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KEMENTERIAN KERJA RAYA



STANDARD SPECIFICATIONS FOR BUILDING WORKS 2020

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This Standard Specifications for Building Works 2020 was managed and developed by the Jabatan Kerja Raya Malaysia with the assistance of the Main Committee of Standard Specifications for Building Works 2020, which comprises representatives from the following departments:

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Cawangan Dasar Dan Pengurusan Korporat (CDPK)

PREFACE

This Standard Specifications for Building Works 2020 was prepared by the Jabatan Kerja Raya (JKR) Malaysia to replace the Standard Specifications for Building Works 2014. The Standard was first compiled in the 2005 Edition.

This Standard serves to establish uniformity and base specifications for materials and workmanship required for building works particularly in conventional tender procurement for JKR projects. It also sets out the level of technical performance and characteristics required to promote an adequate, safe and well-maintained building so as to effectively contribute to the development of the country.

The content of the Standard has incorporated updates and revisions to the previous edition. It has a significant impact on the construction industry as it features current technology development, updating of the international and national standards and revised specifications to be in line with the Government policies.

This Standard Specifications for Building Works 2020 is divided into 25 Sections. Appendix A/1 of Section A : Preliminaries And General Conditions, make reference to the relevant Acts, Regulations and Guidelines et cetera. Compliance with this Standard does not of itself confer immunity from legal obligations.

This Standard may be adopted in whole or in part. Any addition or omission may be effected to suit the requirement of the particular project.

The Committee of Standard Specification for Building Works 2020 was establised in the JKR to coordinate standard specification related to building works in the JKR. The Standard Specifications will be periodically reviewed, updated and new editions issued to cater the current standards and regulations as well as the dynamic technological developments in the construction industry. Between editions, amendments may be issued. It is therefore important that users assure themselves that they are referring to the current Standard.

ACKNOWLEDGEMENT

Jabatan Kerja Raya Malaysia would like to extend our sincere appreciation to all those involved in the development of this standard.

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ABBREVIATIONS

B.Q.	-	Bills of Quantities
CePSWaM	-	Certified Environmental Professional in Scheduled Waste Management
CESSWI	-	Certified Erosion, Sediment and Storm Water Inspector
CIAST	-	Pusat Latihan Pengajar dan Kemahiran Lanjutan
CIDB	-	Construction Industry Development Board
CISEC	-	Certified Inspector of Sediment and Erosion Control
CoW	-	Clerk of Works
DGFR	-	Director General of Fire and Rescue
DOE	-	Department of Environment
DOSH	-	Department of Occupational Safety and Health
EIA	-	Environmental Impact Assessment
EMP	-	Environmental Management Plan
EPD	-	Environmental Protection Department
JKR	-	Jabatan Kerja Raya
MOH	-	Ministry of Health
MSMA	-	Manual Saliran Mesra Alam
MTIB	-	Malaysian Timber Industry Board
NREB	-	Natural Resources and Environment Board
PDRM	-	Polis Diraja Malaysia
P.E.	-	Professional Engineer
R.O.W.	-	Right of Way
S.O.	-	Superintending Officer
S.P.	-	System Provider
SIRIM	-	Standards and Industrial Research Institute of Malaysia
SPAN	-	Suruhanjaya Perkhidmatan Air Negara

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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 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 Domestic waste	• *Solid Waste and Public Cleansing Management Act 2007* • *Solid Waste and Public Cleansing Management (Scheme for Construction Solid Waste) Regulations 2018*

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 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) format to be stored in compact discs or removable storage.

45.1.3. Four (4) sets of Digital Copies in Acrobat (.pdf) 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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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

Trial excavation shall be carried out using the machineries as specified in sub-sections 7.2.5. and 7.2.6. to confirm the materials excavated is categorized under common excavation/ hard mass excavation based on its hourly production rate. The trial excavation shall be carried out on a flat platform as define in sub-section 8.3. in order to develop the rated horsepower at maximum efficiency.

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 shall propose machineries to be used at site for the confirmation purpose subjected to approval by the S.O.. The equivalent production rate of the machineries are shown in **Table B1 & B2** for evaluation purposes.

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. Minimum ten (10) samples from the excavated material resulted from trial excavation as in direct method (i) above 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 equipment shall be calibrated and a valid calibration certificate shall made available to the S.O. upon requested.

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)
150	15.4	99	0.33
200	21.2	170	0.58
250	27	188	0.63
300	31	242	0.67
350	36	271	0.75
400	41.4	321	1.0

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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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 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. Safety Precautions

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

5.2.10. 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.

5.2.11. 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..

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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 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. Damage to Piles

5.3.4.1. The Contractor shall execute the work in such a manner so as to

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minimise damage to piles.

5.3.4.2. 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.

5.3.5. Installation of Precast Reinforced Concrete Piles

5.3.5.1. 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.

5.3.5.2. 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 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

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final set of a pile other than as friction pile, shall be recorded as the penetration in millimetres per 10 blows. The 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.

5.3.5.3. 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

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be replaced with concrete of similar grade or higher.

(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.

5.3.5.4. 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.

5.3.5.5. 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 4.3.5.7. 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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5.3.5.6. Pile Bending Strength Test

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

5.3.5.7. 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 4.3.5.1. and 4.3.5.2.. Piles shall not be installed until the concrete has achieved the specified characteristic strength.

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 shall bear over their complete areas. Shims for packing shall not be accepted. For laterally loaded pile, the pile joint shall be in

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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.

(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,

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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 4.3.5.1. and 4.3.5.2..

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

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(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 5.5.2.3..

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 4.3.5.1. and 4.3.5.2..

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 4.5.3.2..

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 M.S.26.

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 12390 and BS EN 196.

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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

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by S.O..

(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^{o}, 180^{o} and 360^{o} 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

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stabilized by grouting or similar methods. No further excavation will be permitted to proceed until the stabilization 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

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discharging water into the public drainage system.

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

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Construction of Large Diameter Boreholes for Piling and Other Purposes.

(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 *M.S. 26*.

(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

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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 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.

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(viii) Thickness and details of concrete lining.

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

(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

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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.

(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

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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 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.

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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 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:

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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.

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

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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.

(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.

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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-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.

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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.

(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

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(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 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 120 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.

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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 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

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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 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

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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

(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.

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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 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

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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..

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.

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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 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 6.1.4.2..

(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

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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.

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..

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

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	$3\ \sigma_a$	$3\ \sigma_a$	$3\ \sigma_a$

*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

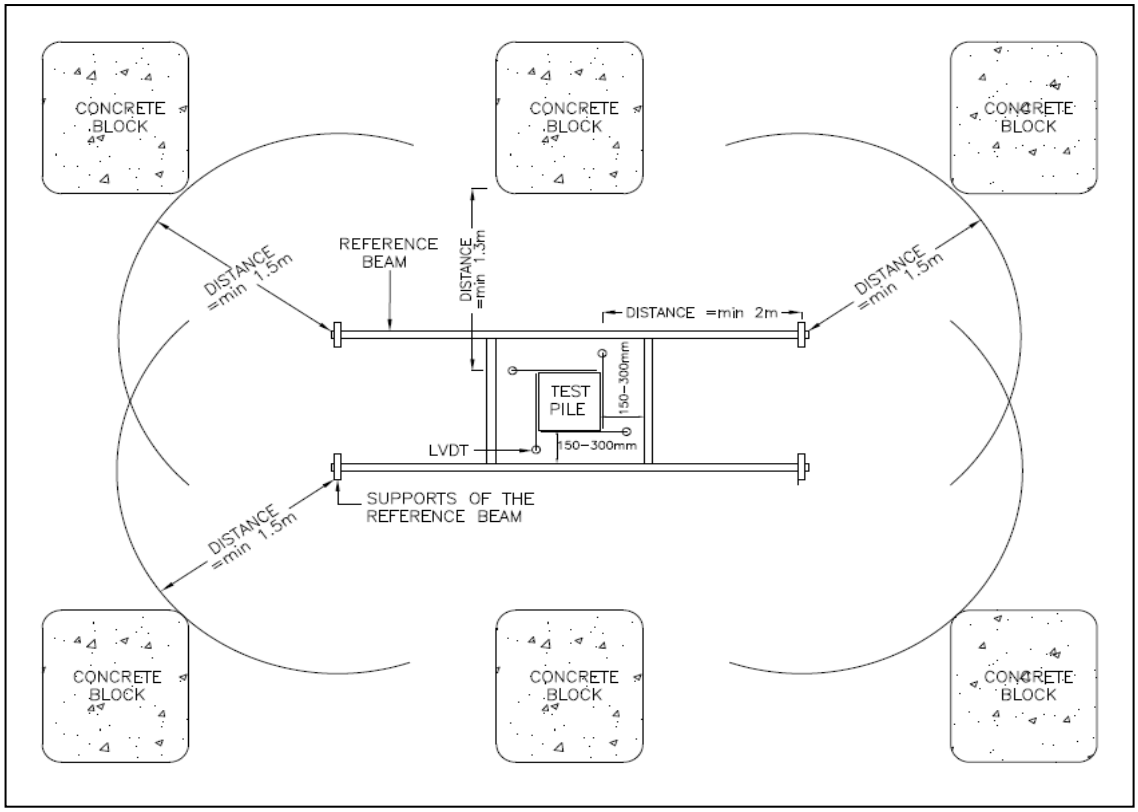
Property	**Units**	**Stages**			**Test Equipment**
		Fresh	**Ready for re-use**	**Before concreting**	
Density	g/ml	< 1.10	< 1.25	< 1.15	Mud balance
Marsh viscosity (946 ml)	sec	32 to 50	32 to 60	32 to 50	Marsh funnel
Fluid loss (30 min)	ml	< 30	< 50	NA	Filter press
pH		7 to 11	7 to 12	NA	pH meter
Sand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

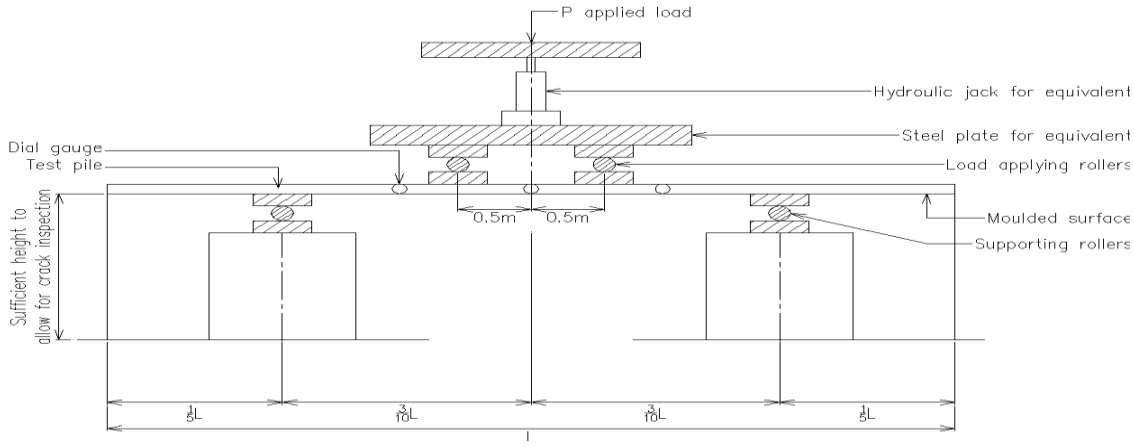


Figure 1- Loading Method

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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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, prescribed 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 D9, Table D10, Table D11** and **Table D12**. Durability recommendation for buildings is specified in **Table D9** and **Table D10**.

1.1.1.2. Designed concrete may be produced at a certified concrete plant or a non-certified concrete plant.

(i) A certified concrete plant is certified by an agency that is accredited by Department of Standards Malaysia or certification body complying with *MS ISO/IEC 17065*.

(ii) A non-certified concrete plant is not certified by an agency that is accredited by Department of Standards Malaysia or certification body complying with *MS ISO/IEC 17065* due to its temporary set up based on the nature of the site.

1.1.1.3. The Contractor shall comply with the following requirements:

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

(ii) Submit a designed concrete report covering all concrete mixes to the S.O. for approval. The designed concrete shall comply with the requirements specified in **Table D9, Table D10, Table D11** and **Table D12** as stated in the drawings.

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

1.1.1.4. When other than CEM I cement is specified to be used, the concrete mix shall be of designed concrete only.

1.1.2. Prescribed Concrete

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

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MS 523-3. Prescribed concrete shall be as detailed in **Table D7** and **Table D8**. The result in **Table D7** and **Table D8** is achieved without the use of admixture.

1.1.2.2. Prescribed concrete is not allowed for all structural works except for remote sites prior approval of the S.O.. A site is considered remote when the journey from the source of the concrete supply is having difficult access by land.

1.1.2.3. Prescribed concrete shall only be produced at site as stated in sub-section 1.2.4..

1.1.2.4. Only CEM 1 cement is specified to be used for prescribed concrete.

1.1.3. Proprietary Concrete

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

1.1.3.2. Where proprietary concrete is specified, the constituent material and requirement of concrete shall comply with Item 2.

1.1.3.3. The Contractor shall provide the information of the proprietary concrete to the approval of the S.O. as follows:

(i) Name of supplier and proprietary concrete.

(ii) The type and standard strength class.

(iii) Product warranty.

(iv) Any other identification deemed necessary.

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

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

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

1.1.3.5. The Contractor shall verify the performance of the proprietary concrete after completion of works as follows:

(i) Product warranty.

(ii) Testing result of product.

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(iii) Non-Destructive Test such as Ultrasonic Pulse Velocity (UPV) or Windsor Probe as when instructed by the S.O..

(iv) Any other verification deemed necessary by the S.O..

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 comprises all measures necessary to maintain the properties of concrete in conformity to 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.

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

1.2.2. Production Control System

Production Control System shall contain adequately documented procedures and instructions. These procedures and instructions shall, where relevant, be established in respect of the control requirement as given in the **Table D21, Table D22, Table D23** and **Table D31**.

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 is batched, either dry or wet. Wet batching is the primary mixing of the concrete is performed in a plant mixer, and the secondary mixing is done in the truck mixer before the concrete is discharged from the truck mixer. Dry batching is the primary mixing and secondary mixing of the concrete is performed in a truck mixer before the concrete is discharged from the truck mixer. No extra water or admixtures are allowing to be added after the concrete left 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

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and dosage of chemical admixtures and other relevant production details such as, but not limited to, details listed in **Table D31** in suitable format. If the Contractor fail 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 a requirement as 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. Prescribed Concrete

1.2.4.1. The quantities of cement, fine aggregate and various sizes of coarse aggregate shall be measured by weight unless otherwise approved by the S.O.. A separate weighing machine shall be provided for weighing the cement. Alternatively, the cement may be measured by using a whole number of bags in each batch. The quantity of water shall be measured by volume or by weight. Any solid admixtures to be added shall be measured by weight, liquid or paste admixtures shall be measured by volume or weight.

1.2.4.2. The batch weight of aggregate shall be adjusted to allow for the moisture content of the aggregate being used. All measuring equipment shall be calibrated on site or their calibration status established by certificates from accredited laboratories.

1.2.4.3. The mixing time shall be not less than two minutes and not more than five minutes or any other time recommended by the concrete supplier after all the ingredients have been placed in the mixer.

1.2.4.4. The mixer shall be thoroughly cleaned before any fresh concrete is mixed.

1.2.4.5. The water content of each batch of concrete may be adjusted so as to produce concrete of the workability required. However, care shall be taken to ensure the free water - cement ratio is maintained. The total amount of water added to the mix shall be recorded.

1.2.5. Proprietary Concrete

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

1.2.5.2. 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.

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1.2.5.3. 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 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 a requirement as in sub-section 1.1.3. before discharging the concrete

2. Material

2.1. Cement

2.1.1. The cement to be used throughout the Work shall be cement obtained from SIRIM-certified manufacturer. 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, damage to 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 as 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.

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2.2.2. Coarse Aggregates

Coarse aggregates shall comply with *MS EN 12620* and tests shall be carried out according to *MS 30*. For work below ground level, only crushed granite shall be used. unless otherwise specified in the Drawings. The property limits shall be as specified in **Table D3**. 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' is used to means 'fine aggregate'. Unless otherwise specified in the Drawings, tests shall be carried out in accordance with *MS 30*. The property limits shall be 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 30* 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 30* and shall be within the limits specified in **Table D5**. However, for prescribed concrete Grading Limit M shall only be used.

2.2.5. Sampling and Testing of Aggregates

Where site mixing is used, 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

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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. No admixtures to be allowed for use in prescribed concrete.

2.4.2. The admixtures, the sampling and testing of the admixtures and the information to be provided with the admixture supplied shall comply with *MS EN 934* and requirements specified in **Table D6**.

2.4.3. All admixtures shall be used strictly in accordance to manufacturer's recommendation.

2.4.4. 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). Prescribed concrete shall be designated as YP where a suffix P shall be added after its minimum characteristic cube strength (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 D9, Table D10** and **Table D11**, 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 D13**)

(ii) Compacting classes (Refer **Table D14**)

(iii) Vebe classes (Refer **Table D15**)

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(iv) Flow classes (Refer **Table D16**)

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 D17**.

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 D18** expressed as a percentage relationship between chloride ions and weight of cement in the mix. The tests shall be carried out in accordance with *BS 1881-124* for each grade of concrete, to demonstrate that these limits are not exceeded.

2.5.5. Maximum Sulphate Content

The total estimated sulphate content of any mix, including that present in the cement shall not exceed 4% by weight of cement in the mix. Where necessary, tests shall be carried out in accordance with *BS 1881-124* for each grade of concrete 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 responsible for the evaluation of conformity of specified requirements of the 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 concrete compressive strength test (cube or cylinder).

3.1.1.3. The designed concrete testing flow chart can refer in **Figure D1**.

3.1.2. Initial Test

3.1.2.1. Initial test is required for designed concrete only and the Contractor shall be responsible for the test.

3.1.2.2. In the case of using a new concrete composition, 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, taking into account of

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the chances in properties of the material and the result of testing.

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±3ºC.

(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 the concrete with the composition to be adopted for the actual case shall exceed the values f_{ck} of **Table D19** or **Table D20**. The margin should be at least 6N/mm2 to 12N/mm2 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 6N/mm^2.

(ii) The consistency of the concrete shall be within the limits of the consistency class as in **Table D17**, at the time at which the concrete likely to be placed or delivered.

(iii) For assessing the properties of concrete, in particular those 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.

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(ii) In the sampling and testing plan and the conformity criteria of concrete compositions distinction is made 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 result are obtained over a period not exceeding 12 months.

(iii) If the production of a concrete composition has been suspended more than 12 months, the criteria, sampling and testing plan given for initial production shall be adopted.

(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 to Item 3.3 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 *MS 26-1-1*. The minimum rate of sampling and testing of concrete shall be in accordance with **Table D21** at the rate that gives the highest number of samples for initial or continuous production.

(ii) The samples shall be taken after any water or admixtures are added 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.

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3.1.3.3. Conformity Criteria for Compressive Strength

(i) Conformity assessment shall be made on test results taken during an assessment period that shall not exceed the last twelve (12) 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 D22** for either initial or continuous production are satisfied

(iv) Initially, the standard deviation (σ) shall be calculated from at least 35 consecutive test results taken over a period exceeding three (3) months and which is immediately prior to the production period during which conformity is to be checked. This value shall be taken as the estimate of the standard deviation (σ) of the population. The validity of the adopted value shall be verified during the subsequent production using Method 1 as stated below. However, Method 2 may be used if approved by the S.O..

a) Method 1

The initial value of standard deviation may be applied for the subsequent period during which conformity is to be checked, provided the standard deviation of the latest 15 results (s_{15}) does not deviate significantly from the adopted standard deviation. This is considered valid provided:

$0.63\sigma \leq s_{15} \leq 1.37\sigma$

Where the value of s_{15} lies outside these limits, a new estimate of σ shall be determined from last available 35 test results.

b) Method 2

The new value of standard deviation (σ) may be estimated from a continuous system and this value is adopted. The sensitivity of the system shall be at least that of Method 1.

3.1.4. Permeability Requirement

For marine structures, a Chloride Diffusion Test shall be carried out according to standard test method for determining the apparent chloride diffusion coefficient of cementitious mixtures by bulk diffusion *(ASTM-C1556-11a)*. The chloride content of a concrete, expressed as the percentage of chloride ions by mass of cement, shall not exceed the value for the selected class given in **Table D18** according to *MS EN 206*.

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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 as that verified as conforming with the characteristic strength via conformity assessment.

3.2.1.2. Identity testing is conducted at the Site upon the 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 D24**.

(ii) A sample is made up of three (3) specimens.

(iii) Samples shall be taken from different batches in accordance with *MS 26-1-1*. 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 D19** and **Table D20**.

(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 exceed 15%, the test result, shall be deemed invalid.

3.2.2.2. Prescribed Concrete

(i) A sample is made up of three (3) specimens.

(ii) Samples shall be taken from different batches in accordance with *MS 26-1-1*. 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*.

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(iii) One (1) specimen from the sample shall be tested for the 7-days compressive strength as given in **Table D23**.

(iv) The remaining two (2) specimens shall be tested for 28-days. The compressive strength of the specimens shall be obtained from the average of the results of the two specimens.

(v) For 28-days compressive strength test, if the difference between the two (2) test result divided by their mean exceed 20%, 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 D25**.

(ii) Concrete is deemed to come from a conforming population if both the criteria in **Table D25** 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 D26** are satisfied for n results derived from strength tests on samples taken from the defined volume of concrete.

3.2.3.3. Prescribed concrete

(i) A sample is made up of three (3) specimens.

(ii) One (1) specimen from each sample shall be tested for 7-days cube compressive strength. The test result shall not fall below the corresponding values given in **Table D23**.

(iii) The remaining two (2) specimens from the sample shall be tested for the 28-days cube compressive strength. The strength requirement shall be considered complied if <u>at least one</u> of the following conditions is satisfied with:

a) None of the two test cubes is below the specified compressive strength as specified in **Table D23**.

b) The average strength of the two test cubes is not less than the specified compressive strength.

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3.2.4. Identity Testing for Slump and Flow

3.2.4.1. Sampling and Testing

(i) Sampling fresh concrete using a spot sample 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 estimated required for the tests in accordance to *MS 26-1-1*.

(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 to *MS 26-1-2* and shown in **Figure D2**.

(iv) For flow test, the maximum dimension of the concrete spread shall be measured in the two direction as shown in **Figure D3**. The flow value (f) is the average dimension of the two direction in accordance to *MS 26-1-5*.

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 D27** or is within the tolerance specified in **Table D28**, the identity test confirms 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 D29** or is within the tolerance specified in **Table D30**, the identity test confirms 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 that was not obvious 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 items above.

3.3.2. In the event that the compressive strength results of the test do not meet

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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 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 make the work secure.

3.3.2.3. The S.O. may instruct the additional tests 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 fail the test shall be removed; or

(ii) The Contractor shall submit the recommendations for repair and strengthening the suspected concrete. All the recommendations shall certify by a Professional Engineer.

3.3.3. All works instructed under this item 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 and maintain 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

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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 of adding the cement to the dry aggregates and within 45 minutes (or any other period of time based on the initial test as sub-section 2.4. and sub-section 3.1.2. and approved by the S.O. if an admixture is used) of adding water to the cement and aggregate. 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 contained in it shall be clean and free from standing water immediately before the 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 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. Except where otherwise approved by the S.O., concrete shall be deposited in horizontal layers to a compacted depth not exceeding 450mm when internal vibrators are used or 300mm in all other cases. The surface of the concrete shall be maintained reasonably level during placing.

4.3.1.5. Concrete shall not be dropped into place from a height exceeding 1.5m. However, higher drops 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.

4.3.2. 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 20mm aggregates, the Tremie pipe shall be of a diameter not less than 150mm 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 70^0C.

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 100mm 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 100mm. 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 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 100mm 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 75mm 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 must 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.

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4.5.7. Concrete shall not be subjected to any disturbance within 24 hours after 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 five (5) days for F1, F2, F3 and F4 surfaces, but not less than three (3) days for F11, F12, F13, F14 and F15 surfaces.

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.

4.6.2.3. Leaching out by rain and flowing water.

4.6.2.4. High internal thermal gradients.

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. Curing and protection shall be accomplished by covering the exposed concrete surface with an impermeable material such as polyethylene sheet, which should be well sealed and fastened and if required, this treatment can be continued efficiently throughout the whole period of curing.

4.6.3.3. When the concrete has attained its final set, one of the following curing methods shall be adopted:

(i) Water curing shall be accomplished by keeping the surface of the concrete continuously wet by ponding with water.

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(ii) Curing may be accomplished by sealing in the water as specified above by covering with an approved waterproofed curing paper or plastic sheeting laid with airtight joints. It must be securely positioned to prevent displacement by wind and protected from tearing or other injury.

4.6.3.4. 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 a method statement to the approval of the S.O..

4.6.3.5. 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

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shall be level and flat unless design considerations make this undesirable. Joint lines shall be so arranged that they coincide with features of the finished work, wherever possible.

5.1.3. At horizontal construction joints, gauge strips about 25mm 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 75mm 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 so as 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 items 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.

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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.

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 so as 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 0.7mm thick aluminium cover strips fixed with masonry nails at 300mm 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

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manufacturer's recommendation to the approval of the S.O..

5.4.3.3. Water stops shall be securely positioned in the formwork to 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:

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(i) Minimum joint movement capacity of ±10% of joint width at 27.5ºC.

(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 50kg/cm².

(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°C.

(ii) Minimum rupture strength of 105kg/cm².

(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°C.

(ii) Excellent resilient properties.

(iii) Density between 35kg/cm³ and 45kg/cm³.

(iv) Total resistance to common acids, lubricants and detergents.

(v) Total resistance to water infiltration by capillary action.

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(vi) Suitability for up to 70°C.

5.5. Measurement of Concrete Cover

5.5.1. General

The Contractor shall ensure all concrete cover thickness to comply with the requirement during the construction as stated in the drawing. Measurement shall be done after removed of formwork and before plastering works begins.

The nominal cover, C_{nom} shall be specified in the drawing and defined as below:

$C_{nom} = C_{min} + \Delta_{Cdev}$

.: Δ_{Cdev} = 10mm

5.5.2. Tolerance

The allowable tolerance for minimum concrete cover (C_{min}) shall be as follows:

5.5.2.1. ±1mm for cover depths ≤ 40mm.

5.5.2.2. ±2mm, for cover depths > 40mm.

5.5.3. Frequency and Verification of Measurement

5.5.3.1. Definition of Stage

Stage is defined as a group of the elements casted or install in the same day.

5.5.3.2. Definition of Element

Element is defined in two type which are individual element (one type of the element) and group of elements which consist different type of element (column, beam, slab, wall, footing). The S.O. shall determine the total number of the element to be measured.

5.5.3.3. The frequency of the measurement shall be in accordance to the stages and measured as follows:

(i) For single storey building, the measurement shall be conducted after the completion of construction of the building elements.

(ii) For multiple storey building, the measurement shall be conducted progressively after the completion of each floor of the building.

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5.5.3.4. Method of Measurement & Calibration of the Equipment

The measurement of concrete cover shall be done by using Electromagnetic Cover Meter in accordance with *BS 1881-204*. The cover meter must be fully calibrated by an accredited certification body.

5.5.3.5. Measurement Location & Sampling

The location chosen to be measured shall consist of all critical element such as beam, slab, column and wall. The S.O. shall identify all critical elements before measurement is done. The sampling of measurement for the elements shall be as shown in **Table D34**.

5.5.4. Compliance Criteria

5.5.4.1. The compliance criteria shall be based on each stage measured. All measurements are to be tabulated and to determine the numbers of measurements lower than minimum concrete cover (C_{min}) and sample size, x and N respectively.

5.5.4.2. For compliance criteria, **Figure D4** shall be referred. However, the chosen compliance is dependent on the total number of measurements per stage.

For N > 10, the 5^{th} percentile shall be use
N ≤ 10, the 10^{th} percentile shall be use

5.5.5. Non-Compliance of the Product

5.5.5.1. The following actions shall be taken by the Contractor in the event of non-compliance of sub-section 5.5.4.:

(i) Check test results and if invalid, take action to eliminate errors.

(ii) If non-compliance is confirmed, take corrective actions.

(iii) Record actions on the items above.

5.5.5.2. The Contractor shall submit to the S.O. the recommendations for repair corrective works to be done with the approval of the S.O..

5.5.5.3. All works instructed under subsection 5.5.5. shall be at the Contractor's expense and no extension of time shall be granted for such works.

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..

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6.2. Materials

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 25mm 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 D32**.

6.2.5. During the course of the work, any reinforcement found to be not in accordance with the MS or BS may be rejected by the S.O. notwithstanding any previous acceptance on the strength of 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*.

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 in excess of 100ºC may only be carried out with the S.O.'s approval and under his supervision. Except where otherwise indicated in the Drawings, bars shall be bent and measured in accordance with *MS 1438*.

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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..

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 no impair the flow of concrete surrounding the reinforcement bar including the concrete cover.

6.3.4. Supporting and Spacer Blocks

6.3.4.1. The size of supporting and spacer blocks required for ensuring that the reinforcement is correctly positioned shall be not more

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than 50mm x 50mm 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.

6.3.4.2. The nominal size of aggregates used shall be 10mm. The concrete spacers shall be of at least the same strength and material's source as the concrete to be poured. 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. Other types of spacers may be used only with the approval of the S.O..

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 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.

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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 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 carried down sufficiently far to provide the necessary support without overstressing the completed concrete structure.

7.1.1.7. Metal ties may only be used with the prior approval of 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 1.2m 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.

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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.

(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 200kPa.

b) Maximum pore size of less than 0.030mm.

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:

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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 minute 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.

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:

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(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.

(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.

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(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.

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 5mm over a 3m gauge length or have any abrupt irregularities of more than 3mm.

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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.'s 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 1m 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 formwork 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 for the safety of the work.

7.4.2. Formwork shall be removed without such shock or vibration as 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 periods between concreting and the removal of forms are given in **Table D33**. 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 provided always the Contractor provide proof of calculation to the S.O. for approval.

7.4.4. For prestressed in-situ components, temporary supports shall not be removed until the components is stressed to the approval of the S.O..

7.4.5. Where it is intended that forms are to be reused, they shall be cleaned

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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 the 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. Mass and Lean Concrete

Mass and lean concrete shall consist of cement, fine aggregate and coarse aggregate in the nominal ratio by volume of 1:3:6 and 1:4:8 respectively. However, where a denser and more workable concrete can be produced by a variation in the ratio of the fine aggregate to that of coarse aggregate, this ratio may be varied within the limits (1:1½) and (1:3), provided that the volumes of fine and coarse aggregate, each measured separately, shall nevertheless equal the sum of the volumes of fine and coarse aggregate appropriate to the nominal mix. The concrete shall be mixed as described for reinforced concrete.

9. 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*.

10. Apparatus

The Contractor shall provide the following apparatus for use on the Site at all times:

10.1. Concrete slump test apparatus and flow test apparatus complying with *MS 26*. One set of the apparatus shall be provided for each concreting location.

10.2. At least twelve (12) numbers of steel or cast iron moulds for casting 150mm concrete test cubes and six (6) numbers of prismatic specimen 40 x 40mm in cross section and 160mm in length for mortar or grout test moulds in accordance to *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.

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10.3. Three (3) measuring cylinders of 250ml capacity, graduated to measure to the nearest 2.0ml., for determination of silt content (field setting method).

10.4. An approved apparatus for measuring moisture content in fine aggregate.

10.5. One (1) electronic calculator with statistical functions.

10.6. One (1) 300 mm steel rule.

10.7. One (1) set of sieves in compliance with *BS ISO 3310*.

10.8. Scale or balance 25kg maximum capacity and weights.

10.9. Trowel, shovel, spanner and other tools.

10.10. One (1) Electromagnetic Concrete Cover Meter.

11. Precast Concrete Works

11.1. 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)*.

11.2. 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*.

11.3. Assembly Drawing

11.3.1. 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:

11.3.1.1. Layout drawing.

11.3.1.2. Section drawing.

11.3.1.3. Connection details.

11.3.1.4. Element types.

11.3.1.5. General drawing.

11.3.2. Assembly Drawings shall show all necessary details and dimensions to enable assembly of components to proceed.

11.4. Installation

11.4.1. The Contractor shall inform the S.O./P.D. at least one month in advance

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of launching or installation operation and submit the following documents to the S.O. for acceptance:

11.4.1.1. Method statement including launching systems and transportation.

11.4.1.2. Proposal for traffic diversion, if appropriate.

11.4.1.3. Detailed program of launching and installation operation.

11.4.1.4. Installation operation safety program.

11.4.2. 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 in the drawings.

11.4.3. 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 shows in **Table D35**.

11.5. Connection

11.5.1. The Contractor shall be responsible to ensure the connection between components (in situ and precast / precast and precast) are properly installed in accordance to the drawings and method statement.

11.5.2. 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 non-shrinkage during hardening.

11.5.3. The grout shall be a mixture of CEM I cement, water and approved admixture. The water/cement ratio shall be between 0.4 to 0.6 or such other proportion as approved by the S.O./P.D.

11.5.4. 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.

11.5.5. The grout shall be tested in accordance to the following method:

11.5.5.1. Fluidity Test by using Cone Method (*BS EN 445*) or;

11.5.5.2. Fluidity Test by using Grout Spread Method (*BS EN 445*) or;

11.5.5.3. Flowability Test using Flow Cone Method (*ASTM C939*) and;

11.5.5.4. Compressive Strength Test (*BS EN 445*).

11.5.6. Placement

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11.5.6.1. 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 100kN/m² is attained. The high pressure cork shall remain closed and in position for a period of one hour after grouting.

11.5.6.2. 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 D36**.

11.5.6.3. 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 component. It can be poured by hand directly along the joint and swept into the gap with suitable tools.

12. Other Concrete Works

12.1. Foundation

12.1.1. 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.

12.1.2. 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 50mm thick. The required cover of concrete under the reinforcement shall be entirely above the blinding layer.

12.2. Pile Caps

12.2.1. 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.

12.2.2. 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.

12.3. Structural Elements Below Ground Level

12.3.1. 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 D9, Table D10, Table D11**

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and **Table D12** shall be constructed in operations which shall ensure water tightness.

12.3.2. All external or 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.

12.3.3. 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 D5**.

12.3.4. For lift shaft enclosure, all the inner surfaces shall form a continuous flush surface without projection or recesses. Refer to **Figure D5**.

12.3.5. 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 ±30mm. Refer to **Figure D6**.

12.3.6. The structural openings shall be vertically aligned one above the other for the full travel of the lift.

12.3.7. The structural opening shall be accurate to the specified dimensions. Deviations from the specified dimensions shall not exceed +12.5mm, -0mm. Refer to **Figure D7**.

12.4. Floors

12.4.1. 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.

12.4.2. 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.

12.4.3. The reinforced concrete ground floor slab shall not be laid directly onto earth surfaces. A blinding layer of 50mm minimum thick of lean concrete as specified in sub-section 8 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.

12.5. Toilet Floors

12.5.1. 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 water tightness. The Contractor shall ensure that holes and fixings are properly constructed.

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12.5.2. 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 150mm.

12.5.3. Testing for Water Tightness

The toilet floor areas should be ponded with water 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.

12.6. Roofs

12.6.1. 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.

12.6.2. 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.

12.6.3. Unless otherwise specified or shown on the Drawings, waterproofing screed to reinforced concrete flat roof shall consist of a 32mm thick screed reinforced with temperature steel.

12.6.4. 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.

12.6.5. The temperature steel shall consist of a mesh 6mm diameter mild steel bars at 150mm 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 19mm to top bars of the temperature steel shall be maintained.

12.6.6. 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 to a smooth finish.

12.6.7. Unless otherwise specified or shown on the Drawings, joints in the screed shall be allowed and located over the main roof beams and shall be filled with approved bituminous compound as soon as possible.

12.6.8. 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

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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.

12.7. 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.

12.8. 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 as specified in sub-section 6.2. 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	Type of Aggregate	Test Methods	Limits
Grading	Both	MS30	Table D4 and Table D5
Elongation Index	Coarse	MS30	Not exceeding 30%
Flakiness Index	Coarse	MS30	Not exceeding 35%
Water Absorption	Both	MS30	Not exceeding 8%
Clay Lumps	Coarse	MS30	Not exceeding 1% by weight
Clay, Silt and Dust	Fine	MS30	Not exceeding 3% by weight or 8% by vol.
Organic Impurities	Fine	MS30	Not exceeding 0.4%
Aggregate Crushing Value	Coarse	MS30	Not exceeding 40%
Soundness Test	Coarse	MS30	Loss in mass after 5 cycles shall not be more than 12% for sodium sulphate or 18% for magnesium sulphate.
Chloride Content	Both	MS30	Not exceeding 0.06% by weight of chloride ions
Sulphate Content	Both	MS30	Not exceeding 0.44% by weight of SO3

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Table D4. Grading for Coarse Aggregate

Sieve size (BS410)	Percentage by mass passing BS 410 sieve for nominal sizes					
	Graded Aggregates			Single-sized Aggregate		
	40 mm to 5 mm	20 mm to 5 mm	14 mm to 5 mm	40 mm	20 mm	10 mm
50.0 mm	100	-	-	100	-	-
37.5 mm	90 to 100	100	-	85 to 100	100	-
20.0 mm	35 to 70	90 to 100	100	0 to 25	85 to 100	-
14.0 mm	25 to 55	40 to 80	90 to 100	-	0 to 70	100
10.0 mm	10 to 40	30 to 60	50 to 85	0 to 5	0 to 25	85 to 100
5.0 mm	0 to 5	0 to 10	0 to 10	-	0 to 5	0 to 25
2.36 mm	-	-	-	-	-	0 to 5

Table D5. Grading for Fine Aggregate

Sieve size (BS410)	Percentage by mass passing BS 410 sieve			
	Overall Limits	Additional limits for grading		
		C	** M	F
10.0 mm	100	-	-	-
5.0 mm	80 to 100	-	-	-
2.36 mm	60 to 100	60 to 100	65 to 100	80 to 100
1.18 mm	30 to 100	30 to 90	45 to 100	70 to 100
600 µm	15 to 100	15 to 45	25 to 80	55 to 100
300 µm	5 to 70	5 to 40	5 to 48	5 to 70
150 µm	0 to 15*	-	-	-

Notes:

* Increase to 20% for crushed rock fines, except when they are used for heavy-duty floors.
** For prescribed concrete only Grading Limit M is applicable.

Individual sands may comply with the requirements of more than one grading. Alternatively, some sands which satisfy the overall limits but may not fall within any one of the additional limit C, M or F may also be used provided that the supplier can satisfy the S.O that such materials can produce concrete of the required quality.

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Table D6. Admixtures Acceptance Test Requirements

Categories of Admixture	Water Reduction	Stiffening Time Time from completion of mixing to reach a resistance to penetration of:-			Minimum Strength as a percentage of the control mix	Age	Length change, Maximum shrinkage	
		0.5N /mm²	3.5N /mm²	27.5 /mm²	Compressive		% of control	Increase
Type 1: Accelerator	-	More than 1hr.	Within 1hr.and 3hrs. earlier than control mix	At least 1hr. earlier than control mix	125 125 100 100	24 hrs. 3 days 7 days 28 days	135	0.010
Type 2: Retarder	-	At least 1hr.later than control mix	Within 1hr.and 3hrs. later than control mix	Not more than 3hrs. later than control mix	90 90 95	3 days 7 days 28 days	135	0.010
Type 3: Normal water-reducing	At least 5%	Within + 1hr. and - 1hr.of control mix	Within + 1hr. and - 1hr.of control mix	Within + 1hr. and - 1hr.of control mix	110 110 110	3 days 7 days 28 days	135	0.010
Type 4: Accelerating water-reducing	At least 5%	More than 1hr.	Within 1hr.and 3hrs. earlier than control mix	At least 1hr. earlier than control mix	125 125 100 100	24 hrs. 3 days 7 days 28 days	135	0.010
Type 5: Retarding water-reducing	At least 5%	At least 1hr.later than control mix	Within 1hr.and 3hrs. earlier than control mix	Not more than 3hrs. later than control mix	110 110 110	3 days 7 days 28 days	135	0.010

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Table D7. Prescribed Mixes for General Use Per Cubic Meter of Concrete by Weight Batching

Grade of Concrete	28-day Strength of Concrete (N/mm^2)	Nominal Maximum Size of Aggregate 20 (mm)			Max free water: cement ratio
		Workability	Medium	High	
		Consistence	25-75	75-125	
15P	15	CEM I (kg) Total aggregate(kg) *Fine aggregate (%)	280 1800 35-50	310 1750 35 - 50	0.60
20P	20	CEM I (kg) Total aggregate(kg) *Fine aggregate (%)	320 1800 25-40	350 1750 20 - 45	0.55
25P	25	CEM I (kg) Total aggregate(kg) *Fine aggregate (%)	360 1750 25-40	390 1700 30 - 45	0.50
30P	30	CEM I (kg) Total aggregate(kg) *Fine aggregate (%)	400 1700 25-40	430 1650 30 – 45	0.45

Note:
*Fine aggregate is crushed aggregate and is expressed as a percentage by weight to the total weight of the dry aggregate

Table D8. Proportions and Strength Requirements for Prescribed Mixes by Volume Batching

Proportion (Grade)	Slump Limits (mm)	Cubic Meters of Aggregate Per 50 kg of CEM I		Max. Free Water: Cement Ratio	Quantity Of Water (Litres)	Strength of Concrete	
		Fine	Coarse (20mm)			At 7 Days (N/mm^2)	At 28 Days (N/mm^2)
1:1:2(30P)	25 - 50	0.035	0.07	0.45	22.5	20	30
1:1.5:3(25P)	25 - 50	0.05	0.1	0.5	25	17	25
1:2:4(20P)	25 - 50	0.07	0.14	0.55 - 0.6	27.5 - 30	14	20
1:3:6(15P)	25 - 50	0.10	0.20	0.6	30*	11	15

Note:
* or as approved by S.O.

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Table D9. 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 D9. 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 D10. 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 D10. 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 D11. 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)	≥ 40mm	14mm	10mm
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 D12. 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 D13. 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 D14. 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 D15. Vebe Classes

Class	Vebe Time In Seconds
V0	≥31
V1	30 to 21
V2	20 to 11
V3	10 to 6
V4	5 to 3

Table D16. 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

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Table D17. 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 D 18. 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 D19. 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

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Table D20. 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

Table D21. 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

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Table D22. 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 D23. Compressive Strength Requirements for Prescribed Mix

Grades of Concrete	28-day Strength of Concrete N/mm^2	Cube Strength at 7 Days* N/mm^2	Average Cube Strength at 28 Days* N/mm^2
15P	15.0	11	15.0
20P	20.0	14	20.0
25P	25.0	17	25.0
30P	30.0	20	30.0

Note:

* Only for CEM1

Table D24. Sampling Rate for Identity Testing

Type of Structure	Minimum volume per sample	Maximum volume per sample
Prestressed concrete, masts, cantilevers, columns, pile caps	10.0 m^3	50.0 m^3 Or every group of 5 batches
Footing, shear wall and retaining wall, slabs, beams, raft foundation	20.0 m^3	100.0 m^3 Or every group of 10 batches
Mass concrete	50.0 m^3	250.0 m^3 Or every group of 25 batches

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Table D25. 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 D26. 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
3	$> f_{ck} + 4$	$> f_{ck} - 4$

Table D27. 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 10mm or greater than 210mm, it is recommended to only use the test for slump ≥ 10mm and ≤ 210mm.

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Table D28. Identity Criteria for Slump Specified as A Target Value

Dimension in millimetres

Specified target slump	Tolerance			
	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
≤ 40	-10	+10	-20	+20
50 to 90	-20	+20	-30	+30
≥ 100*	-30	+30	-40	+40

Note:
* Due to a lack of sensitivity of the slump test at slump values less than 10mm or greater than 210mm, it is recommended to only use the test for slump ≥ 10mm and ≤ 210mm.

Table D29. Identity Criteria for Flow Specified as a Flow Class

Dimension in millimetres

Specified flow 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
F1*	-	350	-	360
F2	340	420	330	430
F3	410	490	400	500
F4	480	560	470	570
F5	550	630	540	640
F6*	620	-	610	-

Note:
* Due to a lack of sensitivity of the slump test at slump values less than 340mm and less, or greater than 62 mm, it is recommended to only use the test for flow diameter > 340mm and ≤ 620mm.

Table D 30. Identity Criteria for Flow Specified as a Flow Value

Dimension in millimetres

Specified flow 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*
All values	-50	+50	-60	+60

Note:
* As permitted, these conformity criteria for target values of consistence take precedence over the values given in MS EN 206. The measured flow shall not differ from the specified target value by more than the amount shown.

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Table D31. 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 concrate	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 D32. Characteristic Strength of Steel Reinforcement

Type	Nominal Sizes (mm)	Yield Strength, fy (N/mm^2)
Steel Bar (MS 146)	All sizes	500
Steel Fabric (MS 145)	All sizes	500
Steel Wire (MS 144)	Up to and including 12	500
Cold Worked (BS 4461)	All sizes	460

Table D33. 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 D34. Measurement Location and Sampling for Element

Element	Total Number of Element Per Stage (n_T)	No of Element To Be Measured	Surface	No. of Point
Column	<10	2	4 Sides	1 point at every 300mm height
	10≤ n_T ≤50	5		
	>50	5		
Beam	<10	2	2 Sides	3 points (2 point at support and 1 point at mid span)
	10≤ n_T ≤50	5		
	>50	5		
Footing	<10	2	2 Sides	1 point at every side
	10≤ n_T ≤50	5		
	>50	5		
Slab	One (1) point for every ten (10) m^2 (at bottom surface)			
Wall	One (1) point for every five (5) m^2			

Note:
For surface that is contact with the ground, the test shall be done on top of the surface.

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Table D35. Recommended Minimum Concrete Strength for Lifting and Handling

Application	Minimum concrete strength $f_{c,cube}$
Lifting which involves significant impact or high acceleration	$15N/mm^{2*}$
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)	$25N/mm^2$

Notes:
* Dependent on anchor length or as recommended by insert manufacturer or otherwise specified

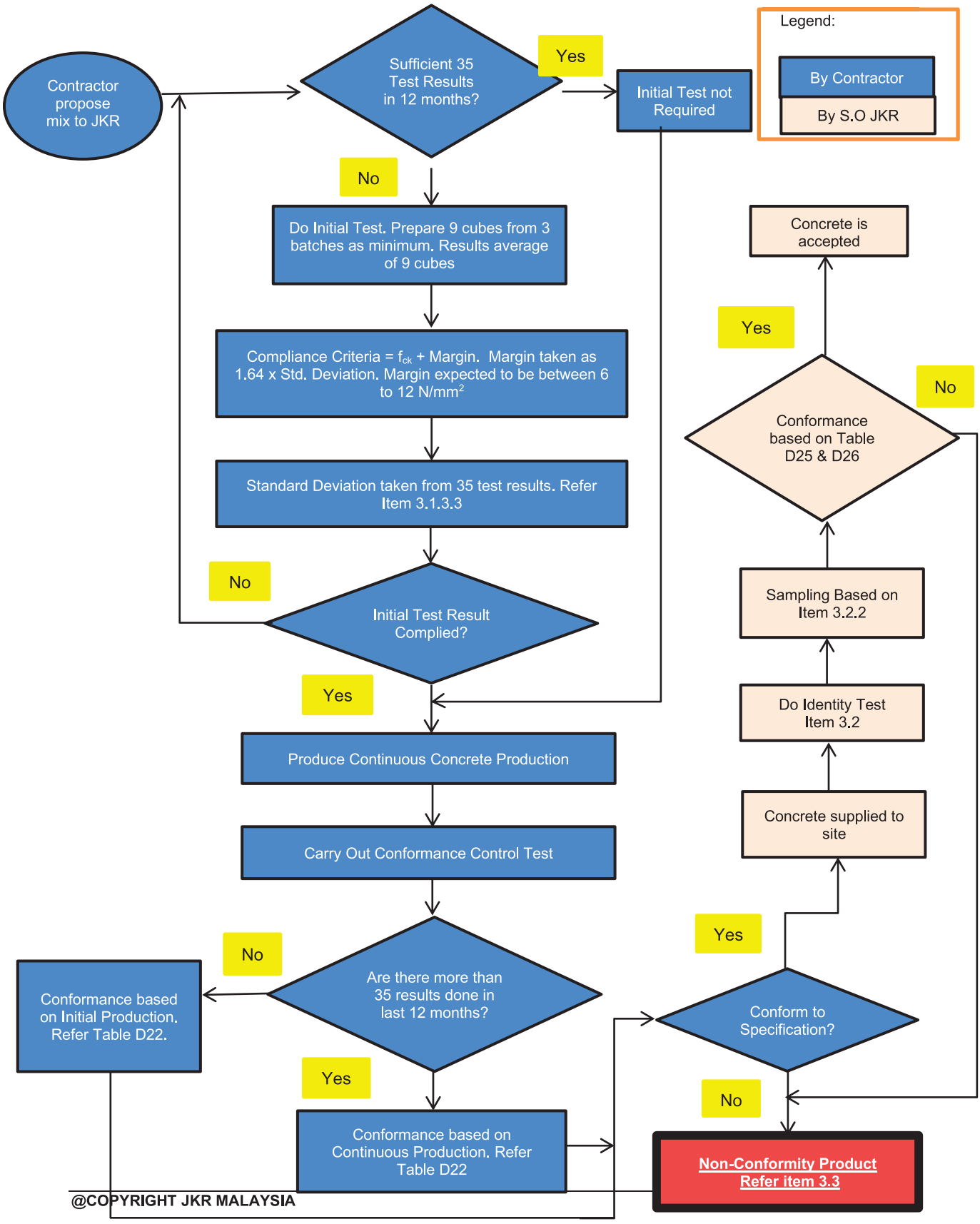
Special care shall be taken with pre-stressed elements to ensure lifting devices are anchored in compression zones, unless covered by specific design

Table D36. 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 D1. Concrete Testing Flow Chart



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Figure D2. Slump Test Measurement

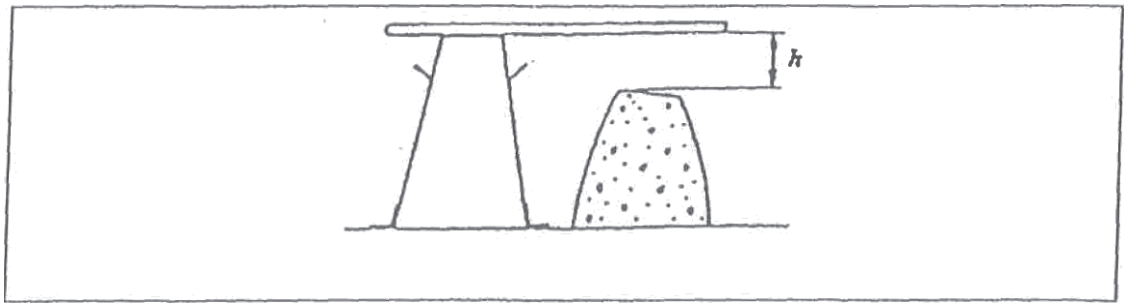
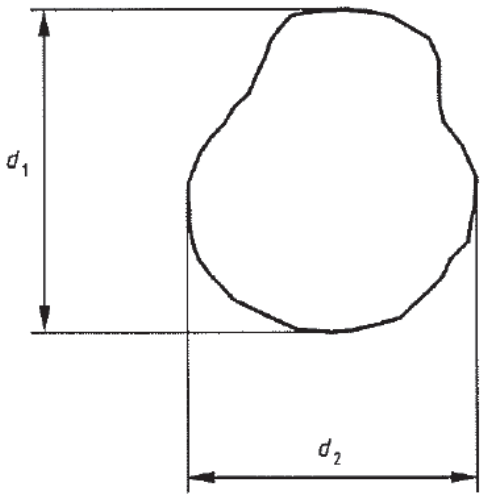


Figure D3. Flow Test measurement



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Figure D4. Qualitative Confirmation-Acceptance Limits for Measurement of Concrete Cover

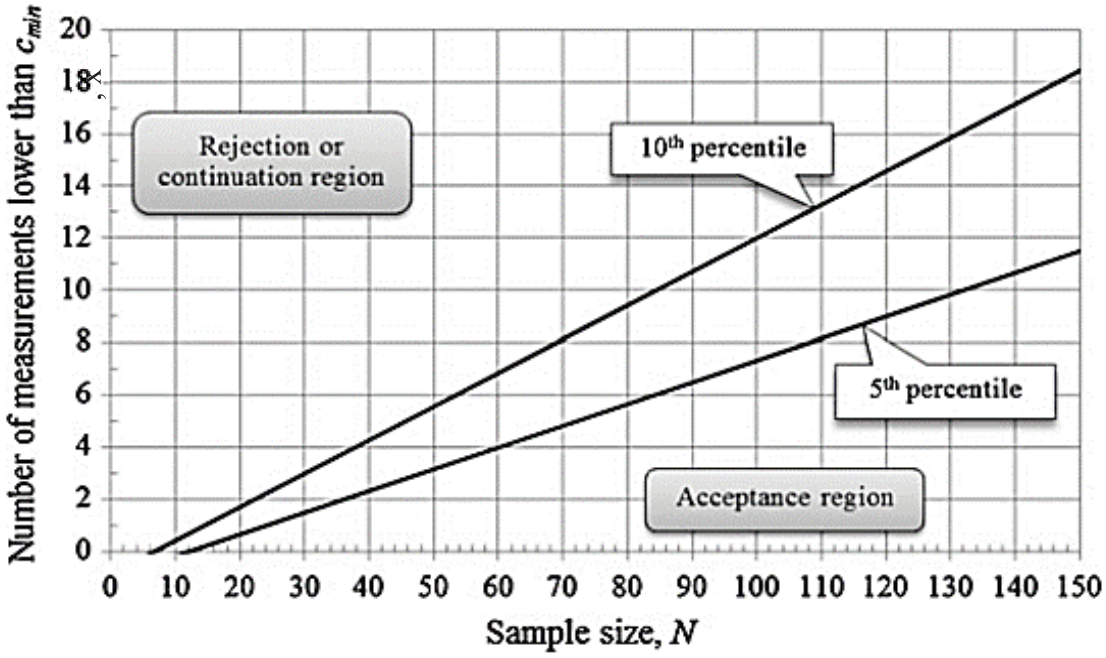
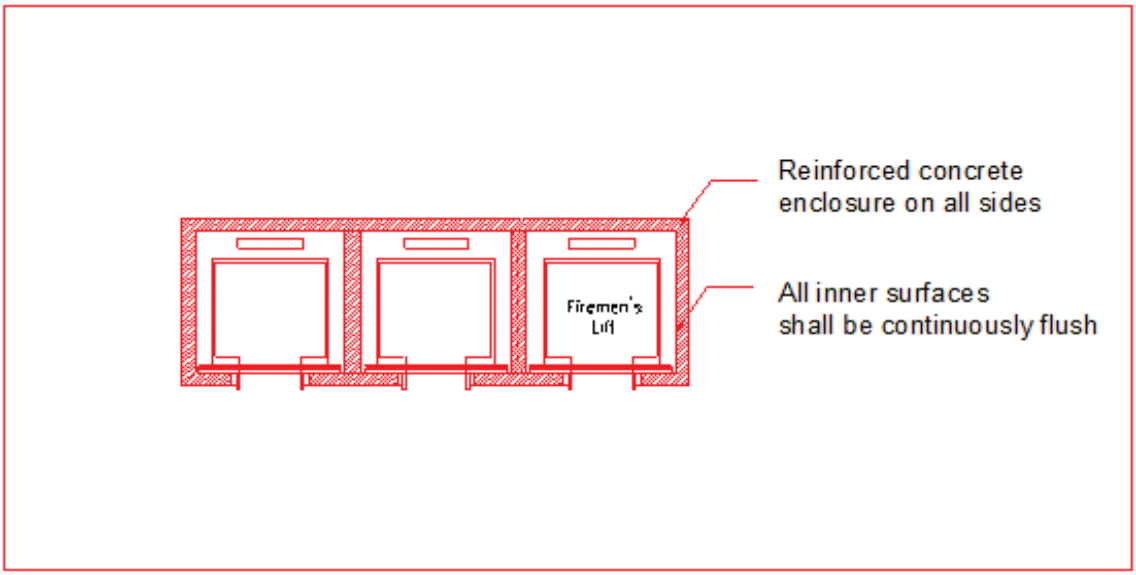


Figure D5. Lift Shaft Enclosure



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Figure D6. Limit of Accuracy of Shaft Plumb on All Sides of Shaft Enclosure

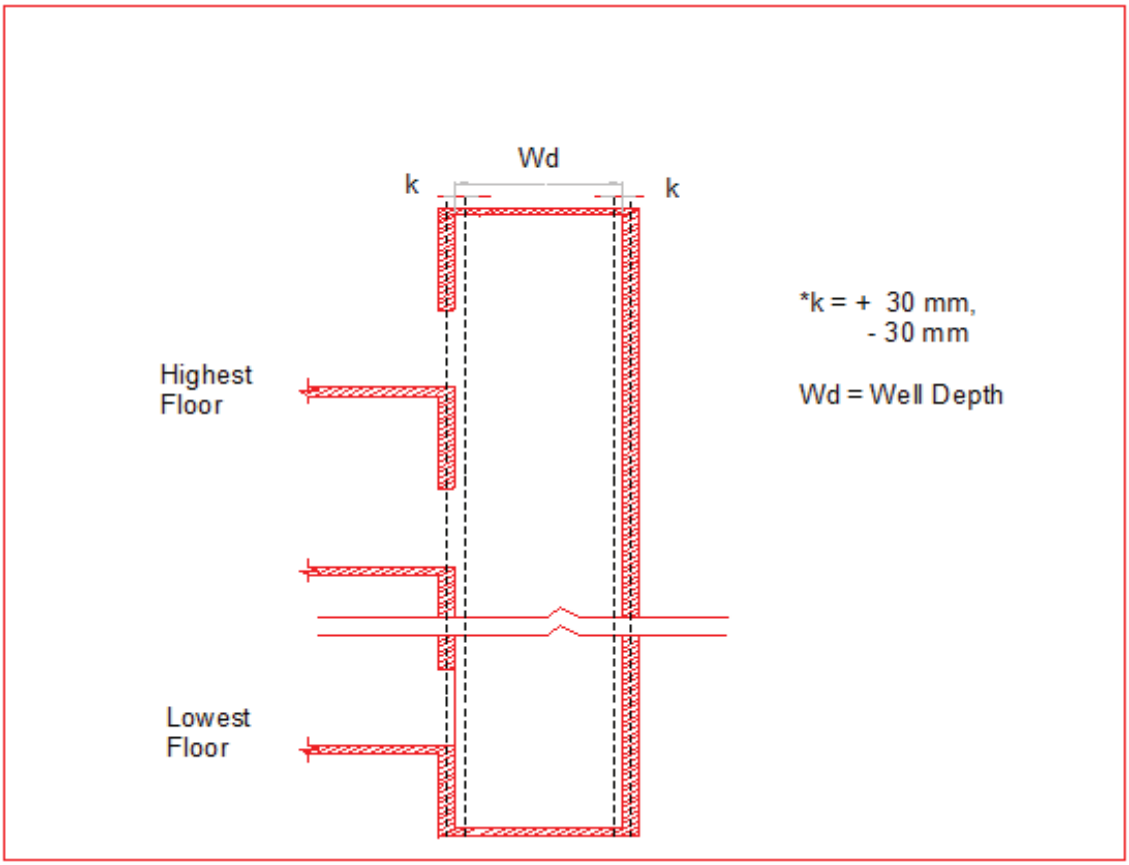
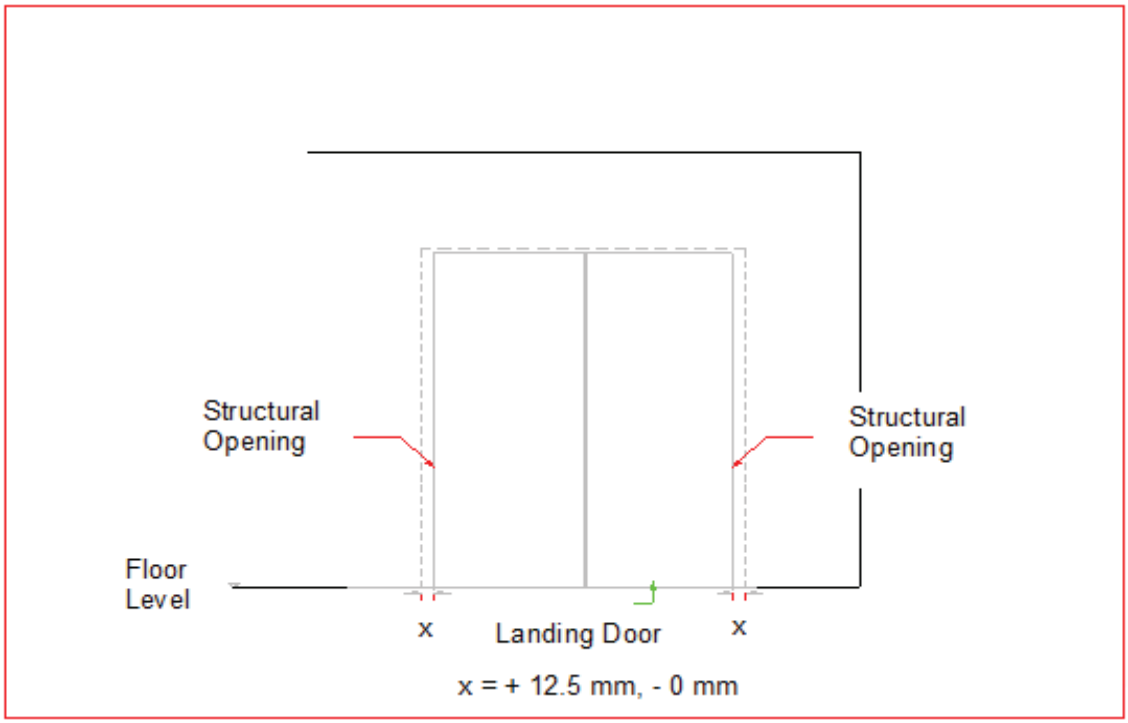


Figure D7. Accuracy of Structural Opening



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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/mm². 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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6.8. 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 be fixed to vent panels and window openings. The mesh shall be secured in position using rebated and mitred timber battens and screws.

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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.

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

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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 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.

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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

6.11.2.4. Each adjoining sheet of roll membrane being overlapped not less than 50mm; or taped together.

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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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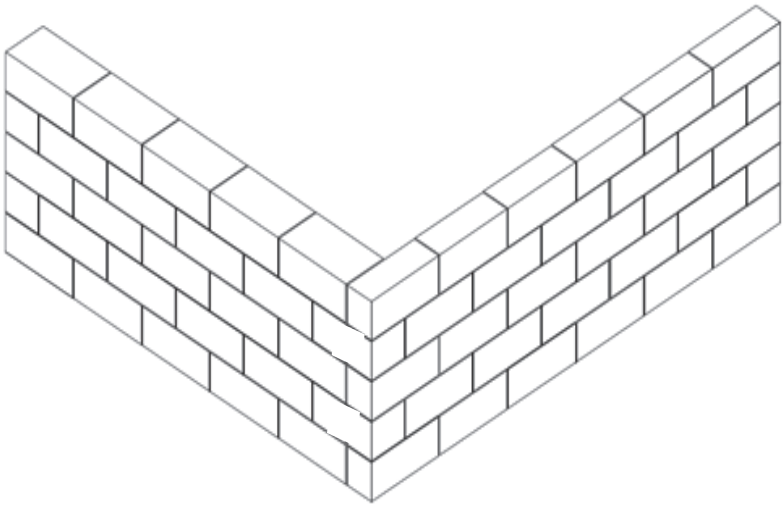


FIGURE E1: RUNNING OR STRETCHER BOND

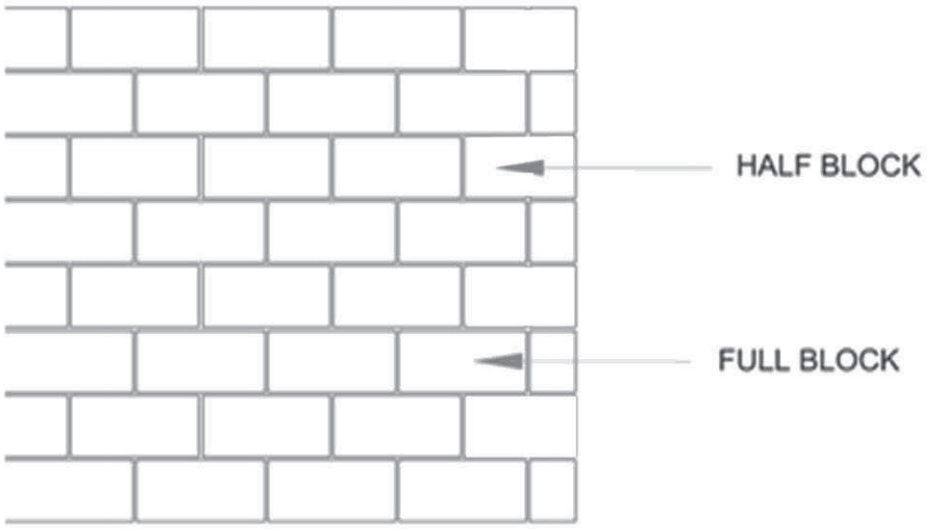


FIGURE E2: RUNNING OR STRETCHER BOND

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1. General

The work 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 work shall terminate up to and including the last manhole or intercepting trap of the system. This section of the work shall be carried out strictly in accordance with the appropriate by-laws and to the approval of the S.O..

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 in 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 only use sewer pipes from suppliers approved by SPAN and all materials shall be inspected and approved by 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.

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.

4.2. The Contractor shall carry out survey work to determine the sewer pipe alignment. Clearance from the building/road shall be 1m. 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.

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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 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 protect and support all existing water pipes, gas and other conduits crossed by the excavation or work to be performed and to arrange for their temporary removal and subsequent replacement.

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, if it is necessary in the opinion of the S.O. then the trench shall be excavated 225mm below the level intended 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 which 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.

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 Grade 20P concrete or other suitable materials well rammed and compacted all 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..

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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).

5. Pipes and Fittings

5.1. Generally, all sewer pipes unless otherwise shown on the Drawings, shall be vitrified clay pipes (VCP) and fittings complying with *MS 1061* and *SPAN 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 complying with *Malaysian Sewerage Industry Guideline (MSIG).*

5.3. Sewer pipes for force mains (which require pump) shall comply with *Malaysian Sewerage Industry Guideline (MSIG).* The type and the diameter of pipe shall be of ductile iron (DI) as shown on the Drawings.

6. Joint for Sewer Pipes

6.1. 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.

6.2. 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.

7. Pipe Laying

7.1. All pipes shall be laid in compliance with *MS 1228* and in accordance with the sizes, locations, dimensions, grades and other particulars as shown in 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 in 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.

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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 and as specified hereinafter.

7.8. The gravity sewer pipes shall be laid to the gradients as shown on the Drawings. Where the gradients are not shown in the drawings, the pipe shall be laid to the following gradients as shown in the **Table F1**.

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.

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. All external underground sewer pipes shall have a minimum cover of 450mm unless otherwise shown on the Drawings.

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. Other requirements

7.13.1. 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 Grade 20P.

8.2. Typical bedding is to be used for all pipes under normal site condition unless directed by the S.O..

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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.

9. Connections

9.1. The Contractor is to 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 shown on the Drawings and *MSIG 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 sulphate resistant cement mortar at least 20mm thick or lined with PVC, HDPE or epoxy coating.

10.3. Manholes

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 Drawings and *MSIG guidelines*.

10.3.1.3. All surfaces of manhole's covers and frames supplied shall be coated as stated in *MSIG 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)

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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 *MSIG guidelines*.

10.3.2.2. A visual inspection shall be conducted on all the external and internal section of each manhole in accordance with *MSIG 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

Unless otherwise as shown on the Drawings, inspection chambers shall be constructed in brickwork in cement mortar (1:2) and the brickwork shall be of clay bricks and constructed on Grade 20P concrete foundation. The thicknesses and sizes shall be as shown on the Drawings. Each inspection chamber shall have channels and open channel junctions of sizes as shown on the Drawings. Concrete benching shall be to a gradient of 1:6 and shall be of Grade 20P concrete finished with 19mm steel troweled water proofed cement and sand (1:3) rendering. The internal sides of the inspection chambers shall be lined with 20mm thick PVC, HDPE or epoxy coating. 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. Inspection chambers shall be provided with covers and unless specified or as shown on the Drawings, covers shall be medium duty 450mm x 600mm cast iron covers with air tight frames.

11. Septic Tank and Sewage Treatment System

11.1. Septic tank and sewage treatment system shall be constructed as shown on the Drawings and to the approval of the S.O..

11.2. All septic tank and sewage treatment system shall be approved only by SPAN. Prefabricated system by the S.P. shall be from the updated Treasury Contract Circular.

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. Sewage Treatment System

11.4.1. 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 of statement including structural, foundation, external work and M & E work duly certified by a

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Professional Engineer with Practicing Certificate (P.E.P.C.) registered with the Board of Engineers Malaysia.

11.4.2. Sewage treatment system shall be approved by the Local Authority/Certified Agency before installation at site. The submission approval to the Local Authority/ Certified Agency is as per **Appendix F/1.**

11.4.3. The S.P. shall provide specification on construction and installation of the system and during these periods, the Local Authority/Certified Agency will carry out inspection to ensure the compliance of their requirements.

11.4.4. 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:

11.4.4.1. 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..

11.4.4.2. As-built drawings and *Operation Manual and Maintenance (OMM)* of the sewage treatment system certified by a Professional Engineer with Practicing Certificate (P.E.P.C.) registered with the Board of Engineers Malaysia.

12. Connections to the Public Sewerage Line

Connections to the public sewerage line, if any, shall be strictly carried out in accordance with requirements of the *SPAN guidelines* and to the approval of the S.O..

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 *MSIG 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.

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

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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 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 registered with SPAN shall be appointed to carry out the inspection works.

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 *SPAN guidelines.*

13.5.2.3. High Risk Areas

(i) 100% CCTV inspection shall be conducted for sewer pipes including manholes laid in the ground with high risk of failure and having the following characteristics:

a) Crossing under buildings, roads, railway, rivers and lakes including their reserve.

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b) Crossing using pipe jacking method and horizontal drilling method.

13.5.3. Witness

Witness from the SPAN, S.O., consultant and contractor responsible for the construction of sewer shall be present during CCTV inspection.

13.5.4. Documentation

13.5.4.1. Within 7 days after completion of the inspection, the Contractor shall submit to the S.O. the following:

(i) Two (2) copies of digital records; and

(ii) One (1) copy of hardcopy report and recommendation

13.5.4.2. The format of the report and documentation shall be in accordance with *MSIG 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 *MSIG 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.

13.5.5. During Defects Liability Period

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 to Drawings and *MSIG 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.

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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 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	5	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.

Table F3. Sewerage Work Submission

No.	Type of System	Allowable Population Equivalent (PE)	Document Requirement
1.	Individual Septic Tank (IST) Network Connection (Single Manhole directly connected to Existing Manhole)	6 - 30	Pre-Tender Sewerage Works Application (SWA) Post-Tender Sewerage Works Completion (SWC)
2.	Small Sewerage Treatment Plant (SSTS)	31 - 149	SWA (Pre-Tender) SWC (Post-Tender)
3.	Sewerage Treatment Plant (STP)	150 – 5,000	Refer Table F4

NOTE : The submission procedure might change due to authority requirement.

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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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1. General

1.1. Unless otherwise stated, the pitch and batten gauge for each type of roof covering shall be strictly in accordance with the manufacturer's recommendation.

1.2. Unless otherwise approved, all roof covering pieces or accessories such as eaves, hips, ridges, valley et cetera, shall be of the same material as the general covering.

2. Interlocking Concrete Tiles

2.1. Interlocking concrete roof tiles shall be laid on timber or steel battens approved for roofing at spacing and tightly nailed or screwed as recommended by the manufacturer.

2.2. Unless otherwise specified, the concrete roof tiles shall be laid to slope in accordance to the manufacturer's recommended pitch and to the S.O.'s approval. The roof tiles shall conform to MS797 and unless otherwise specified on the Drawings, it shall be laid on metal trusses system to engineer's detail and S.O.'s approval.

2.3. Water repellent materials backed with weatherproof self-adhesive compound for ridges and hips solution laid in accordance with manufacturer's instruction.

2.4. Verges, ridges, hips, valley tiles and complete with all roofing accessories shall be provided and laid to bond with the general roof tiling works in accordance with the manufacturer's recommendation.

2.5. Unless otherwise stated in the drawings, where skylight roofing sheets are to be used, they shall be of transparent skylight roofing sheets [acrylic/polycarbonate (PC)/unplasticized poly vinyl chloride (UPVC) multilayer/laminated glass] or translucent skylight roofing sheets [fibreglass reinforced polyester (FRP)] of concrete roof tiles profiles. The minimum thickness gauge and fixing system of the skylight roofing sheets is accordance with the manufacturer's recomendation.

3. Clay Tiles

3.1. Unless otherwise stated in the Drawings, clay tiles shall be of 425mm to 490mm (length) x 280mm to 300mm (horizontal width) pattern confirming to BS 402 or SS 70 and shall be free from cracks, chips and warps.

3.2. Clay tiles shall be laid with a minimum head lap of 75mm to 95mm on timber or steel battens approved for roofing at spacing as recommended by the tile manufacturer. The tiles shall be firmly screwed or nailed at intervals as recommended by the roofing tile manufacturer and as approved by the S.O..

3.3. Ridge capping, hip and valley tiles complete with all roofing accessories shall be provided to match the general tiling works in accordance with the manufacturer's recommendation. All these shall be bedded in matching water repellent materials backed with weatherproof self-adhesive compound.

3.4. Roofing components at roof eave to allow airflow and prevents the entry of birds and vermin into the batten cavity is recommended.

3.5. Unless otherwise stated in the drawings, where skylight roofing sheets are to be used, they shall be of transparent skylight roofing sheets [acrylic/polycarbonate (PC)/unplasticized poly vinyl chloride (UPVC) multilayer/laminated glass] or translucent skylight roofing sheets [fibreglass reinforced polyester (FRP)] of clay

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roof tiles profiles. The minimum thickness gauge and fixing system of the skylight roofing sheets is accordance with the manufacturer's recomendation.

4. Pre-painted Aluminium Roofing Sheet

4.1. Unless otherwise stated, where aluminium roofing sheets are to be used, they shall be of the type, gauge and finish as shown in the Drawings and to be fixed strictly in accordance with the manufacturer's recommendation.

4.2. Unless otherwise stated in the drawings, where skylight roofing sheets are to be used, they shall be of transparent skylight roofing sheets [acrylic/polycarbonate (PC)/unplasticized poly vinyl chloride (UPVC) multilayer/laminated glass] or translucent skylight roofing sheets [fibreglass reinforced polyester (FRP)] of aluminium roof sheets profiles. The minimum thickness gauge and fixing system of the skylight roofing sheets is accordance with the manufacturer's recomendation.

5. Concrete Flat Roofs

Concrete flat roofs shall be as specified under SECTION D: CONCRETING.

6. Pre-painted Steel Roofing Sheet

6.1. Unless otherwise stated, the metal roof decks shall comply with the following:

6.1.1. Materials

6.1.1.1. The roofing sheets shall be produced from zinc coated steel conforming to MS2385 and AS 1397:"Hot-Dip Zinc-Coated Carbon Steel Sheet of Commercial and Drawing Qualities", MS 2384:"Hot-Dip Zinc-Coated Carbon Steel Sheet of Structural Quality" and JIS G3302:"Hot-Dip Zinc-Coated Steel Sheet and Strip" OR be produces from aluminium/zinc alloy coated steel conforming to MS 1196:"Continous Hot-Dip Aluminium/Zinc Coated Steel Sheet of Commercial, Drawing and Structural Qualities" and AS 1397 "Steel Sheet and Strip-: Hot-Dip Zinc Coated or Aluminium/Zinc Coated".

6.1.1.2. The pre-painted finish over the zinc coated base steel OR aluminium/zinc alloy coated base steel shall conform to MS 2383: "Prefinished/Pre-painted Sheet Metal Products for Interior/Exterior Building Applications – Performance Requirements" under product type 3 conforming to ISO 9223 Category 3 (C3) environment. and AS/NZS 2728÷ "Prefinished/Pre-painted Sheet Metal Products for Interior/Exterior Building Applications – Performance Requirements".

6.1.1.3. The exterior finish coat shall have a nominal film thickness of 20µm over 5µm thick corrosion inhibitive primer on top side or weather side. The backing coat shall be with nominal film thickness of 5µm over 5 µm corrosion inhibitive primer.

6.1.1.4. Minimum steel yield strength shall be 300 or 550MPa.

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6.1.1.5. The minimum aluminium/zinc alloy coating mass shall be 150g/m² (Coating Class AZ 150) on both surfaces conforming to ISO 9223 Category 3 (C3) environment.

6.1.1.6. The Contractor shall submit material warranty from the manufacturer in accordance with ISO 9223: "Corrosion of Metals and Alloys – Corrosivity of Atmosphere - Classification" of the project site and the format approved by the S.O. Material warranty shall be up to 25 years against perforation by corrosion, 15 years against flake and peel, 10 years against colour fading and 5 years against dirt staining.

6.1.1.7. The Contractor shall submit shop drawings for the S.O.'s approval prior to commencement of installation works.

6.1.1.8. Unless otherwise stated in the drawings, where skylight roofing sheets are to be used, they shall be of transparent skylight roofing sheets [acrylic/polycarbonate (PC)/unplasticized poly vinyl chloride (UPVC) multilayer/laminated glass] or translucent skylight roofing sheets [fibreglass reinforced polyester (FRP)] of steel roof sheets profiles. The minimum thickness gauge and fixing system of the skylight roofing sheets is accordance with the manufacturer's recomendation.

6.1.2. Metal Sheet Profiles

6.1.2.1. Unless otherwise specified or shown in the Drawings, the metal sheet profile shall be of a concealed fixing system complying with MS2500 as approved by the S.O.. The roofing sheets shall have the following-requirements:

(i) Base Metal Thickness (BMT) = 0.42mm.

(ii) Total Coating Thickness (TCT)= 0.47mm

(iii) Cover width = 430mm to 680 mm.

(iv) Rib height = 25mm to 43 mm.

(v) Coating = Pre-painted aluminium/zinc coated steel with AZ150 (150g/m²) or AZ200 (200g m²/) on both surfaces.

6.1.2.2. Where pierced fixing system complying with MS 2500 is specified or shown in the Drawings, the roofing sheet shall have the following requirements:

(i) Base Metal Thickness (BMT) = 0.42mm.

(ii) Total Coating Thickness (TCT) = 0.47mm

(iii) Cover width = 750 to 1015mm

(iv) Rib height = 16mm to 38mm

(v) Coating = Pre-painted aluminium/zinc coated steel with AZ150 (150g/m²) or AZ200 (200g m²/) on both surfaces.

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6.1.3. Fixing

6.1.3.1. Installation procedures shall conform to the recommendation of the manufacturer.

6.1.3.2. The roofing sheets shall be installed and fixed according to the following method:

(i) Concealed fixing using approved clips compatible with the roofing sheet.

(ii) Pierced fixing using approved fasteners compatible with the roofing sheet.

6.1.3.3. The roofing installer shall be registered with CIDB.

6.1.3.4. Metallic swarf and all other debris including nail, screws, mortar, construction materials et cetera shall be swept away from the roof area and gutters regularly, particularly at the end of each day's work and at completion of the installation works.

6.1.4. Clips and Fasteners

6.1.4.1. Fasteners type shall comply with AS 3566 Class 3 and be certified as such by the supplier of fasteners.

6.1.4.2. The recommended type of fasteners shall conform to the following test:

(i) Salt spray test - 1000 hours

(ii) Kesternich test - 15 cycles.

(iii) Humidity test - 1000 hours.

(iv) UV test - 2000 hours.

6.1.4.3. All fasteners and screws shall be of the self-drilling type either concealed or screwed fixing, complete with preassembled ethylene propylene diene monomer (EPDM) rubber washers.

6.1.5. Flashing and Capping

Approved 0.42mm BMT ridge capping, flashing, capping and trimming shall be manufactured to the required shape and sizes. The flashing and capping materials used shall be from the same material as the roofing sheets.

6.1.6. Sealants

Only neutral cure silicone rubber sealant type Dow Corning 780 or equivalent shall be used conforming to AS 3902.

6.1.7. Lightning Conductors

Aluminum lightning conductor is recommended for use on steel roof system.

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6.2. All fixing accessories shall be rust-resistant and of suitable design and construction as recommended by the manufacturer for the roofing system and as approved by the S.O.. All fasteners and screws shall be of the self-drilling type either concealed or screwed fixing, complete with preassembled EPDM rubber washers.

6.3. Identification, storage and packaging of alum/zinc steel roof decking shall be strictly in accordance with the manufacturer's recommendation and comply with the S.O.'s requirements.

6.4. All roof decking sheets, capping, flashing et cetera or wall cladding shall be new, clean, regular, straight and true to shape with sharp defined profiles, free from cracks, chips, bends and defects detrimental to practical use or from other surface imperfections.

6.5. At Site, the sheets shall be lifted from the transport carrier by a crane and properly stacked clear of the ground, ready to be lifted up to the roof structure for laying. Where sheets are to be manually lifted, care should be taken not drag the sheets to avoid scraping away the surface coating.

6.6. Where storage is necessary, stack heights shall be kept to a minimum and the sheets shall be stacked in a sloping position. Sheets shall be stacked off a dry firm ground, under cover by tarpaulin or polythene sheets but ventilated and away from building operations. Should the stack sheets become wet, they shall be immediately dried to prevent staining and degradation of the surface coatings.

6.7. The Contractor shall be responsible for the absolute water-tightness of the roof and must ensure that the method of installation, fixing and fastening decking sheets, caps, flashings et cetera including acoustical, insulation and expansion joints, whenever required shall conform strictly to the manufacturer's recommendation.

6.8. The completed portions of the roof shall be clear of all metallic particles such as blind rivet shanks, screws, nuts, nails et cetera and dirty foot prints should be wiped off to avoid early deterioration/corrosion and discolouration. Damages to the coating shall be repaired with touch-up paint as recommended by the manufacturer and approved by the S.O..

7. Roofing Sheet for Marine Environment (Coastal Areas)

7.1. The Contractor shall select the correct type of metal sheet profile to be installed for coastal areas as recommended by the roof manufacturer and approved by the S.O..

7.2. Unless otherwise specified or shown in the Drawings, the roofing sheet for marine environment shall be metallic coated steel with minimum zinc coating mass of 350g/m² (Coating Class Z350) OR minimum aluminium/zinc alloy coating mass of 200g/m² (Coating Class AZ 200) on both surfaces.conforming to ISO 9223 Category 4 (C4) and Category 5 (C5) environment.

7.3. Metallic coated steel with zinc or aluminium/zinc alloy shall be manufactured and certified by SIRIM according to MS2385:"Hot-Dip Zinc-Coated Carbon Steel Sheet of Commercial and Drawing Qualities"or MS 2384:"Hot-Dip Zinc-Coated Carbon Steel Sheet of Structural Quality" OR MS 1196 'Continuous Hot-Dip Aluminium/Zinc Coated Steel Sheet of Commercial, Drawing and Structural Qualities' or AS 1397 'Steel Sheet and Strip: Hot-Dip Zinc Coated or Aluminium/Zinc Coated'.

7.4. The pre-painted finish (super polyester paint or PVDF paint) type shall be used over the zinc coated base OR aluminium/zinc alloy coated base steel shall conform to MS 2383: "Prefinished/Pre- painted Sheet Metal Products for Interior/Exterior

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Building Applications - Performance Requirements" and AS/NZS 2728: "Prefinished/Pre-painted Sheet Metal Products for Interior/Exterior Building Applications - Performance Requirements" under product type 5 and 6 conforming to ISO 9223 Category 5 (C-5) environment.

7.5. Fasteners used shall comply with AS 3566 Class 4 and be certified as such by the supplier of fasteners and to the approval of the S.O..

7.6. All fixings and associated components shall be manufactured from compatible metals and coated conforming to ISO 9223 Category 4 (C4) and Category 5 (C5) environment. Flashings shall be made from the same material as the roofing sheets.

7.7. Unless otherwise stated in the drawings, where skylight roofing sheets are to be used, they shall be of transparent skylight roofing sheets [acrylic/polycarbonate (PC)/unplasticized poly vinyl chloride (UPVC) multilayer/laminated glass] or translucent skylight roofing sheets [fibreglass reinforced polyester (FRP)] of roof sheets profiles. The minimum thickness gauge and fixing system of the skylight roofing sheets is accordance with the manufacturer's recomendation.

8. Bituminous Corrugated Roofing Sheets

8.1. Unless otherwise shown on the Drawing, the bituminous corrugated roofing sheets shall have the following minimum requirements:

8.1.1.	Length	= 2000mm
8.1.2.	width	= 950mm
8.1.3.	cover width	= 855mm
8.1.4.	thickness	= 3mm
8.1.5.	weight of material	= 3.3kg/m^2
8.1.6.	thermal resistance R- value	= 0.04mK/W
8.1.7.	thermal conductivity	= 0.066W/mk

8.2. Unless otherwise shown on the Drawings, the Bituminous Corrugated Roofing Sheets shall be laid at a minimum roof pitch of 5° on timber battens at spacing and tightly nailed/screwed as recommended by the manufacturer.

8.3. Ridge capping, nails and screws shall be provided to match the roofing sheets while ridges, verges, eaves, hips, valleys, side-wall and end-wall details shall be fixed strictly in accordance with the manufacturer's recommendation.

9. Bituminous Corrugated Roofing Tiles

9.1. Unless otherwise shown on the Drawing, the bituminous corrugated roofing tiles shall have the following minimum requirements:

9.1.1.	Length	= 1060mm
9.1.2.	Width	= 400mm
9.1.3.	Wave Height	= 40mm

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9.1.4. thickness = 3mm

9.2. Bituminous roofing tiles shall be laid at a minimum roof pitch of 9° and on timber or steel battens approved for roofing at spacing and tightly nailed/screwed as recommended by the manufacturer.

9.3. Ridge capping, nails and screws shall be provided to match the roofing tiles while ridges, verges, eaves, hips, valleys, side-wall and end-wall details shall be fixed strictly in accordance with the manufacturer's recommendations.

10. Fibre-cement Corrugated Sheets

10.1. Fibre-cement corrugated sheets shall comply with MS 1224. The thickness of the sheets shall be 3mm thick for shallow corrugation and 4mm thick for medium corrugation. The cement shall comply with MS 522: Part 1. Asbestos processed or unprocessed shall not be added to fibre-cement sheets.

10.2. The surface intended to be exposed to the weather shall have a generally smooth finish. Variations of the surface appearance which do not impair the characteristics of the sheets as defined in MS 1224 are permitted.

10.3. Unless otherwise stated in the drawings, where skylight roofing sheets are to be used, they shall be of transparent skylight roofing sheets [acrylic/polycarbonate (PC)/unplasticized poly vinyl chloride (UPVC) multilayer/laminated glass] or translucent skylight roofing sheets [fibreglass reinforced polyester (FRP)] of corrugated roof tiles profiles. The minimum thickness gauge and fixing system of the skylight roofing sheets is accordance with the manufacturer's recomendation.

11. Heat Insulation

11.1. General

Heat insulation system shall comply with MS 1020 and MS 1525. 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.

11.2. Reflective Foil

11.2.1. Reflective foil shall be fire retardant double sided aluminium reflective foil bonded to reinforced high density polyethylene woven fabric comply with MS2095 : 2014

11.2.2. The reflective foil materials used shall conform to fire safety requirements and BS 476 Part 6 & Part 7 (Class O): Fire Test on Building Materials and Structures on the following test:

11.2.2.1. Part 6: Method of test for fire propagation for products conforming to BS 476

11.2.2.2. Part 7: Method of test to determine the classification of the surface spread of flame confirming to BS 476

11.2.3. Reflective foil properties shall conform to the following:

11.2.3.1. Thickness : 137 ± 20 micron thick.

11.2.3.2. Grammage : 163 ± 10g/m^2.

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11.2.3.3. Tensile strength : 500 N/ 50mm (MD), 500 N/50mm (Cross Direction) MD≥9.5 ; CD≥6.0.

11.2.3.4. Emissivity ASTM E408 ≤ 0.05(97±2%) / Reflectivity = 95% ASTM C1371 ≤0.05

11.2.3.5. Initial Tear resistance: ASTM D1004 >30N ≥65.0

11.2.4. Reflective foil material may be used on its own with all types of roofs except with metal decking roof. Where roof is of metal decking, the reflective insulation material shall be laid below stone wool or glass wool for effective thermal and acoustic performance.

11.2.5. The reflective foil material shall be installed strictly in accordance with the manufacturer's recommendation. A uniform air space of 20mm to 50mm between the tile roof covering and the insulation material shall be provided to ensure the effectiveness of the reflective surface. All punctures shall be effectively sealed with similar reflective material to prevent air leakage and moisture transfer.

11.2.6. The reflective foil surface shall be free from any thin film of oil, plastic or lacquer coatings. All dust and/or moisture, if any, shall be thoroughly cleaned prior to installation. All dust and/or trademarks shall be limited to a maximum of 5% of the total reflective area. The insulation material shall be fitted closely around electrical outlet boxes, plumbing and et cetera, and taped securely to eliminate gaps or voids through which air or water vapour might pass into the cooler space.

11.3. Glass Wool Insulation

11.3.1. Unless otherwise shown in the Drawings, It shall have R-Value @ R2.0 to R2.3 m²KW (tested at a mean temperature of 20°C based MS1020 and MS1525 tested according to ASTM C177/C518). The glass wool insulation material used shall conform to BS 476 for Fire tests on building materials and structures on the following:

11.3.1.1. Part 6: Method of test for fire propagation for products conforming to BS 476

11.3.1.2. Part 7: Method of test to determine the classification of the surface spread of flame confirming to BS 476

11.3.2. The glass wool insulation material used shall be of no added urea formaldehyde and as approved by the S.O.. Glass wool insulation shall be fixed in accordance with the manufacturer's recommendations and to the approval of the S.O..

11.3.3. Where single skin metal roof is applied, galvanized wire mesh BRC 3316 or equivalent shall be used to support the reflective foil and the glass wool insulation.

11.4. Mineral Wool Insulation

11.4.1. Unless otherwise shown in the Drawings, it shall have R-Value @ R2.0 to R2.3 m²KW (tested at a mean temperature of 20°C based MS1020 and MS1525 tested according to ASTM C177/C518). The mineral wool insulation material used shall conform to BS 476 for Fire tests on building materials and structures on the following:

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11.4.1.1. Part 6: Method of test for fire propagation for products conforming to BS 476.

11.4.1.2. Part 7: Method of test to determine the classification of the surface spread of flame confirming to BS 476.

11.4.2. The mineral wool insulation material used shall be of no added urea formaldehyde and as approved by the S.O.. Mineral wool insulation shall be fixed in accordance with the manufacturer's recommendations and to the approval of the S.O..

11.4.3. Where single skin metal roof is applied, galvanized wire mesh BRC 3316 or equivalent shall be used to support the reflective foil and the mineral wool insulation.

11.5. Stone Wool Insulation

11.5.1. Unless otherwise shown in the Drawings, stone wool insulation shall be 50mm thick minimum. It shall have R-Value @ R2.0 m²·KW (tested at a mean temperature of 20°C based MS1020 and MS1525 tested according to ASTM C177/C518). The stone wool insulation material used shall conform to BS 476 for Fire tests on building materials and structures on the following:

11.5.1.1. Part 6: Method of test for fire propagation for products conforming to BS 476.

11.5.1.2. Part 7: Method of test to determine the classification of the surface spread of flame confirming to BS 476.

11.5.2. The stone wool insulation shall conform to the following:

11.5.2.1. Thermal conductivity 0.034 - 0.036 W/mK at 20°C mean temperature tested in accordance to ASTM C518.

11.5.2.2. Noise reduction coefficients (NRC) of up to 1.0 tested to BS EN ISO354 at 50mm thickness.

11.5.2.3. Non-combustible according to BS 476 Part 4 or EN 13501-1 and melting point of at least 1000°C in accordance to ASTM E794.

11.5.2.4. No CFCs, HFCs, HCFCs or asbestos shall be used in the manufacture of the product.

11.5.2.5. No perceptible odor shall be present when tested in accordance to ASTM C665.

11.5.2.6. Not sustaining fungus growth under normal conditions according to ASTM C1338.

11.5.2.7. The metal plates (steel and aluminium) in contact with the insulation shall show no corrosion greater than that observed on the comparative plates in contact with sterile cotton according to ASTM C665.

11.5.2.8. Flame spread index less than zero (0) and smoke developed index less than five (5) according to ASTM E84.

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11.5.2.9. Total VOC emission shall be less than 0.25 mg/m3 and particles emission shall be less than 0.02 mg/m^3 tested according to ASTM D5116.

11.5.2.10. Moisture absorption shall be less than or equal to 0.04%vol. according to ASTM C1104/C1104M and water absorption shall be less than or equal to 0.5kg/m^2 (short-term immersion) according to EN1609.

11.5.3. The stone wool insulation material used shall be of no added urea formaldehyde and as approved by the S.O.. Stone wool insulation shall be fixed in accordance with the manufacturer's recommendation and to the approval of the S.O..

11.5.4. The insulation material must be protected from the exposure of rain, water immersion and chemical contamination during the storage and installation. If the insulation is in contact with water, adequate drying time must be allowed to ensure that the insulation is completely dried prior to covering of the roof covers.

11.5.5. The stone wool insulation shall be installed to the thickness specified and place butt jointed. Wherever possible the Contractor shall avoid the compression of the insulation material.

11.5.6. Where single skin metal roof is applied, galvanized wire mesh BRC 3316 or equivalent shall be used to support the reflective foil and the stone wool insulation.

11.6. Cellulose Insulation

11.6.1. Unless otherwise shown in the Drawings, spray applied cellulose insulation shall be 30mm thick minimum. It shall have K-Value of 0.029 W/mK based MS1020 and MS1525 tested according to ASTM C177. The spray applied cellulose insulation material used shall conform to BS 476 Part 6 &7 for Fire tests on building materials and structures on the following:

11.6.1.1. Method of test for fire propagation for products.

11.6.1.2. Method of test to determine the classification of the surface spread of flame.

11.6.2. Cellulose insulation shall be:

11.6.2.1. Thickness = 30mm

11.6.2.2. Thermal conductivity (k-value) = 0.0029 W/mK tested to ASTM C-177.

11.6.2.3. Fire retardant Class "O" complying with BS476 Part 6 & 7 and endorsed by Jabatan Bomba Dan Penyelamat Malaysia.

11.6.2.4. Average moisture absorption of not more than 15% as per ASTM C739.

11.6.2.5. Tested Noise Reduction Coefficient of NRC 0.75 at 30mm thickness.

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11.6.2.6. Tested to be non-toxic and asbestos free, contain no carcinogenic materials and shall not cause any skin irritation to humans

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1. General

1.1. Unless otherwise specified or shown in the Drawings, the timber species used for the Works shall be as stated hereinafter in the **TABLE H1**: Schedule of Timber Grouping and Usage. The strength grouping for timber shall be in accordance with MS 544 as shown hereinafter in the **TABLE H2**: Schedule of Timber Species in Accordance with Strength Grouping.

1.2. All carpentry and joinery work shall include all necessary notching, halving, morticing and tenoning, wedging, scarfing, dovetailing, sinking for heads of bolts and nuts and trimming for opening.

1.3. All carpentry work shall be left with a sawn surface except where particularly described to be wrot. All joinery shall be wrot and finished with sand paper as required and all sizes stated are the finished sizes. Sizes for carpentry shall be within the tolerances stated in sub-section 2.1. and sizes for joinery shall be within the tolerances stated in sub-section 2.2..

1.4. Unless otherwise indicated in the Drawings, all fire protection materials and systems must show evidence that they have been subjected to the fire resistance test in accordance with BS 476 or other approved equivalent standards.

2. Timber Grades And Size Tolerances

2.1. Unless otherwise specified, sawn timber for carpentry work shall be as stated hereunder:

2.1.1. Select Structural Grade - for roof truss

2.1.2. Standard Structural Grade - for structural work

2.1.3. Sound Grade - for General Market Specification (GMS) and strips

2.1.4. Serviceable Grade - for scantling

2.2. Grading shall be carried in accordance with the Malaysian Grading Rules (MGR) by timber graders registered with the MTIB. Every timber consignment shall be accompanied by the Grading Summary and Certificate of Compliance certified by registered timber grader. The sample of Certificate of Compliance is shown in **Appendix H/2** as stipulated in MS 1714. Notwithstanding the certificate, the S.O. reserves the right to carry out independent tests at Makmal Anatomi Kayu, FRIM or Fibre and Biocomposite Centre (FIDEC), MTIB to determine the species and Strength Group (SG). The sizes of sawn timber, except where otherwise specified, shall be within the margin of permissible variations stated hereunder:

2.2.1. For widths, depths or thicknesses not exceeding 75mm - within 3mm of the specified size.

2.2.2. For widths, depths or thicknesses exceeding 75mm - within 5mm of the specified size.

2.3. The Contractor shall provide any necessary blocks, wedges or battens to compensate for irregular surfaces caused by any variations in size of timbers hereby permitted.

2.4. Unless otherwise specified or shown in the drawing, sawn timber for joinery work shall be of Sound Grade (General Market Specification (GMS) and Strips) and

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Serviceable Grade (Scantlings). The finished size for joinery, unless otherwise specified, shall be within the margin of permissible variation stated hereunder:

2.4.1. For widths, within 3mm of the specified finished size.

2.4.2. For thicknesses, within 2mm of the specified finished size.

2.5. Unless otherwise specified or shown in the drawing, the required actual dimensions shall be referred to the common commercial timber sizes given in **Table H6**.

3. Treatment of Timber

3.1. All timber except the heartwood of the naturally durable timbers as scheduled in **TABLE H2** hereinafter and timber for formwork, scaffolding, and other temporary works shall be impregnated by means of vacuum pressure processes in accordance with MS 360 using copper/chrome/arsenic (CCA) wood preservatives conforming to MS 733 in the treatment plant registered with the MTIB.

3.2. If a timber component has sufficient natural resistance to decay and insect attack by virtue of the natural durability of its heartwood, it may be used without treatment even where the hazard exists. The natural durability classification of Peninsular Malaysia and Sabah and Sarawak timbers for ground contacts can be found in MS 360 and as shown in **TABLE H4** and **TABLE H5**. Sapwood should not be used without preservative treatment.

3.3. All preservatives timber component for internal use and direct contact with humans shall be coated with a minimum of two coats of protective coating and shall be applied in accordance with the manufacturers' specification to S.O.'s approval.

3.4. Unless otherwise specified, the average moisture content for all timber shall not exceed 25% in accordance with MS 360. The moisture content shall be determined in accordance with one of the methods given in MS 837.

3.5. All timber shall be sawn or planed before treatment to achieve the finished cross-section required. As far as possible, all cross-cutting, boring, drilling or other processing should be carried out before treatment.

3.6. The pH value of the treating solution shall not be higher than 3.0 when determined by a glass electrode or pH paper at ambient temperature in accordance with MS 360.

3.7. The net dry salt retention shall be determined in accordance with one of the methods given in MS 360 and MS 821. The minimum salt penetration shall be determined by one the test methods given in MS 833.

3.8. The material shall be collected by drilling to the required depth as recommended and shown in MS 360 **-TABLE 4**. It can also be collected by sawing to the required depths, and then chipped to the small size. Either sawdust or chipped materials shall be ground to fine powder.

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3.8.1. The minimum net dry salt retention for CCA shall be as shown in the table below.

No	Use	Minimum Net Dry Salt Retention For CCA
i)	Interior and above the ground	5.6 kg/m³
ii)	Exterior and above the ground	8.0 kg/m³
iii)	Exterior and in contact with the ground (other than foundation piles)	12.0 kg/m³

3.8.2. All sapwood shall be fully penetrated by the preservative and for heartwood, the depth of penetration shall be at least 6mm for the surface of the specimen and any cracked section which may appear.

3.9. The Contractor, when required by the S.O. shall produce a certificate from a preservative treatment plant which certifies that timber required to be impregnated by means of vacuum pressure processes has been impregnated and has achieved the necessary nett dry salt retention. Notwithstanding the certificate, the S.O. reserves the right to carry out independent tests to determine the nett dry salt retention and the result so obtained shall be conclusive.

3.9.1. Treatment certificate

3.9.2. A treatment certificate shall be produced for each batch of timber delivered from the treatment plant. The relevant charge sheets shall be attached with each treatment certificate. The following information shall appear on the certificate:

3.9.2.1. Name and address of buyer;

3.9.2.2. Project title/reference;

3.9.2.3. Name of treating company;

3.9.2.4. Name of preservative(s) used;

3.9.2.5. Average retention of preservative obtained;

3.9.2.6. Charge sheet number and date of treatment;

3.9.2.7. Species of timber treated together with sizes and volume;

3.9.2.8. Commodity and hazard class; and

3.9.2.9. Other registration number (where applicable)

3.9.3. The certificate shall be signed by authorized personnel of the treating company, certifying that the timber has been treated in accordance with MS 360.

3.9.4. Timber treatment with other type such as heat treatment are allowed in accordance to relevant standard.

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4. Moisture Content And Storage

4.1. At the time of installation, the moisture content of the timber for the various applications shall not exceed that as specified in **TABLE H3** in accordance with MS 544: Part 1.

4.2. Moisture content for foundation piles, formworks and temporary works is not critical for these applications and therefore is not specified.

4.3. Moisture content of timber shall be determined as follow as in accordance with MS 837. The summary of standard procedure are as follows:

4.3.1. For determination of the average moisture content of test specimens, immediately weigh each of the test specimens or sections which are required to be free from saw dust and any loose splinters.

4.3.2. In cases when it is not possible to weigh the test specimens or sections immediately after cutting, place them in previously tared packets of moisture-proof plastic films and tightly sealed.

4.3.3. Dry the weighed test specimens or sections at a temperature of 103ºC ± 2ºC for at least 24 hours. To ensure that the test specimens or sections have attained approximately constant mass, a repeated weighing of two or three control pieces is required after further 2 hours. The difference in mass between the two successive weighing shall be less than 0.2%.

4.4. On delivery to the site, all timber other than timber for foundation piles, formworks and temporary works shall be properly open-stacked, under cover. Kiln dried timber shall be properly wrapped and stored under cover if it is not used immediately.

4.5. Care should be taken on site to ensure that the timber is adequately protected from the weather. This is particularly important with material dried to below 19% moisture content, since the full design load should not be applied if the moisture content rises above 19%.

5. Structural Assemblies Of Timber

5.1. The workmanship and method of assembly of structural timber shall generally be in accordance with MS 544 and in particular, the following requirements:

5.1.1. The quality of the surface, as finished, shall be appropriate to the position and use of the timber.

5.1.2. When grade or other necessary marks are removed, provisions shall be made for remarking in accordance with *Malaysian Grading Rules.* Surfaces at any joint in an assembly shall be such that the parts may be brought into contact over the whole area of the joint before connectors are inserted or any pressure or restraint from the fastening is applied. These surfaces shall have a good sawn or planed finish.

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5.1.3. Bearing surfaces of notches and other cuttings shall be true and smooth and in appropriate relation to the other surfaces of the piece.

5.2. Notches other than at the ends of beams shall be U-shaped formed by parallel cuts to previously drilled holes. The diameter of the hole shall be equal to the width of the required notch.

5.3. Where splitting is likely to have a deleterious effect, end sealing is recommended. For timbers known to split and check especially after installation, the ends of the boards and scantlings shall be protected with a coating designed to minimise end checking and checking and splitting. In severe cases where the ends and sides of heavy joists of timbers are liable to excessive split and check due to exposure to windward slanting sunlight, appropriate skirting or cover with a thin timber board shall be necessary.

6. Timber Joints

6.1. When solid timber members are to be jointed together using mechanical fasteners, the workmanship and method of assembly shall be in accordance with MS 544: Part 5. The mechanical fasteners are as listed below:

6.1.1. Nailed Joint

Where necessary to avoid splitting, nails shall be driven into pre-drilled holes or diameter not greater than four-fifths of the diameter of the nails. Care shall be taken to avoid placing nails in any end split.

6.1.2. Screwed Joint

Lead holes shall be used to ensure good workmanship in making screwed joints. The diameter of the hole for the shank shall be equal to the diameter of the shank, and for the threaded portion, the diameter of the hole shall not be greater than seven-eighth of the diameter of the root diameter of the screw thread adjacent to the shank. Care shall be taken to avoid placing screws in any end split.

6.1.3. Bolted Joint

6.1.3.1. Bolt holes shall be drilled to diameters as close as possible to the nominal diameter of the bolt and in no case more than 2mm larger than the bolt diameter. Care shall be taken to avoid placing a bolt in any end split. A minimum of one complete thread shall protrude from the nut.

6.1.3.2. A washer shall be fitted under the head of each bolt and under each nut. The minimum sizes of washers are shown in **Table H7** as given in accordance with MS 544: Part 6. Where joints using split-rings are to be used, as shown in the Drawings, the members of the joints shall be fitted together in their appropriate positions and clamped or spiked together before drilling. Alternatively, drilling jigs or multiple head boring machines may be used, or individual members may be marked out from the setting-out or by use of prepared templates.

6.1.3.3. If either of the latter methods is employed, sample members (usually the first ones produced) shall be carefully checked against the setting-out.

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6.1.3.4. In all instances holes for bolt positions shall be accurately determined by reference to the point intersection of the centre lines of the member. Great care is necessary if the first set members marked out is to be used subsequently as drilling templates. Greater accuracy can usually be obtained by the use of special marking or drilling templates located by a pin at the intersection of the center lines.

6.1.3.5. Bolts holes shall be drilled at right angles to the surface of the joint. The contact surfaces of the members should be grooved to the appropriate dimensions as given in Part 6 of MS 544.

6.1.3.6. Drilling and grooving may be done in a single operation; alternatively, if the hole is predrilled the pilot of the grooving tool shall fit in the bolt hole, thus centering the groove about the hole.

6.1.3.7. Care shall be taken to ensure that all chips and shavings are removed, and rings shall be expanded before being placed in the grooves.

6.1.3.8. The joint shall be finally assembled and bolts inserted. Washers of the correct dimension shall be placed under the head of the bolt and the nut, and the nut tightened to hold the members together.

6.1.3.9. Recess for shear-plate connectors shall be accurately cut by means of a suitable tool to be appropriate dimensions as given in MS 544: Part 6.

6.1.3.10. Assembly of units shall be done on a level bed and in such a way as to avoid damage to any of the members and so that the finished structural units conform to detailed Drawings and specification supplied.

6.1.3.11. When assembly is to be performed on the site, one set of component parts shall be fitted together and dismantled prior to dispatch to the site, in order to ensure that the assembled structural units conform to the detailed Drawings and Specifications. Twisted or damaged members shall be replaced before erection on the site.

6.1.3.12. Before proceeding with bulk production, a complete assembly of one of each framed truss or other structural unit shall be checked to prove the accuracy of the templates, etc. A similar check shall be carried out from time to time to control the wear and tear on templates and gauges.

6.1.3.13. Timber members and built-up units shall be marked in accordance with a marking diagram.

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7. Prefabricated Timber Roof Truss System

7.1. 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 *Specification for Prefabricated Timber Roof Trusses (JKR 20601-0190-12)* or the latest edition published by JKR.

7.2. All projects shall be registered through J-Truss Online System in accordance to the latest requirement imposed by JKR Malaysia.

7.3. System Provider

The System Provider (S.P.) is a supplier of a proprietary roof truss system appointed by the Contractor and approved by the S.O., which employs Quality Assurance procedures in the design, detailing, connection, bracing, erection criteria and manufacture of truss components for the structural roof truss system.

7.4. Duties of Professional Engineer

7.4.1. The S.P. shall appoint a Professional Engineer (P.E.) whose duties shall include the following:

7.4.1.1. Preparation of roof truss analysis and design;

7.4.1.2. Preparation of drawings;

7.4.1.3. Design changes in every stage of work;

7.4.1.4. Certification for completion of roof truss installation;

7.4.1.5. Final certification for roof truss installation prior to issuance of Certificate of Practical Completion for the whole Works to the Contractor.

7.5. Fabricator

All trusses shall only be assembled by licensed fabricators approved by the S.P. and registered with CIDB. A copy of the CIDB registration certificate shall be submitted to the S.O. for verification.

7.6. Installer

All installation works shall be executed and supervised by qualified personnel with valid certificates issued by CIDB. The S.O. shall verify the identification and qualification of the installer prior to the installation.

7.7. General Truss Limitation

7.7.1. Prior to any pre-fabricated timber roof trusses works, the following general limitation shall be applied:

7.7.1.1. Maximum unsupported truss span 12m with permitted deviation of ±0.05m.

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7.7.1.2. Maximum truss spacing of 1.2m with permitted deviation of ±0.025m.

7.7.1.3. The minimum basic wind speed shall be 35 m/s. However, the minimum basic wind speed shall be increased to 41 m/s for lightweight roof covering.

7.7.1.4. Maximum roof pitch shall be of 45º.

7.8. Analysis, Design Report and Drawings Submission

7.8.1. The S.P. through the Contractor shall propose to the S.O. or his approval 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 shall indicate all loads, load combinations, connections criteria, bracings and tie-down of the truss. Design output of the truss members, battens, connections, tie-down and wall plates, anchors, bracings, truss accessories, splicing and stiffeners where related to the analysis shall be included in the design report. (In accordance to *Specification Pre-Fabricated Timber Roof Truss - JKR 20601-0190-12).*

7.8.2. All details in the construction drawings shall be sufficient to enable checking against the analysis and design report, by specifying and providing not limited to: the truss layout and configuration, timber grades, section properties of members, length of members in each truss configuration, properties of truss accessories, specification of fastener and anchor, tie-down and anchoring details and all types of connection details including the connection of all attachments to the trusses.

7.8.3. Technical specifications for fastener and anchor of which the design refers to shall also be submitted. Verification test certificate from an approved accredited laboratory on the technical parameter specified in the technical specifications shall be submitted upon request by the S.O..

7.9. Warranty

7.9.1. When a refabricated timber roof truss system is used, the Contractor shall submit to the S.O. a warranty from the S.P. certified by a P.E. with the following provisions:

7.9.1.1. All roof truss components shall be manufactured only by approved S.P. producing quality assured products and services.

7.9.1.2. System Provider's Warranty against any defects or damages which may arise during a period of ten (10) years from the Date of Practical Completion of Works due to any defect, fault or insufficiency in design, materials or workmanship or against any other failure which an experienced Contractor may reasonably contemplate but shall not include normal replacement and maintenance. (In accordance to *Specification Pre-Fabricated Timber Roof - JKR 20601-0190-12).*

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8. Engineered Timber Product (ETP) for Structures

8.1. General

8.1.1. This sub-section shall apply to the construction of all structures or parts of structures to be composed of engineered timber products which is glulaminated timber (Glulam), laminated veneer lumber (LVL) and cross laminated timber (CLT) (refer Figure H1). The work shall be carried out all in accordance with this specification and the lines, levels, grades, dimensions and cross-sections shown in the Drawings and as required by the S.O..

8.1.2. Glue-laminated timber (Glulam) is a structural timber product manufactured by gluing together individual pieces of dimensioned timber, having their grained essentially parallel and manufactured in accordance with the relevant Standards. The laminations thickness is allowed within 2mm up to 50mm.

8.1.3. LVL is a structural timber product manufactured by bonding together rotary peeled or sliced thin wood veneers under heat and pressure. The minimum numbers of veneer shall be five (5) and maximum thickness of each veneer shall be 6mm.

8.1.4. CLT is a solid wood board which is manufactured by gluing boards/battens crosswise in several layers.

8.2. Design Requirement

8.2.1. Design Data

8.2.1.1. Load Item

All loads shall be clearly itemised as below: -

(i) Dead Load

Dead load shall be specified as per requirement in MS EN 1991-1-1, whichever standard adopted. However, the actual weight of ceiling, mechanical and electrical (M&E) services shall not be less than 0.25kN/m2.

(ii) Imposed Load

The value and requirement of imposed load shall be as per MS EN 1991-1-1, whichever standard adopted. Notwithstanding to the value in the standard, the minimum value of imposed load shall be 0.25kN/m2 distributed uniformly over the whole area supported and 0.9kN concentrated over a length of 125mm (or in the case of coverings, over a square of 125mm side so placed as to produce maximum stresses in the affected members).

(iii) Wind Load

(a). The requirement of wind load shall be as per MS 1553 or MS EN 1991-1-4 , whichever standard adopted, with the minimum basic wind speed as

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per sub-section 2.2 of this specification or the value in MS 1553 whichever higher.

(b). Load combinations shall be clearly identified (as per MS EN 1991-1-1, MS 544 : Part 3 or other equivalent standards recognised internationally) and itemised to enable design checking to be carried out upon the most adverse conditions or the effect (of uplift) under consideration.

8.2.2. Design Standards

The design of ETP members, bracings, connections shall be in accordance with the following alternative of principal standards:

8.2.2.1. MS 544 Code of Practice for Structural Use of Timber

8.2.2.2. Any other equivalent standards recognised internationally

8.2.3. Eccentricity

The centroidal axes of the connected members should meet at a point, otherwise the effect of eccentricity of the connection should be taken into account in the design of the members and their connections.

8.2.4. Frame Stability

The analysis of ETP structure frame shall take the following requirements for frame stability:

8.2.4.1. Lateral forces i.e wind load, notional load, seismic load, whichever governs.

8.2.4.2. Identification of loadpath for lateral stability.

8.2.4.3. Bracing system i.e shear wall, steel brace etc.

8.2.4.4. Provision of ties for stability against progressive collapse

8.2.5. Designing to Avoid Tension Perpendicular to Grain

8.2.5.1. Whenever possible, joints should be designed to avoid causing tension perpendicular to grain stresses in ETP members.

8.2.5.2. Long lines of fasteners spaced together along the grain should be avoided, particularly if the bolts are in tightly drilled holes. These types of connections may induce tension perpendicular to grain stresses due prying actions from secondary moments.

8.2.6. Load Suspended from ETP Member

Loads suspended from ETP beams or girders should preferably be suspended from the top of the member or above the neutral axis.

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8.2.7. Jointing, Connection and Bracing

8.2.7.1. Appearance

All connections/joints of ETP members shall be designed as concealed to provide neat joint appearances on all glulam ETP timber frames. Column to foundation and main rafter to column shall be constructed with flanges bolted connections with concealed internal connection to flange plates.

8.2.7.2. Uplift and Anchorage Loads

In cases where the ETP framing members must carry uplift and/or horizontal loads resulting from wind, seismic or construction conditions, such members are required to be anchored against any horizontal or vertical movements or incidental forces. As such, connection design shall include anchorage resistance to uplift and lateral movement apart from providing adequate bearing alone. The steel plate base shall be designed to be sufficient enough to take moment forces due to the frame being free standing structure during installation stage. The installation of J-Bolt (if required) shall be part of works of the main contractor.

8.3. Detailing and drawings

8.3.1. Detailing Consideration

8.3.1.1. Consideration of Decay

(i) Where ETP member is exposed to the external weather conditions, all details shall ensure that water and moisture is dispersed and not allowed to pond or accumulate. Prevention of moisture and water entrapment can be achieved by measures such as the usage of moisture barriers, protective overhangs, flashings and other protective features.

(ii) Arch and column bases shall be elevated a minimum of 300mm above the concrete floor level to cater potential for wetting of the floor.

8.3.1.2. Consideration of Shrinkage and Swelling

Whenever possible, all connections/joints detailing shall take into consideration the effect of timber swelling and shrinking due to moisture content changes in service to avoid splitting of member.

8.3.2. Detail Drawings

Construction drawing shall consist of:

8.3.2.1. Layout Drawings

Layout drawings shall indicate the plan view of all ETP members together with ties, bracing etc.

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8.3.2.2. Design Detail Drawings

The design detail drawings shall clearly indicate the following:

(i) Shape of member

(ii) Span, height, spacing, pitch, overhang and camber

(iii) Designed wind load

(iv) Structural capacity of member i.e bending, shear, axial capacity etc

(v) Magnitude and direction of forces transferred to the supporting structure

(vi) Bracing

(vii) Cambering

Each member shall be clearly drawn on a separate drawing that clearly itemises all member sizes, grade, lengths, angles, connector sizes, orientations and positions.

8.3.2.3. Bracing

Bracing layout and details shall be provided for the total ETP structure, by specifying the type of bracing and the connection details.

8.3.2.4. Connection

The connection method and fixing type of each member to member connection shall be clearly detailed to enable checking, installation and inspection. Type of connections shall be in accordance with sub-section 6.

8.4. Material and testing

8.4.1. Timber for ETP

8.4.1.1. Grade and Strength Group

Timber used for manufacturing of ETP intended for structural use shall be graded to Hardwood Structural Grade as stated in Table 1 MS 1714 by timber graders registered with the MTIB. The strength group shall be a minimum of SG5 or equivalent, in accordance with MS 544: Part 2. The cost involved in the visual strength grading shall be borned by the Contractor. Notwithstanding the certificate, the S.O. reserves the right to carry out independent tests at Makmal Anatomi Kayu, FRIM or Fibre and Biocomposite Centre (FIDEC), MTIB to determine the species and Strength Group (SG).

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8.4.1.2. Mixture of species

Timber of single species shall be used in a ETP structure, and it is proven to be suitable for the manufacturing of ETP by the qualification test given in MS 758. Lamination of ETP member shall not be of a mixture of different timber species.

8.4.1.3. Moisture Content

The moisture content of the timber at the time of gluing, shall be within the range of 8% to 15% for non-treated timber and 11% to 18% for treated timber as stipulated in MS 758. The range of moisture content of the laminations in a ETP member shall be not greater than 4%. Method for the determination of the moisture content of is as stipulated in MS 837 or equivalent method. The summary of standard procedure to determine the moisture content is as stated in sub-section 4.4 of this section.

8.4.2. Preservative Treatment

8.4.2.1. The timber species should attain sufficient natural durability and resistance to decay and insect attack as stipulated in MS 544: Part 10.

8.4.2.2. Where it is not possible to use timbers which have sufficient natural durability, the timber shall be preservative treated. The treatment of timbers shall be in accordance with specification stipulated in in MS 544: Part 10. If the preservative chemical is Copper Chrome Arsenic (CCA), it shall conform to MS 733 and sub-section 3.0 of this section.. If any other preservative chemical is used, the main contractor shall provide necessary documents as may be required by the S.O representative to prove the efficiency of the chemical treatment. Timber treatment with other type such as heat treatment are allowed in accordance to relevant standard.

8.4.3. Adhesive

8.4.3.1. Selection of Adhesive

The adhesive shall be capable of producing strong and durable joints, ensuring that the integrity of the bond is maintained throughout the intended lifetime of the structure. The adhesive shall meet the requirement for adhesive Type 1 and Service Classes as stipulated in Table 1 MS 758:2001.

8.4.4. Verification of Design Properties of ETP

The finished ETP shall comply to the required design properties as stipulated in MS 758. Verification shall be provided through:

8.4.4.1. Qualification Tests

(i) The Contractor shall be fully responsible to carry out qualification tests which shall be witnessed by the S.O.. The Contractor shall carry out a qualification test whenever a new process or process change involving

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new adhesive, species combination, finger joint profile and lamination thickness.

(ii) Unless otherwise stated and approved by the S.O. in writing, a minimum of five (5) qualification tests shall be carried out before any actual manufacturing is allowed.

(iii) The Contractor shall provide in test report the information on the design properties which include; characteristics values for bending strength, modulus of elasticity, compression strength, shear strength and tension strength. These properties values to be declared are characteristic values as shown in drawing.

(iv) The test shall be carried out in accordance with BS EN 408 at any accredited approved laboratory at the expense by of the Contractor.

8.4.4.2. Quality Control Tests

The Contractor shall provide information on the glue line integrity, results of delamination tests and results of glue line shear test as stipulated in MS 758. Unless otherwise stated and approved by the S.O. in writing, a minimum of ten (10) quality control tests shall be carried out before any actual manufacturing is allowed.

8.4.5. Coating Specification

8.4.5.1. All ETP members shall be coated with a minimum of two coats of a clear construction sealer to provide a moisture resistant coating and shall be applied in accordance with the manufacturers' specification to the S.O.'s approval.

8.4.5.2. This should not be considered as a final finish as rectification of damage after erection shall be part of the Contract.

8.4.5.3. Details of the sealer used shall be documented and provided for on-going maintenance of the building.

8.4.5.4. All ETP members shall routinely receive a coat of protective sealer before shipping/transport and is wrapped for protection during shipping/transport and erection. The wrapping should be left in place as long as possible and ideally until permanent protection from the weather is in place.

8.5. Manufacturing

8.5.1. Manufacturing Requirement

8.5.1.1. All glued laminated timber building components shall be manufactured and assembled by licensed glued laminated timber manufacturers approved by the S.O.. The Contractor shall provide the necessary documents relating to the proposed manufacturer such as valid licenses or other certificates to the S.O. for approval prior to the commencement of any manufacturing work.

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8.5.1.2. All glued laminated timber members shall be manufactured in a factory which has quality control and quality assurance procedures in place as approved by the S.O.. The S.O. reserves the right to visit the factory before giving any approval.

8.5.1.3. The manufacturing of ETP shall conform to MS 758 and relevant standards which specifies all the requirements for the manufacture of ETP which include among others;

(i) Production conditions – premises, and equipment and workmanship, quality assurance programme.

(ii) Adhesives - The adhesive shall meet the requirement for adhesive Type I and minimum Service Class 2 as stipulated in MS 758.

(iii) (Manufacture – laminations, bonding, clamping, curing and conditioning.

8.5.1.4. When laminations are joined by finger joints these shall be produced in conformity with BS EN 385 or equivalent Malaysian standard. The finger joint of each lamella layer shall be laid in a staggered positions.

8.5.1.5. The maximum permitted deviation from the average thickness within a lamination length of 1m is 0.2mm. Where non-gap-filling adhesives are used the limit deviation shall no exceed 0.1 mm. The difference in thickness over the cross-sectional width of the lamination shall be less than 0.15% of the width and in no case exceed 0.3mm.

8.6. Fabrication

8.6.1. Prior to fabrication, the Contractor shall notify the S.O. the dates of tests that shall be carried out. The S.O. may appoint a representative in the event the S.O. cannot be present during the tests. The Contractor shall forward a copy of the test results jointly certified by the manufacturer for the S.O.'s acceptance and approval.

8.6.2. Prior to the manufacture and fabrication of the glued laminated timber, the Contractor shall provide two (2) copies of the following documents for the S.O.'s approval:

8.6.2.1. Particulars of the manufacturer

8.6.2.2. Quality assurance programme of the manufacturing process

8.6.2.3. Method statement for assembly, installation, handling and transportation

8.6.2.4. Manufacturer's fabrication drawings

8.6.2.5. Manufacturer's assembly drawings

8.6.2.6. Grading summary of timber to be used in the manufacturing of glued laminated timber, issued by timber grader certified by MTIB

8.6.2.7. Results of qualification tests

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8.7. Handling and Installation

The Contractor shall submit method statement of installation for the approval of S.O.. The method statement shall explain the sequence of erection of ETP structures and required safety measures.

8.7.1. Handling

8.7.1.1. At all stages of construction, all ETP structures components shall be properly protected to prevent damage.

8.7.1.2. During on-site storage, ETP members shall be stored off the ground with spacer blocks spaced between members. If construction delays occur, the wrapping shall be cut on the underside to prevent the accumulation of water condensation. Proper transit, storage and construction methods are required to avoid rapid changes in the moisture content of members.

8.7.1.3. During handling, correct lifting equipment shall be used. All ETP members must be protected from damages due to strap, chains and wire ropes.

8.7.1.4. When ETP are stored on-site, they should be placed above the firm ground on supporting block to protect them from water. If the ETP members are stored horizontally, the supporting block shall be spaced as such to prevent bending of the member. If the ETP members are stored vertically, they should be supported at the designed support location in a manner to prevent tipping or toppling.

8.7.2. Installation

8.7.2.1. The installation of ETP members shall be as the approved detail drawings.

8.7.2.2. During erection, ETP must be transversely braced to provide stability in accordance to method statement prepared by the Contractor and approved by S.O.. All other bracings shall be provided for this purpose. ETP gable ends shall be braced before installation of others internal frame.

8.7.2.3. The engagement of licensed surveyor to determine the accuracy of base plate and position of ETP structure shall be under the scope of work of the Contractor.

8.7.2.4. The Contractor shall inspect the prepared foundations and holding down bolts for position and level not less than seven days before erection of ETP work starts. He shall then inform the S.O.. If he finds any discrepancies which are outside the deviations specified in the drawing requesting that remedial work be carried out before erection commences.

8.8. Defects and alteration

8.8.1. Glued laminated timber structures shall not have any debonding. Glued laminated timber structures affected by debonding shall be marked as ‘Rejected’ and removed from site.

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8.8.2. No element of the ETP roof truss, roof frames or roof ancillary members shall be cut or notched or removed or otherwise altered from its original state without the prior written approval of the S.O..

8.8.3. Where defects exceeding the limits or permitted tolerances are detected, rectification works shall be carried out based on the recommendations made by the P.E. and to the approval of the S.O..

8.9. Warranty

8.9.1. The Contractor shall submit to the S.O. a performance warranty by the Contractor on the performance of the ETP member against debonding which may occur during a period of ten (10) years from the date of practical completion. The terms of the performance warranty shall be as stipulated in **APPENDIX H/1** and as approved by the S.O..

9. Carpentry Works

9.1. All carpentry shall be accurately set out in strict accordance with the Drawings and shall be framed together and securely fixed to the approval of the S.O.. Timber framing shall be properly braced and checked, halve, screwed or bolted together as required. Longitudinal joints in plates, ridge, fascias, et cetera shall be formed over supports. Those timber members with lapped joints shall lap at least 150mm or twice the depth of the timber whichever is the greater. The brads, nails, screws, spikes, plugs, bolts, framing anchors and timber connectors shall be provided wherever necessary and as detailed. Other than those detailed, no joints are permitted in structural work unless prior permission is obtained from the S.O.. No structural member shall be notched unless instructed by the S.O..

9.2. For the carpentry works, timbers shall, as far as possible be in piece between continuing lengths. At corners, timbers shall be halved for materials of the same thickness, and sufficiently lapped for materials of different thicknesses.

10. Joinery Works

10.1. All doors, windows, louvers, screens and the like shall be constructed as shown in the Drawings. Frames shall be assembled at the commencement of the work and all members shall be carefully morticed and tenoned together but no wedging, pinning or gluing shall be done until the framing is prepared in readiness for immediate fixing. All doors, windows, louvers, screens and the like shall be properly stored on site.

10.2. Immediately before fixing in its final position, joinery shall be wedge and pinned by drawn hole pinning with 10mm diameter Strength Group 1 and 2 timber dowels pins. The pins shall be left projecting until permission is given for flushing off. The methods of framing and putting together of all Works shall be approved by the S.O. before being executed. Any portions that warp, twist or develop any other defects shall be replaced before wedging up. All framed work shall be pinned before being framed together.

10.3. The choice of species for joinery should be based on working properties of timbers that is maximum percentage of shrinkage.

10.4. Jointing or connection for joinery that is nailed joint, screwed joint, coach screwed joint or bolted joint shall comply with MS 544 : Part 5.

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11. Timber Floor Finish

11.1. Unless otherwise shown in the Drawings, timber floors shall be constructed using 100mm x 38mm wrot, tongued and grooved boarding's, well cramped up and secret nailed to each joist or batten with 62mm wire nails. Floor boarding shall be in long lengths with splayed heading joints and no two adjacent joints shall occur over the same joist. On completion, the flooring shall be planed, sanded and all gaps sealed with an approved sealer. The floor shall then be cleaned off and unless otherwise specified, it shall be finished with three coats of approved polyurethane paint applied strictly in accordance with the manufacturer's instructions.

11.2. Wrot timber skirting shall be provided where shown and as detailed in the Drawings. Skirting shall be in long lengths with splayed heading joints and with mitres, returns and ends neatly cut and fitted and fixed to grounds.

11.3. Where engineered timber flooring are specified or shown in the Drawings, it shall be finished with high abrasive protective overlay and a moisture barrier balancing film to be applied on timber flooring backing in accordance with the manufacturer's recommendations and S.O.'s approval.

11.4. Timber strip and parquet flooring shall be as specified in SECTION K: PLASTERING, PAVING, TILING AND CARPET.

12. Ceiling Timber Battens

Where ceiling battens are used for ceilings, it shall be fixed to the frames with butt `V' joint using nails or screws. Asbestos-free cement flat sheets for ceiling shall be 5mm thick fixed to frames using mitred profiled timber cover battens and brass screws with rounded edge beading. Ceiling panels shall be set out symmetrically from the centre line of the ceiling. Suspended ceiling systems shall be as specified in SECTION I: CEILING.

13. Timber Partitions

Non-structural timber partitions shall be as specified in SECTION E: WALL SYSTEM.

14. Fascia And Barge Boards

Unless otherwise shown on the Drawings, fascia and barge boards shall be 25mm thick wrot timber and supplied in long lengths. The boards shall be fixed in whole lengths and where joints are necessary, they shall be scarfed jointed and the joints shall occur only over the ends of roof framing members and mitred corners. Board, 250mm wide and less shall be in one width and those deeper shall be formed by multiple of boards jointed together by tongue and groove and 'V' joint.

15. External Boarding

15.1. Unless otherwise shown on the Drawings, all external boarding shall be formed with 150mm x 19mm horizontal, vertical or diagonal boarding in wrot pressure-treated timber in long lengths and to the sectional profile as detailed in the Drawings.

15.2. Unless otherwise shown, lapping for plain weather boarding shall be 38mm. Boarding shall be secured to the frames using 75mm galvanized steel nails and in the case of plain weather boarding, nails shall not be driven through the lapped

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portions. The exposed bottom ends of all external vertical boarding shall be splayed inward at an angle of 30º and treated with preservatives.

15.3. The timber boarding shall be cleaned off and unless otherwise specified, it shall be finished with approved polyurethane base paint with UV protection applied strictly in accordance with the manufacturer's recommendations. The strength grouping for external timber flooring shall be in accordance with the Properties of Malaysian Timber as shown hereinafter in **TABLE H8**.

15.4. For coastal environments and exposed weather applications subjected to airborne salts deposition, metal connectors and fasteners used shall comply with AS 3566 Class 4 and be certified as such by the supplier of fasteners and to the approval of the S.O..

15.5. All fixings and associated components shall be manufactured from compatible metals and coated conforming to ISO 9223 Category 4 (C4) and Category 5 (C5) environment. Flashings shall be made from the same material as the roofing sheets.

16. Staircase And Balustrades

16.1. Unless otherwise shown in the Drawings, the Contractor shall prepare Shop Drawings as required for the Works. Prior to the fabrication and installation works, the Contractor shall submit the Shop Drawings to the S.O.'s for approval.

16.2. The preferred sizes for modular staircase and stair openings shall comply with MS 1064: Part 3.

17. Timber Solid Panel Doors

17.1. All fire doors shall be of the appropriate Fire Resistance Period (FRP) in accordance with the Ninth Schedule of the Uniform Building By-Laws.

17.2. All fire doors including frames shall be constructed to a specification of the relevant FRP in accordance with MS 1073 and shall be tested by a laboratory, approved and certified by DGFR and have obtained a Product Certification Scheme from an accredited certification body.

17.3. All double leaf doors with rebated meeting stiles shall be provided with coordinating device so as to fit fully within the door openings with a gap of not more than 3mm between the frame and the edge of the door when closed

17.4. Where shown on the Drawings, approved vision panel of suitable size shall be incorporated in the Fire Rated Door.

17.5. Flush doors shall generally comply with MS 1506: Specification for Wooden Door with plywood facing and strength group 1 and strength group 2 timber lipping, mitred around all edges. The plywood and strength group 1-4 shall in all respects with the Specifications mentioned hereinbefore.

17.6. The preferred sizes for modular door sets shall comply with MS 1064: Part 4 and for modular windows shall comply with MS 1064: Part 5.

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18. PVC Doors

18.1. Unless otherwise specified in the Drawings, PVC doors shall be of strong impact resistance and waterproof/moisture resistant laminated timber finish on both sides. Unless otherwise shown in the Drawings, the door shall be 38mm thick.

18.2. PVC toilet doors shall be of full single panel of flush type. It shall be 100% waterproof, strong impact resistance and not be discoloured easily. Unless otherwise shown on the Drawings, the door shall be 38mm thick. PVC door shall be delivered to the site complete with ironmongery as listed in the '**TABLE 9**: SCHEDULE OF IRONMONGERY'.

19. Products And Materials

19.1. Plywoods

19.1.1. Unless otherwise specified, plywood used for interior and exterior purposes other than for formworks and temporary works shall be manufactured with Moisture Resistant (MR) bond and Weather and Boil Proof (WBP) bond respectively in compliance with MS 228. Boards which are to be painted or varnished shall be properly sanded down and holes and crevices filled with approved wood putty or filler.

19.1.2. Plywood intended for use as shuttering board shall be of the Weather and Boil Proof (WBP) type.

19.1.3. Plywood intended for structural use, shall be of Malaysian Basic Structural Grade (MBSG) rated or equivalent and shall comply with MS 544: Part 4.

19.1.4. Plywood to be used in marine environment or severe wet conditions shall be in accordance with MS 544: Part 4.

19.2. Blockboard

19.2.1. Blockboard shall comply with MS 1123. Fixing of blockboards shall generally be in accordance with the manufacturer's instructions.

19.2.2. Boards which are to be painted or varnished shall be properly sanded down and holes and crevices filled with approved wood putty or filler to the approval of the S.O..

19.3. Chipboards

19.3.1. Chipboards shall be of the type manufactured from wood chips or shavings combined with a thermosetting synthetic resin glue binder bonded and hot-pressed together and complying with MS 1036 for medium density chipboard. The type and quality of boards shall be approved by the S.O.. The boards shall be fixed as detailed in the Drawings with a minimum edge distance of 12mm for nailing.

19.3.2. Boards which are to be painted or varnished shall be properly sanded down and holes and crevices filled with approved wood putty or filler to the approval of the S.O..

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19.4. Fibre Building Boards

19.4.1. All fibre building boards namely, Hard Board, Medium Board and Medium Density Fibre Board (MDF) shall comply with MS 1429 and MS 1912. The type and quality of Fibre building boards shall be as approved by the S.O. Perforated hardboards shall be not less than 3.2mm thick with maximum of 4.8mm perforation at 19mm centers unless otherwise stated in the Drawings.

19.4.2. All fibre building boards shall be fixed strictly in accordance with the manufacturer's instruction. Unless otherwise detailed in the drawings, the ceiling boards shall be butt and `V' jointed.

19.5. Composite Boards

19.5.1. The type and quality of composite boards shall be as approved by the S.O. and shall be fixed strictly in accordance with the manufacturer's instruction.

19.5.2. Fixing of timber base composite boards shall comply with the manufacturer's instructions. Panels which are to be painted or varnished shall be properly sanded down and holes and crevices filled with approved wood putty or filler to the satisfaction of the S.O.. Panels which are for wet prone area, shall comply with MS 1787.

19.6. Woodwool Slabs

Woodwool slab shall comply with MS 1036 and shall be of the type and quality as approved by the S.O.. Unless otherwise specified in the Drawings, the slab shall be laid with its length at right angles to support, fixed strictly in accordance with the manufacturer's instruction.

19.7. Wood Cement Boards

19.7.1. Wood cement boards shall comply with the requirements of MS 934 or MS 544: Part 4. In fixing, the board must be supported on all four edges and at immediate positions at centres not exceeding 610mm. Joints between boards shall occur on centers of supports. Minimum edge distance shall be 20mm.

19.7.2. Boards which are to be painted shall be lightly sanded and any dust shall be removed from the surface with a piece of clean coarse cloth. Any filling compounds used shall be alkali-resistant. Fixing of the board shall be in accordance with the manufacturer's instructions.

19.8. High Pressure Laminate (HPL)

High Pressure Laminate is a thermoset paper/plastic composite, where decorative papers impregnated with melamine are consolidated over phenolic-impregnated craft papers at high temperature and pressure to form a homogenous laminate. Unless otherwise specified, HPL shall comply with MS 1787: Part 1-15 for durability.

19.9. Wood Plastic Composite (WPC)

WPC shall be made from minimum 70% rice husk and balance recycled HDPE. WPC solid decking system shall be of 145mm (w) x 25mm (t) fixed onto 300mm c/c on Suspended Leveling System with hot dipped zinc-aluminium alloy coated steel with a minimum coating mass of AZ150 to AS/NZS 1397-2002 steel sheet

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grade G300 on to flat concrete slab with ENSS03 stainless steel clip, all in accordance with manufacturer's recommendation and S.O.'s approval.

20. Ironmongery

20.1. Unless otherwise shown on the Drawings, the Contractor shall supply and fix all ironmongery as listed in the **TABLE H9**: Schedule of Ironmongery attached hereinafter, complete with fixing screws of the same material and finish.

20.2. Proper sockets shall be provided for all bolts to fix flush in floors, cills and door and window frames. Each lock shall be provided with three keys and no locks shall have identical keys, unless specifically required by the S.O..

20.3. All doors, windows, gates, joinery, et cetera, shall be provided with anti-rust heavy duty ironmongery appropriate for its function, complete with fixing screws of the same material and finish

20.4. All doors shall be provided with door-stops, door-closers and other appropriate ironmongery where applicable or as shown on the Drawings.

20.5. The submission of ironmongery set shall have been tested and certified by Certification bodies accredited by Jabatan Standard Malaysia.

21. Built-in Furniture

21.1. General

21.1.1. Built-in furniture shall be constructed and properly framed in wrot timber as shown on the Drawings. Where fittings are not to be painted, unless otherwise specified, they shall be stained and varnished as described in SECTION O:PAINTING.

21.1.2. All interior furniture works shall be coordinated with mechanical and electrical works and as approved by the S.O..

21.1.3. All built-in furniture materials shall be protected wrapped in strong waterproof paper or polythene/polyethylene (PE) sheeting to protect against damp and scratching during transportation from the factory. The wrapping shall not be removed until installation starts.

21.1.4. Built-in furniture materials shall be unloaded and handled in a manner which will not result in damage, deformation or contamination to the built-in furniture materials.

21.1.5. Built-in furniture materials and loose furniture delivered to the site shall be properly stored by arranging them in stacks, keeping them properly wrapped and stored under cover if they are not used or assembled immediately.

21.2. Materials

21.2.1. All composite wood products, such as Medium Density Fibreboard (MDF) shall comply with MS 1429 and the use of Particleboards shall comply with MS 1912.

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21.2.2. The formaldehyde emission for all composite wood products and wood based panels shall comply with MS 1787.

21.2.3. Laminates used in composite wood products shall comply with MS ISO 4586.

21.2.4. Unless otherwise specified in the Drawings or Specification the resin used in composite wood products shall be phenol-formaldehyde (PF), melamine-urea-formaldehyde (MUF), melamine-urea-phenol formaldehyde (MUPF), polymeric diphenyl methane diisocyanate (PMDI) or polyurethane (PU).

21.2.5. Adhesive for wood and composite wood products shall be phenol-formaldehyde resin adhesive classified as weather-proof and boil-proof, in accordance with MS 908.

21.2.6. Thermoplastic fittings, such as handles and accessories, where applicable, shall be polyamide (PA) or polypropylene (PP). Thermoplastics shall comply with MS 2324.

21.2.7. Solid surface shall be non-porous, homogenous, stain and chemical resistant, fire resistant and with a composition of acrylic polymer, aluminium trihydrate filler and pigment.

21.2.8. Where timber species are used it shall be constructed and properly framed in wrot timber as detailed in the Drawings.

21.3. Component Assemblies

21.3.1. Unless otherwise stated in the Drawings, steel frames, where applicable, shall be square and flat with mitred, welded corners.

21.3.2. Screws shall have countersunk heads which shall comply with MS ISO 1482.

21.3.3. Hinges shall have a spring mechanism to lock the door in a close or open position, remain completely hidden behind the door and enable the door to open to 120º.

21.3.4. Drawer slides shall be epoxy powder coated metal, mounted from the bottom and provided with friction bearing-mounted nylon rollers.

21.3.5. Unless otherwise specified, drawers shall have the ‘soft-close’ and/or ‘positive-close’ functions, which are mechanisms enabling drawers to quietly shut, or which fully shut after being only partially pushed. Drawers can be lifted up and removed easily for cleaning purposes.

21.3.6. All drawers, unless otherwise specified, shall have ¾ extension and be able to sustain up to 25kg. Kitchen cabinet drawers shall have full extension and be able to sustain up to 45kg, which is suitable for large pots, pans and/or woks.

21.3.7. Drawers for storing small kitchen cutlery shall have thermoplastic inserts with subdivided compartments.

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21.3.8. Drawer handles and cabinet pulls shall be ergonomic. Thermoplastic handles and pulls shall recess into the door panels. Metal handles and pulls that extrude shall either be epoxy powder coated and/or anodized aluminium.

21.3.9. Solid surface worktops and countertops shall be 12mm thick, 600mm deep with backsplash 100mm high, with integral bowl, where applicable. Actual dimension of solid surface worktops shall be measured at site. Upon installation of the solid surface worktops, it shall be polished and set level to S.O.'s approval.

21.3.10. Unless otherwise specified, worktops and countertops shall have a flat edge finishing at the perimeter. Worktops and countertops shall be provided with holes and cut-outs for plumbing components, where applicable. All joints shall be inconspicuous and use the manufacturer's recommended adhesive and silicone sealant.

21.3.11. Built-in furniture sliding doors shall be fitted with guides or similar fittings, rollers or ball bearings, pull handles, stops and locking mechanisms.

21.3.12. Cabinet doors with glass inserts and/or panels shall be constructed with proper support to ensure that the glass remains securely fixed. Support shall be bedded in mastic with all interstices completely filled.

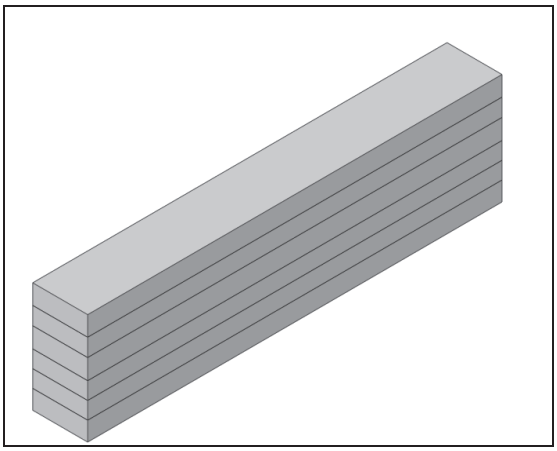
21.3.13. Glass inserts and/or panels and glass shelves, where applicable, which needs to be structurally strong shall be tempered glass. Tempered glass shall comply with MS 1498.

21.3.14. Cupboards, wardrobes, cabinets and shelves shall have peg-holes on either side internally, allowing for adjustable shelf height. Adjustable legs, if applicable, shall be of a proprietary system type as approved by the S.O..

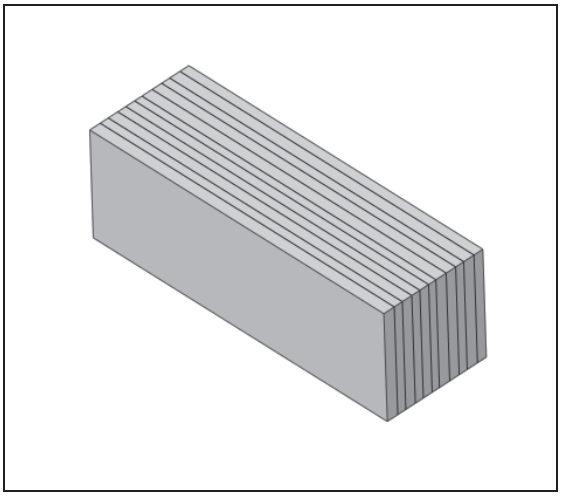
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FIGURE H1: ENGINEERED TIMBER PRODUCTS:

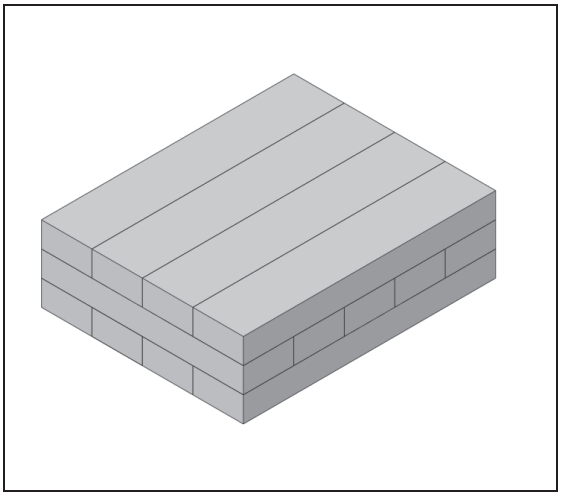
(a) Glued Laminated (Glulam) Timber



(b) Laminated Veneer Lumber (LVL)



(c) Cross Laminated Timber (CLT)



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Table H1. Schedule of Timber Grouping and Usage

No	Typical Usage	Species
1	**Structural frames**	
	1.1 All columns, stilts and beams	SG4
2	**Bearer to water tank**	SG5
3	**Staircase and component elements**	
	3.1 Stinger & treads/Riser	SG5
	3.2 Trimmer beams	SG5
	3.3 Balustrades, nosing and handrails	SG5
4	**Flooring**	
	4.1 Floor bearers, joists and strutting for joists	SG5
	4.2 Floor boardings	SG5
	4.3 Gymnasium floor boarding	SG4
	4.4 Parquet flooring	SG5
	4.5 Skirtings	SG5
5	**Walling**	
	5.1 Wall and partition framings	SG5
	5.2 External wall boardings	SG5
	5.3 Internal wall boardings	SG7
6	**Roof structures**	
	6.1 Roof trusses, rafters, purlins, wall plates and other roof members	SG1 - SG4
	6.2 Fascia boards	SG5
7	**Ceiling frames**	
	7.1 Ceiling joists and spacers	SG5
	7.2 Cover battens to joints of ceiling sheets	SG7
	7.3 Ceiling strips and soffit battens	SG7
8	**Door and window frames**	
	8.1 All doors, windows, vent frames, grounds, stops and architraves	
	8.1.1 External usage	SG5
	8.1.2 Internal usage	SG7
9	**Furniture fitting**	
	9.1 Built-in fittings and furniture in general	
	9.1.1 Carcassing	SG5
	9.1.2 Lining/Panelling	SG7
	9.1.3 Top	SG5
	9.2 Workshop furniture top	SG5
10	**Beading fillets and edgings in general**	SG5

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Table H2. Schedule of Timber Species in accordance with Strength Grouping (S.G)

S.G 1	S.G 2	S.G 3	S.G 4	S.G 5	S.G 6	S.G 7
A) Naturally Durable						
Balau	Belian	Bekak	Giam	Jati		
Bitis	Mata Ulat	Delek	Malabera	Tembusu		
Cengal	Kekatong	Keranji	Merbau			
Penaga			Resak			
B) Requiring Treatment						
	Dedaru	Agoho	Berangan	Alan Bunga	Bayur	Ara
	Kempas	Balau Merah	Dedali	Babai	Damar Minyak	Batai
	Merbatu	Kelat	Derum	Balik Angin Bopeng	Durian	Geronggang
	Mertas	Kembang Semangkuk	Kapur	Bintangor	Jelutung	Laran
		Kulim	Kasai	Brazil Nut	Jenitri	Pelajau
		Pauh Kijang	Keruntum	Gerutu	Jongkong	Pulai
		Penyau	Mempening	Kundur	Kasah	Sesenduk
		Perah	Meransi	Kedondong	Macang	Terentang
		Petaling	Meranti Bakau	Keledang	Medang	
		Ranggu	Merawan	Keruing	Melantai/ Kawang	
		Ru	Merpauh	Ketapang	Meranti Merah Muda	
		Surian Batu	Nyalin	Kungkur	Meranti kuning	
		Tualang	Perupuk	Melunak	Mersawa	
			Punah	Mempisang	Sengkurat	
			Rengas	Mengkulang	Terap	
			Simpoh	Meranti Merah Tua		
				Meranti Putih		
				Nyatuh		
				Penarahan		
				Petai		
				Ramin		
				Kayu Getah		
				Sengkuang		
				Sepetir		
				Tetebu		

Notes :

1. For naturally durable timbers, sapwood should be excluded. If sapwood is included, preservative treatment is necessary.(Source: MS 360:1986)
2. For timber requiring treatment, they should be amenable to preservative treatment.

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Table H3. Schedule of Moisture Contents (M.C) of Timber for Various Positions in Building

Application	Maximum M.C. At Time Of Installation For Non Air-Conditioned Application	Maximum M.C. At Time Of Installation For Airconditioned Application (Kiln-Dried Timber)
Structural Components • Columns, beams, bearer, studs, joists, ties and struts	30% (Thickness >100mm) 25% (Thickness <100mm)	Not applicable Not applicable
Roofing • Rafters, ties, struts, purlins and bracing • battens	25% 25%	Not applicable Not applicable
Staircase • stringers, treads, trimmer beam and handrail • balustrades	19% 19%	12% 12%
Flooring • floor boarding and parquetry • skirtings	19% 19%	12% 12%
Walling • wall, partition framing • external wall boardings • internal wall boardings • fascia boards	19% 19% 19% 19%	12% Not applicable 12% Not applicable
Ceiling Frames • cover battens to joints of ceiling sheets • ceiling strips and soffit battens **Door & Window Frames** • door, window and vent frames including their stops and grounds • door leaves, window and vent sashes	25% 19% 19% 19%	Not applicable 12% 12% 12%
Furniture • built in fittings, furniture generally • workshop furniture • science laboratory tops Beading fillets and edgings generally	19% 19% 19% 19%	12% 12% 12% 12%

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Table H4. Natural Durability[1] Classification of Peninsular Malaysia Timbers for Ground Contact

Class 1	Class 2	Class 3		Class 4	
Very durable (More than 10 years)	**Durable (5 to 10 years)**	**Moderately durable (2 to 5 years)**		**Not durable (Less than 2 years)**	
Chengal	Balau	Agoho[2]	Rengas	Api-api	Nyatoh[6c]
Giam	Bekak	Balau, red	Sepetir	Ara	Perapat
Penyau	Bitis	Bakau	Tumu	Berangan	Perah
Resak	Kasai	Bungor	Tualang	Balek angin	Perupok
Tempinis	Kapur [4a]	Derum	Telor buaya	Bintangor	Petai
	Nyatoh[6a]	Dedali	Pelong	Batai	Podo
	Merbau	Dedaru	Kerukup	Bayur	Pulai
	Mersawa	Delek	Brazil nut[2]	Damar minyak	Putat
	Merbau lalat	Dungun	Keruntum	Dungun paya	Ramin
	Delinsem[2]	Acacia[3]	Keruing[8a,b,c]	Durian	Samak
	Malabera	Pauh kijang	Keledang[9a,b]	Engkabang	Sena
	Medang[5a,b]	Kapur[4b]	Mata ulat	Jelutong	Sawa luka
	Penaga	Kelat	Medang[5c]	Gaham badak	Sepul
	Pelajau	Kembang semangkok	Meranti,[7a,b,c,d,e] dark red	Geronggang	Sesenduk
	Pelawan	Kempas	Mempening	Gerutu	Sentang[3]
	Ranggu	Keranji	Mengkulang	Gading	Simpoh
	Surian batu	Gegatal	Meransi	Gapis	Sempilor
	Teak	Kulim	Merbatu	Meranti bakau	Terentang
	Tembusu	Kungkur	Merawan	Meranti, light red	Tapus
		Leban	Merbau kera	Jenitri	Terap
		Nyalas	Meranti, white	Jongkong	Tuai
		Pauh kijang	Mertas	Kasah	Tulang daing
		Petaling	Nyatoh[6b]	Kekabu	Ketapang
		Punah	Nyireh	Kawang	Rubberwood
			Nipis kulit	Keledang[9c,d,e]	Pine[3]
				Kapur[4c]	Yemane[3]
				Kayu malam	Coconut
				Kedondong	Tengkurung
				Kungkur	Penarahan
				Meranti, yellow	Keruing[8d,e]
				Laran	Meranti tembaga
				Lelayang	Machang
				Lilin	Medang[5d, e]
				Limpaga[2]	Mempisang
				Ludai	Merbatu
				Merpauh	Melantai
					Minyak berok

NOTE:

For reference to source of data see Bibliography.

The results were obtained from the graveyard test from the Forest Research Institute Malaysia test site.

[1] All samples taken from heartwood area except for the timber which their sapwood and heartwood cannot be differentiated. Timber of the same species but from different regions in Malaysia may have different durability classifications.
[2] The timber is not Peninsular Malaysia origin.
[3] Plantation timber, originally from other countries.
[4a] *Dryobalanops aromatica*
[4b] *Dryobalanops rappa*
[4c] *Dryobalanops oblongifolia*
[5a] *Alseodaphne insignis*
[5b] *Dehaasia nigrescens*
[5c] *Cinnamomum porrectum*
[5d] *Litsea firma*
[5e] *Litsea megacarpa*
[6a] *Palaquium impressinervium*
[6b] *Palaquium maingayi*
[6c] *Palaquium gutta*
[7a] *Shorea uliginosa*
[7b] *Shorea platyclados*
[7c] *Shorea pauciflora*
[7d] *Shorea singkawang*
[7e] *Shorea curtisii*
[8a] *Dipterocarpus sublamellatus*
[8b] *Dipterocarpus crinitus*
[8c] *Dipterocarpus verrucosus*
[8d] *Dipterocarpus kerrii*
[8e] *Dipterocarpus lowii*
[9a] *Artocarpus interger*
[9b] *Artocarpus lanceifolius*
[9c] *Artocarpus dadah*
[9d] *Artocarpus rigidus*
[9e] *Artocarpus heterophyllus*

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Table H5. Natural Durability[1] Classification of Sarawak Timbers for Ground Contact

Class 1	Class 2	Class 3		Class 4	
Very durable (More than 10 years)	**Durable (5 to 10 years)**	**Moderately durable (2 to 5 years)**		**Not durable (Less than 2 years)**	
Belian	Kapur bukit	Baru	Kapur paji	Acacia	Bindang
Penyau	Kapur kelansau	Bedaru	Kapur paya	Alan	Geronggang
Selangan batu[2]	Kawi	Kandis	Luis/Chengal pasir	Asam	Jadap
	Luis	Kasai	Medang luis kasar	Bajan	Jelawai
	Lun runcing	Leban	Mengkulang	Bayur	Jelutong
	Mertama	Nyireh	Mersawa kunyit	Bengang	Kayu cina
	Nyatoh[3]	Pelajau	Petai belalang	Benuah	Kayu malam
	Rhu	Resak membangun	Sempilor	Binuang	Kelampayan
	Selangan batu[4a]	Seladah[4b, c]		Bintangor	Kembang semangkok
		Selumar		Bintawak	Kepayang babi
		Selunsur		Dungun	Keranji
		Tapang		Durian	Keruing
		Urat mata		Empenit	Ketiau
				Entuyut	Kumpang
				Litoh	Legai
				Medang	Meranti, light red
				Menggris	Yellow flame
				Mersawa paya	Meranti, yellow
				Minggi	Mergasing
				Ngilas	Peran/bilat
				Nyatoh[5a, b]	Segera
				Pelai	Seladah[6a, b]
				Perah	Sentang
				Perupok	Simpoh Tampoi
				Petai	Tekalong
				Pitoh	Teruntum Ubah
				Ramin	Upi
				Resak paya	
				Sawih	

[1] The results were obtained from the graveyard test from Oya Road, Sibu test site. All samples taken from heartwood area except for the timber which their sapwood and heartwood cannot be differentiated. Timber of the same species but from different regions in Malaysia may have different durability classifications.

[2] *Shorea pulricostata*

[3] *Palaquium rivulare*

[4a,b,c] *Shorea flava, S. laecis, S. spp*

[5a,b] *Dacryodes incurvata, Santira laevigata*

[6a,b] *Palaquium pseudorostratum, Ganua motleyana*

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Table H6. COMMON COMMERCIAL TIMBER SIZES

Sizes and geometrical properties of Malaysian structural timbers

Shape	Nominal Size (mm x mm)	Minimum timber sizes (mm)		
		Fullsawn	Baresawn	Dressed Timber
Square	25 x 25 (1" x 1")	28 x 28	25 x 25	20 x 20
	50 x 50 (2" x 2")	55 x 56	50 x 50	45 x 45
	75 x 75 (3" x 3")	80 x 81	75 x 75	70 x 70
	100 x 100 (4" x 4")	106 x 106	100 x 100	90 x 90
	125 x 125 (5" x 5")	131 x 131	125 x 125	115 x 115
	150 x 150 (6" x 6")	159 x 159	150 x 150	140 x 140
Rectangle	25 x 50 (1" x 2")	28 x 56	25 x 50	20 x 45
	25 x 75 (1" x 3")	28 x 81	25 x 75	20 x 70
	25 x 100 (1" x 4")	28 x 106	25 x 100	20 x 90
	25 x 125 (1" x 5")	28 x 131	25 x 125	20 x 115
	25 x 150 (1" x 6")	28 x 159	25 x 150	20 x 140
	25 x 175 (1" x 7")	28 x 184	25 x 175	20 x 165
	25 x 200 (1" x 8")	28 x 212	25 x 200	20 x 190
	38 x 50 (1½" x 2")	41 x 56	38 x 50	33 x 45
	38 x 75 (1½" x 3")	41 x 81	38 x 75	33 x 70
	38 x 100 (1½" x 4")	41 x 106	38 x 100	33 x 90
	38 x 125 (1½" x 5")	41 x 131	38 x 125	33 x 115
	38 x 150 (1½" x 6")	41 x 159	38 x 150	33 x 140
	38 x 175 (1½" x 7")	41 x 184	38 x 175	33 x 165
	38 x 200 (1½" x 8")	41 x 212	38 x 200	33 x 190
	50 x 75 (2" x 3")	55 x 81	50 x 75	45 x 70
	50 x 100 (2" x 4")	55 x 106	50 x 100	45 x 90
	50 x 125 (2" x 5")	55 x 131	50 x 125	45 x 115
	50 x 150 (2" x 6")	55 x 159	50 x 150	45 x 140
	50 x 175 (2" x 7")	55 x 184	50 x 175	45 x 165
	50 x 200 (2" x 8")	55 x 212	50 x 200	45 x 190
	63 x 100 (2½" x 4")	68 x 106	63 x 100	58 x 90
	63 x 125 (2½" x 5")	68 x 131	63 x 125	58 x 115
	63 x 150 (2½" x 6")	68 x 159	63 x 163	58 x 140
	63 x 175 (2½" x 7")	68 x 184	63 x 175	58 x 165
	63 x 200 (2½" x 8")	68 x 212	63 x 200	58 x 190
	75 x 100 (3" x 4")	80 x 106	75 x 100	70 x 90
	75 x 125 (3" x 5")	80 x 131	75 x 125	70 x 115
	75 x 150 (3" x 6")	80 x 159	75 x 175	70 x 140

(Source : MS 544 : Part 2)

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Table H7. Minimum required size of Washers for Structural Bolted Joints

Bolt diameter (mm)	Washer size (mm)		
	Thickness	Min. diameter for round washers	Min. side length for square washers
M6	1.6	30	25
M8	2.0	36	32
M10	2.5	45	40
M12	3.0	55	50
M16	4.0	65	57
M20	5.0	75	65
>M20	6.0	85	75

(Source: MS 544 : Part 6)

Table H8. Properties of Malaysian Timber

Heavy Hardwoods				
No	Species	Strength	Tangential Movement	Air-dry density (kg/m^3)
1	Balau	Very strong	2.1 – 2.5%	850-1155
2	Merbau	Strong	2.1 – 2.5%	515-1040
3	Red Balau	Strong	2.1 – 2.5%	800-880
Medium Hardwoods				
1	Kelat	Strong	2.1 – 2.5%	495-1010
2	Kempas	Very strong	> 3.1%	770-1120
3	Keruing	Strong	2.6 – 3.0% 3.1%	690-945
4	Mengkulang	Strong	2.1 – 2.5%	625-895
5	Merpauh	Strong	1.5 – 2.0%	640-880
Light Hardwoods				
1	Bintagor	Moderately strong	1.5 – 2.0%	495-865
2	Dark Red Meranti	Moderately strong	< 1.5% 1.5 – 2.0%	560-865
3	Gerutu	Moderately strong	2.6 – 3.0%	575-880
4	Mersawa	Moderately strong	2.1 – 2.5%	515-735
5	Yellow Meranti	Moderately strong	1.5 – 2.0%	575-735

(Source: Choo KT, Gan KS & Lim SC, Movement of Seasoned Timber in Service, FRIM Technical Information Handbook No. 18)

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Table H9. Schedule Of Ironmongery

Type of Doors, Windows etc.	Ironmongery for each type of doors, windows etc.
1. Single Leaf Door	
1.1. Plywood Flush Door	a) 3 Nos. of 102mm x 76mm x 2mm galvanised steel hinges with nylon rings. b) 1 No. upright 3 lever mortice lockset with satin chrome lever handle furniture of approved manufacture with 2 Nos. chrome plated keys of different serial number for each building. c) 1 No. stainless steel door stopper.
1.2. Timber Panelled Door	a) 3 Nos. of 102mm x76 mm x 2mm stainless steel hinges with nylon ring. b) 1 No. medium duty cylindrical lockset, 5 pin tumbler with knob and rose of stainless steel with hairline finish complete with 3 Nos. nickle-plated brass keys of different serial number for each building. c) 1 No. stainless steel door stopper.
2. Double Leaf Door 2.1. Plywood Flush Door	a) 6 Nos. 102mm x 76mm x 2mm stainless steel hinges with nylon rings. b) 1 Set Hollow Lever Handle Stainless Steel Mortice Lock Body with single key thumb turn cylinder. c) 1 No. solid brass mortice lock rebated part. d) 1 Set of 150mm and 300mm Flush Bolt Lever Type Stainless Steel. e) 1 No. dust socket medium. f) 2 Nos. stainless steel door stopper.
2.2. Timber Panelled Door	a) 6 Nos. 102mm x 76mm x 2mm stainless steel hinges with nylon rings. b) 1 No. cylindrical lock stainless steel, 5 pin tumbler with knob and rose of stainless steel with 3 nos nickle-plated brass keys c) 1 No. solid brass mortice lock rebated part. d) 1 Set of 150mm and 300mm Flush Bolt Lever Type Stainless Steel. e) 1 No. dust socket medium. f) 2 Nos. stainless steel door stopper.
3. PVC Door To Toilet /Bathroom Cubicles	a) 3 Nos. 102mm x 76mm x 2mm stainless steel hinges with nylon rings. b) i) Residential Quarters - 1 No. stainless steel cylindrical lock with privacy locking device operated by turn from inside and knob handle. ii) Non-residential buildings - 1 No. stainless steel indicator bolt toilet. c) 1 No. hat & coat hook stainless steel.
4. Single Leaf Fire Rated Door	
4.1. Standard size of 800 mm x 2100 mm ½ hr & 1 hr fire rated door (Metal Frame & Timber Door)	a) 3 Nos. 127mm x 89mm x 2.5mm heavy duty stainless steel hinges. b) 1 Set Hollow Lever Handle Stainless Steel Mortice Lock Body with single key thumb turn cylinder approved by DGFR. c) 1 No. stainless steel door stopper. d) 1 No. door closer. e) 1 No. floor spring for double swing door.
4.2. Standard size of 900 mm x 2100 mm ½ hr & 1 hr fire rated door (Metal Frame & Timber Door)	a) 3 Nos. 12mm x 89mm x 2.5mm heavy duty stainless steel hinges. b) 1 Set Hollow Lever Handle Stainless Steel Mortice Lock Body with single key thumb turn cylinder approved by DGFR. c) 1 No. stainless steel door stopper. d) 1 No. door closer. e) 1 No. floor spring for double swing door.
4.3. Standard size of 900mm x 2100mm 2 hr fire rated door (Metal Frame & Timber Door)	a) 4 Nos. 127mm x 89mm x 2.5mm heavy duty stainless steel hinges. b) 1 Set Hollow Lever Handle Stainless Steel Mortice Lock Body with single key thumb turn cylinder approved by DGFR. c) 1 No. stainless steel door stopper. d) 1 No. door closer. e) 1 No. floor spring for double swing door. f) 2 Nos. of ball bearings. g) 1 No. of heavy duty stainless steel latch with 75 mm long backset.
5. Double Leaf Fire Rated Door	
5.1. Standard size of 1200mm x 2100mm	a) 4 Nos. 127mm x 89mm x 2.5mm heavy duty stainless steel hinges. b) 1 Set Hollow Lever Handle Stainless Steel Mortice Lock Body with single key thumb turn cylinder approved by DGFR. c) 1 No. solid brass mortice lock rebated part. d) 1 Set of 150 mm and 300 mm Flush Bolt Lever Type Stainless Steel. e) 1 No. dust socket medium.

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