struck. Bricks shall be obtained from manufacturers approved by the S.O.

13.2. Brick Laying

13.2.1. Brickwork shall be executed with cement mortar and shall be of the thickness and bonds as shown on the Drawings. Bricks shall be kept damp until used and shall be laid on a full bed of mortar.

13.2.2. The brickwork shall be true to line and plumb, and courses shall be kept truly level. The thickness of mortar joints shall not exceed 10 mm and shall be such that 4 courses of brickwork forms a height of 300 mm.

13.2.3. Any brickwork that is damaged shall be taken down and rebuilt and the joints raked out and pointed as directed by the S.O. Any such remedial work shall be at the Contractor's expenses.

13.3. Plastering Works

13.3.1. All exposed brickwork surfaces shall be plastered. The plaster shall be applied in 2 coats generally to a total thickness of 20 mm and shall be finished with a steel trowel for internal surfaces and with a wooden float for external surfaces.

13.3.2. Application of plain plaster shall comply with MS 794

13.3.3. Weep holes shall be provided as shown on the Drawing(s) or as approved by the S.O.

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Table S1. Grading Limits for Sand Backfill

B.S. Sieve Size	% Passing by Weight
10.0mm 5.0mm 1.18mm 300 µm 150 µm	100 90 - 100 45 - 80 10 - 30 2 - 10

Table S2. Grading Limit for Granular Backfill other than Sand

B.S Sieve Size	% Passing by Weight		
	A	B	C
37.5mm 28.0mm 20.0mm 10.0mm 5.0mm 2.0mm 425 µm 75 µm	100 70 -100 60 - 90 45 - 75 30 - 60 20 - 50 10 - 30 0 - 2	- 100 70 - 100 45 - 75 35 - 65 25 - 50 10 - 30 0 - 2	- - 100 - 45 - 75 30 - 60 15 - 35 0 - 2

Table S3. Maximum Depths of Open Drain

Cover/Handrail Fence Condition	Maximum Depth (m)
Without protective covering	0.6
With solid or grated cover	1.2

Table S4. Maximum Steepness of the Side Slopes

Drain lining	Maximum steepness of the maximum side slopes (V:H)
Concrete, brickwork and blockwork	Vertical
Stone Pitching	1:1.5
Grassed/Vegetated, rock riprap	1:2

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Table S5. Filter Material

B.S. Sieve Size	% Passing By Weight
10.0mm	100
5.0mm	90 - 100
2.36mm	75 - 100
1.18mm	55 - 90
600µm	35 - 59
300µm	8 - 30
150µm	0 - 10

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