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STANDARD SPECIFICATIONS FOR BUILDING WORKS **2025**



JABATAN KERJA RAYA MALAYSIA

STANDARD SPECIFICATIONS

FOR BUILDING WORKS

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COMMITTEE REPRESENTATION

This Standard Specifications for Building Works 2025 was managed and developed by the Jabatan Kerja Raya Malaysia with the assistance of the Main Committee of Standard Specifications for Building Works 2025, which comprises representatives from the following departments:

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Cawangan Dasar Dan Pengurusan Korporat (CDPK)
Cawangan Perancangan Aset Bersepadu (CPAB)

PREFACE

This Standard Specifications for Building Works 2025 was prepared by the Jabatan Kerja Raya (JKR) Malaysia to replace the Standard Specifications for Building Works 2020. 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 2025 is divided into 25 Sections. Appendix A1 of Section A: Preliminaries and General Conditions, make reference to the relevant Acts, Regulations and Guidelines etc.. 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 affected to suit the requirement of the particular project.

For Design and Build projects, the term 'Superintending Officer (S.O.)' shall mean or refer to Project Director (P.D.).

The Committee of Standard Specification for Building Works 2025 was established 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

AASHTO	-	Standard Method of Test for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
ACC	-	Autoclaved Aerated Concrete
ACMV	-	Air-Conditioning and Mechanical Ventilation
AHU	-	Air Handling Unit
ANSI	-	American National Standards Institute
AS	-	Australian Standard
AS/NZS	-	Australian/New Zealand Standard
ASHRAE	-	The American Society of Heating, Refrigerating and Air-Conditioning
ASTM	-	The American Society for Testing and Materials
B.Q.	-	Bills of Quantities
BIOECODS	-	Bio-Ecological Drainage System
BS	-	British Standard
CBR	-	California Bearing Ratio
CD	-	Cross section
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
CMGD	-	Certificate Making Good Defect
CoW	-	Clerk of Works
CP	-	Codes of Practice
CPC	-	Certificate Practical Completion
CPC	-	Certificate of Practical Completion
CPM	-	Critical Path Method
CWMP	-	Construction Solid Waste Management Plan
DGFR	-	Director General of Fire and Rescue
DOE	-	Department of Environment
DOSH	-	Department of Occupational Safety and Health
DPAK	-	Dasar Pengurusan Aset Kerajaan
DPC	-	Damp Proof Course
DPM	-	Damp Proof Membrane
E.O.	-	Environmental Officer
EIA	-	Environmental Impact Assessment
EMP	-	Environmental Management Plan
EMR	-	Environmental Monitoring Report
EN	-	European Standards
EPD	-	Environmental Protection Department
EQA	-	Environmental Quality Act 1974
ESC	-	Erosion and Sedimentation Control
ESCP	-	Erosion and Sediment Control Plan
ETP	-	Engineered Timber Product
F.O.B	-	Free on Board
FRIM	-	Forest Research Institute Malaysia
GI	-	Galvanized Iron
GMS	-	General Market Specification
GPSS	-	Manual for Green Product Scoring System
HOPT	-	Head of Project Team
IBS	-	Industrialised Building System
ICE	-	Institute of Civil Engineers
ISO	-	International Organization for Standardization
JAS	-	Jabatan Standard Malaysia
JAS	-	Jabatan Alam Sekitar
JBPM	-	Jabatan Bomba dan Penyelamat Malaysia
JBPM	-	Jabatan Bomba dan Penyelamat Malaysia
JIS	-	Japanese Industrial Standards
JKR	-	Jabatan Kerja Raya

JMG	-	Jabatan Mineral dan Geosains
JPS	-	Jabatan Pengairan dan Saliran Malaysia
JPSPN	-	Jabatan Pengurusan Sisa Pepejal Negara
JSM	-	Jabatan Standard Malaysia
LED	-	Light Emitting Diode
M&E	-	Mechanical and Electrical
MAMPU	-	Malaysian Administrative Modernisation and Management Planning Unit
MBSG	-	Malaysia Basic Structural Grade
MDD	-	Maximum Dry Density
MOH	-	Ministry of Health
MPAM	-	Manual Pengurusan Aset Menyeluruh Kerajaan
MS	-	Malaysian Standard
MSIG	-	Malaysian Sewerage Industry Guideline
MSMA	-	Manual Saliran Mesra Alam
MTIB	-	Malaysian Timber Industry Board
MTL	-	Max Test Load
MTO	-	Modal Transport Operators
MTR	-	Material Test Report
NCR	-	Non-conforming reporting
NREB	-	Natural Resources and Environment Board
NSW	-	Non-structural wall
NWQS	-	National Water Quality Standards
OMC	-	Optimum Moisture Content
OMM	-	Operation Manual and Maintenance
OSH	-	Occupational Safety and Health
OSHA	-	Occupational Safety and Health Act
P.E.	-	Professional Engineer
P.E.P.C	-	Professional Engineer with Practicing Certificate
PDRM	-	Polis Diraja Malaysia
PeDATA	-	Pengumpulan Data & Pelabelan Aset Tak Alih
PeDATA	-	Garis Panduan Pengumpulan Data Aset Tak Alih
PERHILITAN	-	Jabatan Perlindungan Hidupan Liar dan Taman Negara
PMS	-	Pantone Matching System
PPS	-	Perakuan Pematuhan Standard
PVC	-	Polyvinyl Chloride
PVD	-	Prefabricated vertical Drains
PWD	-	Public Work Department
QA	-	Quality Assurance
QAP	-	Quality Assurance Plan
QC	-	Quality Control
R.O.W.	-	Right of Way
RORO	-	Roll-On Roll-Off
S.O.	-	Superintending Officer
S.P.	-	System Provider
SAKPKR	-	Surat Arahan Ketua Pengarah Kerja Raya
SFC	-	Sabah Wildlife Department, Sarawak Forestry Corporation
SIRIM	-	Standards and Industrial Research Institute of Malaysia
SKATA	-	Sistem Kod Aset Tak Alih
SKKP	-	Sijil Kemahiran Kompetensi Pembinaan
SPAN	-	Suruhanjaya Perkhidmatan Air Negara
SPAS	-	Sistem Pengurusan Alam Sekitar
SPB	-	Sistem Pengurusan Bersepadu
SPK	-	Sistem Pengurusan Kualiti
SSTS	-	Septic Tank, Small Sewage Treatment System
STP	-	Sewerage Treatment Plant
SUStoM	-	Sarawak Urban Stormwater Management
SW	-	Structural wall
TAM	-	Total Asset Management
TNB	-	Tenaga Nasional Berhad
UBBL	-	Uniform Building By-Laws

uPVC	-	Unplasticised Polyvinyl Chloride
UV	-	Ultra-violet
VOC	-	Volatile Organic Compounds
WELPS	-	Water Efficient Product Labelling Scheme
WEPLS	-	Water Efficient Product Labeling Scheme

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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 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 Construction Industry Development Board Act (CIDB) Act 520 (Amendment 2011) stipulates that only building products and materials (Fourth Schedule of the Act) that have received the Standard Compliance Declaration (Perakuan Pamatuhan Standard or PPS) can be used in construction projects. The main technical document required for consideration of PPS is the Product Certification (PC) or Full Type of Test Report (FTTR) issued by any recognized accrediting body.
- 2.4. The PPS is issued to ensure that any local or imported building products and materials listed in the Fourth Schedule of the Act comply with the applicable standard, safeguarding the quality of the building materials and products to be used on site. Failure to comply with the requirements will result in a penalty as per penalty tariff stipulated in the Act.
- 2.5. The latest listing of the approved construction products and materials as prescribed in the Fourth Schedule of the CIDB Act 520 (Amendment 2011) can be accessed from the CIDB's official website; Certification of Construction Product & Material (CCPM).

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;

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- 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 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.

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- 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 respects as regards to regulations and standards, 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 QAS International Sdn. Bhd. and/or other body accredited by the Jabatan Standard Malaysia (JSM), 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 QAS International Sdn. Bhd. and/or other body accredited by Jabatan Standard Malaysia (JSM). whichever is relevant.
- 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 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

The full requirements are specified under SECTION B: SUSTAINABILITY of this Specification.

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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 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.

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12. Contractor's Plant and Machineries

- 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 craneage 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 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.

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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 than RM10 Million.

13.1.5.2. Contractor to Submit Quality Assurance Plan

- (i) The Contractor shall submit to the S.O. an outline of 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 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).

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- (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 Sistem Pengurusan Kualiti (SPK) Jabatan Kerja Raya Malaysia.

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
 - b) Possess not less than five (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 two (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.

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- 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 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 to be printed at minimum 300 dots per inch (dpi) 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, etc. 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.

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18. Temporary Diversion and Relocation of Existing Overhead and Services Underground

- 18.1. Before commencing any excavation, etc., the Contractor shall enquire from the various authorities whether any underground pipes, cables, etc. 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, etc., he shall immediately stop work and refer to the S.O. for further instructions and make arrangements for the disconnection, etc. The Contractor shall be responsible for making good all damage to the cables, etc., 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.
- 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 A1**.

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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)

The full requirements are specified under SECTION B: SUSTAINABILITY of this Specification.

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 metres 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;

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- 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;
- 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.

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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. ¹+.....

28.2. The Contractor shall store or stack at all times, all materials, tools, etc.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. Temporary Internet Access

The Contractor shall provide temporary internet access at a minimum speed of 300mbps and sufficient capacity at the S.O.'s site office for the sole use of the S.O., his representatives and staff in connection with the supervision and administration of the Contract. The Contractor shall pay for the installation, rental charges including any maintenance required by the internet provider and disconnection charges and uninstallation works.

¹+ Insert other item if required

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31. Personal Protective Equipment for S.O.

31.1. Personal Protective Equipment

The Contractor shall provide personal protective equipment as listed in JKR Specifications for Occupational Safety and Health In Constructions Works 2025 or its latest edition for the use of the S.O. and his supervisory staff throughout the duration of the Contract which comply with the DOSH requirements.

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 A2** 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 A3**.

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.

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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 m² all in accordance with the relevant drawings including water and electricity supply. The Laboratory shall be equipped with the necessary equipment required to carry out the tests as identified in **APPENDIX A4** (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 A4**.
- 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 or accredited by Jabatan Standard Malaysia (JSM) or 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 Occupational Safety and Health Act 1994 [Act 514] and all regulations thereunder, JKR Specifications for Occupational Safety and Health in Constructions Works 2025 or its latest edition and relevant local by-laws to ensure safe working area.

36. Safety, Health and Welfare

- 36.1. The Contractor shall provide and maintain at his own risk adequate water supply, power supply, sanitary system, lighting, temporary rest area, first aid facilities, drinking water and ventilation where required for use in the Works and shall pay all costs, fee and charges and comply with all safety regulations and by-laws in connection therewith.

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- 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 Ministry of Health (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 Department of Environment (DOE).
- 36.5. All safety measures shall be carried out in accordance with Occupational Safety and Health Act 1994 [Act 514] and all regulations thereunder, JKR Specifications for Occupational Safety and Health in Constructions Works 2025 or its latest edition 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 full time competent and qualified person as Safety and Health Practitioner throughout the entire contract period as below:

Project Cost (RM)	Requirement of Person
More than RM20 million	1 Safety and Health Officer (SHO) and 1 Site Safety Supervisor (SSS)
Below RM20 million	1 Site Safety Supervisor (SSS)

- 36.6. 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 Site Possession. The S-Plan shall be as per requirements in JKR Specifications for Occupational Safety and Health in Constructions Works 2025 or its latest edition. The Contractor shall submit revised S-Plan whenever required.
- 36.7. The Contractor shall form a Safety and Health Committee in accordance with the Occupational Safety and Health (Safety and Health Committee) Regulations 1996 and organise meetings at minimum once in every three (3) months.
- 36.8. The Contractor shall conduct Occupational Safety and Health (OSH) related programmes for the workmen including sub-contractors in accordance with JKR Specifications for Occupational Safety and Health in Constructions Works 2025 or its latest edition.
- 36.9. The Contractor shall carry out site safety and health inspections and submit monthly safety and health reports to the S.O. in accordance with *Prosedur Kawalan Keselamatan dan Kesihatan Pekerjaan under the latest Sistem Pengurusan Bersepadu (SPB)*, JKR - (LAMPIRAN 3 – Format Laporan Keselamatan dan Kesihatan Pekerjaan).
- 36.10. 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 Constructions Works 2025 or its latest edition.

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36.11. The Contractor shall provide and maintain adequate traffic safety signage, warning signs and warning lights at place of Works and close proximity to public.

36.12. The Contractor shall provide and maintain traffic control by competent persons including provision of flagmen where Works is in close proximity to public roads.

36.13. 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

The full requirements are specified under SECTION B: SUSTAINABILITY of this Specification.

39. Environmental Protection Works

The full requirements are specified under SECTION B: SUSTAINABILITY of this Specification.

40. Water and Air Quality, Noise and Vibration Control

The full requirements are specified under SECTION B: SUSTAINABILITY of this Specification.

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, etc. are required to be formed or left.

41.1.2. Making good of walls, ceilings, floors, roofs, etc. 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.

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- 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.
- 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, etc.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, etc.that are required for the Sub-contract Works not covered by sub-section 42.1(v) above.

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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 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 Coordinator 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 Coordinator Based on Project Cost As Followed:

Project Cost (RM)	Minimum Requirement of M&E Coordinator
Below 10 Million	One (1) CoW
Between 10 to 50 Million	One (1) Engineer & One (1) CoW
More Than 50 Million	One (1) Engineer & two (2) CoW

43.4. Qualification and Competency of M&E Coordinator:

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.

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43.4.3. Responsibilities of M&E Coordinator

43.4.3.1. The M&E 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, 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 etc..

43.5. Coordinated Drawings

The Contractor shall prepare and submit to the S.O. a complete set of Coordinated Service 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 Service 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, lightings, 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 Service 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..

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45. As-built Drawings

45.1. The Contractor shall provide and deliver to the S.O. approved As-built drawings after completion of each section of the Works in the form of:

45.1.1. Four (4) sets of As-built drawings as actually constructed pertaining to the Works including all services and facilities systems and all supporting documents such as Operation and Maintenance Manual, Testing and Commissioning Certificates.

45.1.2. Four (4) sets of Digital Copies in AutoCAD (.dwg) or any other compatible format to be stored in removable storage devices.

45.1.3. Four (4) sets of Digital Copies in Acrobat (.pdf) or any other compatible format to be stored in removable storage devices.

45.2. For building(s) / block(s)/ works with BIM adoption, the Contractor shall provide approved As-built documentation generated from the final updated Construction Model as follow:

45.2.1. 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.

45.2.2. Four (4) sets of Digital Copies in AutoCAD (.dwg) or any other compatible format to be stored in removable storage devices.

45.2.3. Four (4) sets of Digital Copies in Acrobat (.pdf) or any other compatible format to be stored in removable storage devices.

45.2.4. Four (4) sets of Digital Copies in native file format (.rvt and .dwg), Design Web Format (.dwfx and .nwd) and any other compatible format generated from As-Built Models, to be stored in removable storage devices.

45.3. 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

46.3. Introduction

46.3.1. 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.

46.3.2. Total Asset Management practices cover the asset whole life-cycle as outlined in the *Manual Pengurusan Aset Menyeluruh Kerajaan (MPAM)*, namely the following phases:

46.3.2.1. Asset Planning

46.3.2.2. Asset Creation

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46.3.2.3. Asset Utilization

46.3.2.4. Asset Disposal

46.4. General Requirement

46.4.1. 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.

46.4.2. The contractor shall have a team of experienced and adequate knowledge in operation and maintenance to ensure:

46.4.2.1. Quality of design and construction

46.4.2.2. Excellent supervision

46.4.2.3. Compliance to specification and method statement

46.4.2.4. Excellent cost control and construction period management

46.4.3. The contractor shall execute the government interest in continuous improvement agenda and applying best practices in the implementation of government programmes and projects.

46.5. Asset creation Phase

46.5.1. The highest performance deliverables shall be considered in order to fulfil government services delivery.

46.5.2. Asset creation shall be in compliance to contract requirements, existing laws and regulations.

46.5.3. The design shall incorporate design for maintainability to avoid loss to the government and affect productivity due to the following:

46.5.3.1. High operation and maintenance cost

46.5.3.2. Longer waiting time for repair works

46.5.3.3. High downtime of system/components

46.5.3.4. Risk of accident/injury during maintenance and repair works

46.5.4. Planning, design and construction of the building shall consider the following, but not limited to:

46.5.4.1. Catering for cultural diversity of the building users

46.5.4.2. Effective space planning for usage and maintenance

46.5.4.3. Ease of maintenance including accessibility for maintenance purpose.

46.5.4.4. Security and safety

46.5.4.5. Comfort and ergonomics

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46.5.4.6. Good environmental qualities

46.5.4.7. Sustainable building, energy efficient and fulfill water tightness condition

46.5.4.8. Maintainability, serviceability and accessibility

46.5.4.9. Operational efficiency of completed facility

46.5.4.10. Life Cycle Cost (Total Cost of Ownership)

46.5.4.11. Functionality

46.5.5. Space for maintenance team and works shall be provided (e.g. Utilities Room, Janitor Room)

46.6. 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.

46.7. 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 easy to maintain and easily available as approved by S.O..

46.8. Asset Registration and Labelling Works

46.8.1. 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. for approval.

46.8.2. 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.

46.9. Project Handover

46.9.1. The contractor shall provide all information required by the S.O. for the purpose of asset registration. The details are described in sub-section 46.4. and 46.5..

46.9.2. The Contractor shall submit digital copy in the form of Microsoft Word/ MS Excel files of the followings to the S.O.:

46.9.3. Label identification layout plan drawings using 'SKATA room naming convention' in hard cover binding.

46.9.4. Asset Information's form (D.A.3 - D.A.6) & template (MS Excel) format as approved by S.O.) and List of DAK Komponen (as per Borang D.A 7 in *Garis Panduan Pengumpulan Data & Pelabelan Aset Tak Alih (PeDATA): Aset Bangunan*

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- 46.10. 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..

47. Site Investigation Works

All site investigation works carried out shall comply to Standard Specification For Road Works Section 17: Site Investigation JKR/SPJ/2013-S17 or its latest version.

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, etc., 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 etc. 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 A1

LEGISLATION AND REGULATIONS

1. BS 5228: Code of Practice for Noise control on Construction and Demolition Site
2. Construction Industry Development Board Act, 1994 (Act 520) and Regulations under the Act
3. Electricity Regulations, 1994
4. Electricity Supply Act, 1990
5. Energy Efficiency and Conservation Act 2024
6. Environmental Quality Act (EQA), 1974
7. Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 2015
8. Environmental Quality (Clean Air) Regulation 2014
9. Environmental Quality (Scheduled Waste) Regulation 2005
10. Environmental Quality (Industrial Effluents) Regulation 2009
11. Environmental Quality (Sewage) Regulation 2009
12. Explosives Act 1957 (Revised 1978)
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 the Prevention of Falls at Workplaces, 2007, DOSH
18. Guidelines on Occupational Safety and Health In Tunnel Construction, 1998, DOSH
19. Guidelines on Occupational Vibration, 2003, DOSH
20. Industry Code of Practice for Safe Working in A Confined Space, 2010, DOSH
21. Irrigation Areas Act 1953 (Revised 1989)
22. Land Conservation Act 1960 (Act 385)
23. Local Government Act, 1976
24. MS 2318: Code of Practice for Demolition of Buildings, 2010
25. National Land Code (Act 56 of 1965)
26. Occupational Safety and Health Act (OSHA)1994 [Act 514] and Regulations under the Act
27. Prevention And Control of Infectious Diseases (Amendment) Act 2025
28. Protection of Wildlife Act, 1972 (Act 76)
29. Solid Waste and Public Cleansing Management Act 2007 (Act 672)
30. Solid Waste and Public Cleansing Management (Scheme for Construction Solid Waste) Regulations 2018
31. Standard ISO 45001: Occupational Safety and Health Management System
32. Standard ISO 14001: Environmental Management System

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LEGISLATION AND REGULATIONS (cont'd)

33. Street, Drainage and Building Act, 1974
34. Street, Drainage and Building Act, 1974: Act 133 and Amendment, 1978
35. The Planning Guidelines for Environmental Noise Limits and Control (DOE, 2004)
36. The Planning Guidelines for Vibration Limits and Control in Environment (DOE, 2004)
37. The Radiation Protection (Basic Safety Standards) Regulations 1987
38. Town and Country Planning Act 1976, (Act 172)
39. Uniform Building By-Laws (UBBL), 1984
40. Wildlife Conservation Act, 2010 (Act 716) Amendment 2012
41. Wildlife Conservation Enactment 1997
42. Workers' Minimum Standards of Housing and minAmenities Act 1990 (Act 446)

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APPENDIX A2

LIST OF S.O.'S FACILITIES AND EQUIPMENT

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APPENDIX A3

LIST OF S.O.'S TRANSPORT SERVICES

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APPENDIX A4

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

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Test	Equipment	Quantity
	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
	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 0.01mm divisions 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
		1

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Test	Equipment	Quantity
	28. Malaysian Standard MS 1056 – Soils for Civil Engineering Purposes – Test Method, latest edition	
	29. Malaysian Standard MS 2038 – Site Investigations – Code of Practise	1

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1. General

- 1.1. This section contains four (4) main sub-sections namely Environmental, Green Rating Tools, Energy Efficiency and Renewable Energy to assist the Government in achieving sustainable development in order to move towards a more resilient, sustainable and stable progression. The work shall be carried out all in accordance with this specification and as shown on the Drawings or as required by the S.O..
- 1.2. The environmental specification outlined in sub-section 2 covers Environmental Protection Works (EPW) that consist of Non-physical Works and Physical Works. Non-physical Works mainly involve policies, regulations, planning and community engagement activities. Physical Works mainly involve tangible actions to protect the environment. Both types of Works are essential for comprehensive environmental protection efforts.
- 1.3. The green rating tools in sub-section 3 encompasses a range of topics which aim to ensure the implementation of green rating in the projects as per requirement of Surat Arahan Ketua Pengarah Kerja Raya (SAKPKR). These include green rating implementation on products, submission, scoring and others related to Green Rating Tools are crucial for assessing and enhancing the sustainability and environmental performance of buildings and infrastructure projects.
- 1.4. The energy efficiency specification outlined in sub-section 4 is an essential aspect of sustainable development. Generally, it involves designing, constructing, and operating buildings in a manner that minimises energy consumption while enhancing a maintained comfort and functionality covered by the several conditions of energy efficiency, passive design and active design requirements and principles.
- 1.5. While sub-section 5 outlines the general principles, conditions, and requirements for renewable energy. Renewable energy refers to sources of energy that are naturally replenished and sustainable in the long term.
- 1.6. Unless otherwise specified, requirement for sub-section 3: Green Rating Tools, sub-section 4: Energy Efficiency and sub-section 5: Renewable Energy shall be applied to the projects that are required to be implemented with *Penarafan Hijau JKR* (pH JKR).

2. Environmental

2.1. Environmental Protection Works (EPW)

The Contractor shall identify the significant environmental aspects and impacts of the projects and execute all mitigating measures proposed in the Conditions of Approval by the Approving Authority and/or in the Environmental Management Plan (EMP) /Environmental Compliance Report (ECR). Reference shall be made to the JKR Standard JKR/SIRIM 3:2020 Environmental Protection and Enhancement Works for Projects or latest edition for more comprehensive understanding of the scope of works.

2.2. Non-physical works

- 2.2.1. Environmental Impact Assessment (EIA)/ Proposal for Mitigation Measures (PMM) for projects subjected to EIA/PMM study, the Contractor shall ensure full compliance to all EIA/ PMM approval conditions stipulated by *Jabatan Alam Sekitar* (JAS) or other relevant authorities (please refer to **TABLE 1** of JKR/SIRIM 3: 2020).

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2.2.2. Social Impact Assessment (SIA)

For projects subjected to SIA study, the Contractor shall ensure full compliance to all SIA approval conditions stipulated by PLAN Malaysia or other relevant Authorities.

2.2.3. Other impact assessments, if applicable, subjected to relevant Authorities' requirements;

The Contractor shall ensure full compliance to all other impact assessments such as Health Impact Assessment (HIA), Heritage Impact Assessment (HIA), Wildlife Impact Study (WIS) or other relevant assessments (if applicable) approval conditions subjected to relevant Authorities.

2.2.4. Environmental Management Plan (EMP) / Environmental Compliance Report (ECR)

2.2.4.1. The Contractor shall prepare the EMP for the following situations:

- a) Project sites located in the Environmental Sensitive Area (ESA) as defined in the National Physical Plan by PLAN Malaysia (*Jabatan Perancangan Bandar dan Desa*) and/or;
- b) Projects where EIA has been carried out and/or;
- c) as may reasonably be required.

2.2.4.2. The EMP/ ECR shall be prepared by a Registered Environmental Consultant. For EIA/PMM project, the EMP/ECR shall be submitted to *Jabatan Alam Sekitar* (JAS)/ Natural Resources and Environment Board Sarawak (NREB)/ Environment Protection Department of Sabah (EPD) for the approval, while for non-EIA/PMM projects, it shall be submitted to the S.O. for approval. The Contractor shall ensure EMP/ ECR must be approved before commencement of site clearing and earthwork activities on Site. The EMP/ECR shall be concise, up to date and site specific. The EMP/ ECR shall refer to the following but not limited to:

- a) JAS/ NREB/ EPD format for the preparation of EMP/ ECR (For EIA/PMM projects);
- b) The approved EIA/PMM report and conditions imposed (if any);
- c) JKR format based on latest Guideline JKR/SIRIM 3:2020 (For non-EIA projects) or latest edition;
- d) The Contractor is also required to submit the following documents as **TABLE 8** from JKR/SIRIM 3:2020.

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2.2.5. Environmental Officer (E.O.)

The Contractor shall appoint a qualified person as a full time E.O. to monitor the environmental management works on Site throughout the contract period for EIA/PMM project and non-EIA/PMM project (if applicable). The Contractor must submit details of the E.O. to the S.O. and obtain the S.O.'s approval prior to his/her appointment.

a) Requirements for EIA/PMM project:

E.O. shall have a Degree in Civil Engineering or Environmental Science with 3 years of related experience and be certified with CESSWI/CISEC/CePSWaM or equivalent as required by JAS/NREB/EPD.

b) Requirements for non-EIA/PMM project:

E.O. shall have a Degree in Civil Engineering or Environmental Science with 1 year of related experience.

2.2.6. Land-Disturbing Pollution Prevention and Mitigation Measures (LD-P2M2)

2.2.6.1. For EIA projects, LD-P2M2 document shall be prepared by an Environmental Consultant and submitted together with the EMP. The Environmental Consultant preparing the LD-P2M2 shall be knowledgeable, have experience in the subject matter and hold a certification as a professional in erosion and sediment control issued by the JAS (refer eGIM, 2016 and Guideline on LD-P2M2, 2017).

2.2.6.2. The LD-P2M2 shall act as a guidance to the E.O. to prevent, reduce or eliminate the generation of pollutants resulting from land disturbing activities, as well as in preparing the required documentation and reports.

2.2.7. Erosion and Sediment Control Plan (ESCP)

2.2.7.1. For development sites involving one (1) hectare or more, the ESCP shall be submitted to local Authorities for approval.

2.2.7.2. The ESCP shall be prepared in accordance with the following but not limited to:

- a) Description of site condition, concept of development, erosion and sediment control approach and any information deemed important for evaluation of the ESCP;
- b) Results of two (2) assessments (hydrological analysis and soil loss analysis)

Hydrological analysis on various site conditions including pre-construction and post-construction, every stage/phase of earthwork for construction; and soil loss analysis for the difference of soil condition before and after the inclusion of erosion and sediment control Best Management Practices (BMPs);

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c) If required, hydrogeological analysis (Analysis of ground water conditions;)

d) Engineering design and calculation of selected BMPs

The design shall cover selected runoff management BMPs, erosion control BMPs, sediment control BMPs and any part of permanent stormwater conveyance or BMPs to be utilised as erosion and sediment control on Site;

e) Site plans and Engineering Drawings

Site plans are visual interpretation of the entire ESCP and thus shall be prepared in two (2) versions, i.e. the pre-bulk grading plan and post-bulk grading plan. Engineering Drawings of selected BMPs, shall clearly state the size, dimension and detailing of structures to be constructed.

f) Other supporting documents such as Bill of Quantities (BQ) for the ESCP (breakdown of each BMPs and maintenance cost) and material or installation specifications to be applied on-site; and

g) Inspection and maintenance plan

Specify all aspects of maintenance and inspection including person-in-charge, type of maintenance and inspection required and its scheduling, as well as record keeping (checklist, test results, Drawings, maintenance log, etc.).

2.2.8. Environmental Monitoring

2.2.8.1. The Contractor shall engage a JAS/ NREB-registered Environmental Consultant to carry out environmental monitoring and to provide the Environmental Monitoring Report (EMR) upon commencement of the project to report the progress of the project and to state the environment quality within the Site.

2.2.8.2. The Contractor shall monitor parameters relevant to the project. Categories of monitoring shall include but not limited to:

- a) Performance Monitoring (PM)
- b) Compliance Monitoring (CM)
- c) Impact Monitoring (IM)

2.2.8.3. The Contractor shall ensure that all samples taken during monitoring shall be tested by an accredited laboratory. Where the use of an accredited laboratory is specified, it shall be ensured that the laboratory's scope of accreditation covers the tests to be carried out.

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2.2.8.4. The Contractor shall produce environmental monitoring reports according to the latest requirement by JAS/ NREB, consisting of in-situ and accredited laboratory results, sampling photographs with weather charts and analysis of the monitoring data in terms of environmental performance.

2.2.8.5. The Environmental Monitoring Report shall be prepared in accordance with JKR/SIRIM 3: 2020 or latest edition.

2.2.8.6. For each type of monitoring, the Contractor shall indicate the sampling and test procedures, the results and comparison to the baseline, and conclusion on result findings. The required monitoring is as follows:

- a) Water quality monitoring
 - i. Conduct in-situ quality monitoring for river/stream/other water body as specified and as shown on the Drawings or as directed by the S.O. throughout the project for the following parameters:
 - a) Turbidity;
 - b) pH;
 - c) Dissolved oxygen (DO);
 - d) Temperature and/or other parameters specified by S.O. and/or relevant Authorities.
 - ii. Conduct laboratory quality monitoring for river/stream/other water body quality monitoring as specified and as shown on the Drawings or as directed by the S.O. throughout the project for the following parameters:
 - a) Total suspended solid (TSS);
 - b) Biochemical oxygen demand (BOD₅);
 - c) Chemical oxygen demand (COD);
 - d) Eescherichia coli (E.coli);
 - e) Ammoniacal nitrogen;
 - f) Oil and grease and/or other parameters specified by S.O. and/or relevant Authorities.
 - iii. Conduct in-*situ* water quality monitoring of the sewage discharge at accommodation, workshop and canteen area as specified and as shown on the Drawings or as directed by the S.O. throughout the project for the following parameters:
 - a) Turbidity;

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- b) pH;
 - c) DO;
 - d) Temperature and/or other parameters specified by S.O. and/or relevant Authorities.
 - iv. Conduct laboratory water quality monitoring of the sewage discharge at accommodation, workshop and canteen area as specified and as shown on the Drawings or as directed by the S.O. throughout the project for the following parameters:
 - a) TSS;
 - b) BOD₅;
 - c) COD;
 - d) E.coli;
 - e) Ammoniacal nitrogen;
 - f) Oil and grease and/or other parameters specified by S.O. and/or relevant Authorities.
 - v. Conduct laboratory water quality monitoring at the discharge outlet of silt trap, sediment pond, sediment basin as specified and as shown on the Drawings or as directed by the S.O. throughout the project for turbidity and TSS.
 - vi. Conduct in-situ turbidity test at the discharge outlet of the silt trap, sediment pond, sediment basin within 30 minutes after rainfall event of more than 12.5mm or as directed by the S.O. If raining continues for more than 24-hour, the measurement shall be done daily (for EIA projects only).
 - vii. The results shall comply with the requirements from Environmental Quality (Sewage) Regulations, 2009 and National Water Quality Standards (NWQS). Depending on the discharge point to the water body, the requirement for lake and groundwater may be applicable. The requirements for both water bodies are given in Annex H of JKR/SIRIM 3:2020.
- b) Ambient air quality monitoring
- i. Conduct ambient air quality monitoring for Particulate Matters (PM₁₀/PM_{2.5}), NO₂, SO₂, CO and O₃ for 24-hour period including wind velocity and direction as specified or as directed by the S.O. throughout the project.
 - ii. All equipment or generator sets that produce heat and power shall be monitored for NO₂ and CO as specified or as directed by the S.O. throughout the contract period.

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- iii. The results shall comply with the requirements from New Malaysia Ambient Air Quality Standard (2020).

c) Noise monitoring

- i. Conduct noise level monitoring for a representative sample of locations, existing noise zones; identification of the major sources of sound including L_{eq} , L_{10} , L_{90} , L_{min} and L_{max} as specified or as shown on the Drawings or as directed by the S.O. throughout the project for daytime (7.00 am to 10.00 pm) and nighttime (10.00 pm to 7.00 am).
- ii. The location of the noise monitoring station shall be placed to the nearest sensitive receptor such as hospital, school, and housing scheme as identified and directed by the S.O.. The Contractor shall comply with the general recommendations set out in Guidelines for Environmental Noise Limits & Control 2019 (JAS) and Guidelines for Noise Labelling and Emission Limits of Outdoor Sources 2021 (JAS) or latest edition together with any other specific requirements.

d) Vibration monitoring

- i. Conduct vibration monitoring as specified or as directed by the S.O. throughout the project for ground vibration and structural vibration.
- ii. The results shall comply with the requirements from The Planning Guidelines for Vibration Limits and Control of the Environment (JAS).

e) Coral reef and seagrass bed health monitoring

- i. Where applicable, conduct monitoring throughout the project by using standard methods such as reef check survey, or line intercept transect (100m permanent transect) and 1m x 1m permanent quadrat for seagrass bed (3 quadrat on each 20m transect with start point, middle point and endpoint) for at least five sites or as determined by *Jabatan Perikanan Malaysia*. The result shall comply with the requirement given in **TABLE B1**.
- ii. Critical observation includes coral bleaching and physical damage (breakage).
- iii. Type of report to be submitted are written report, photos and video of survey site.

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TABLE B1: CORAL REEF CONTROL STANDARD

Aspects	Parameter	Observations
Coral reef health	Live coral cover according to Reef Check Procedure	Maintain live coral cover of fair category (26% to 50% live coral cover)

- f) Marine parks water quality monitoring
 - i. Conduct monitoring as specified and as shown on the Drawings or as directed by the S.O. throughout the project for the following parameters:
 - a) Turbidity;
 - b) pH;
 - c) TSS;
 - d) DO;
 - e) Sea surface temperature;
 - f) Arsenic (III);
 - g) Lead;
 - h) Oil and grease;
 - i) E.coli;
 - j) Ammoniacal nitrogen;
 - k) Phosphate and/or other parameters specified by S.O. and/or relevant Authorities.
 - ii. The monitoring parameters shall be in accordance with the Malaysia Marine Water Quality Criteria and Standard. The report shall be submitted to the *Jabatan Perikanan Malaysia* and JAS.

2.2.9. Environmental Auditing Programme

The audit programme and report submission shall be conducted with reference to JKR/SIRIM 3: 2020 or latest edition.

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2.2.10. Other Management Plans

2.2.10.1. Flora Management Plan

The Contractor shall provide a flora survey report, including Site Inventory Analysis and *Penilaian Hasil Hutan*, and prepare a Flora Management Plan as specified by *Jabatan Perhutanan Semenanjung Malaysia*, *Jabatan Perhutanan Sabah*, *Jabatan Hutan Sarawak* or other relevant Authorities, for tree conservation which includes method of preservation and course of actions to be taken, if applicable.

2.2.10.2. Wildlife/Fauna Management Plan

The Contractor shall prepare a Wildlife Management Plan and/or wildlife rescue and monitoring plan as specified by *Jabatan Perlindungan Hidupan Liar dan Taman Negara (PERHILITAN) Semenanjung Malaysia*, Sabah Wildlife Department, Sarawak Forestry Corporation (SFC) or other relevant Authorities, for monitoring, enforcement and mitigation of wildlife, if applicable.

2.2.10.3. Coral Reef and Marine Ecosystem Management Plan

The Contractor shall provide a Coral Reef and Marine Ecosystem Survey Report and prepare a Coral Reef and Marine Ecosystem Management Plan as specified by *Jabatan Perikanan Malaysia*, Sabah Parks, *Jabatan Hutan Sarawak*, SFC or other relevant Authorities, for translocation of coral colonies and immobile marine organisms, if applicable.

2.2.10.4. Construction Solid Waste Management Plan (CWMP)

The Contractor shall provide a CWMP as specified by *JKR Malaysia*, *Jabatan Pengurusan Sisa Pepejal Negara (JPSPN)* or other relevant Authorities, for management of waste including storage, segregation and disposal, if applicable.

2.2.10.5. Conservation Management Plan

The Contractor shall provide a Conservation Management Plan as specified by *Jabatan Warisan Negara* or other relevant authorities, for management of a construction site that does not disturb natural or man-made heritage sites, if applicable.

2.3. Physical Works

2.3.1. Erosion and Sedimentation Control (ESC)

2.3.1.1. The Contractor shall execute the ESCP and all control measures as shown on the Drawings or JKR/SIRIM 3: 2020 or latest edition 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 Urban Storm Water Management (MSMA) relating to erosion and sediment control.

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- 2.3.1.2. 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 and/or as directed by S.O. as well as maintenance, replacement or repairs to inadequate or damaged controls and devices to ensure effective and efficient operation.
- 2.3.1.3. The Contractor shall maintain all the temporary works regularly throughout the construction period, or as directed by the S.O. and make good of any damaged portions during the course of the works.
- 2.3.1.4. The Contractor shall make proper provision for the drainage of surface water from the work site (run-off) including rainwater from surrounding areas (run on) which drain on to the Site.
- 2.3.1.5. 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.
- 2.3.1.6. The Contractor shall implement protection measures and maintain erosion control in accordance with the requirements outlined in SECTION C: EARTHWORKS, sub-section 9.
- 2.3.1.7. The Contractor shall construct construction stabilization access as shown on the Drawings unless otherwise directed by the S.O. for reducing tracking of mud and dirt onto public 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.
- 2.3.1.8. The Contractor shall construct temporary waterway crossing as shown on the Drawings unless otherwise directed by the S.O., for providing erosion-free access points across a waterway for the Contractor's vehicles or equipment and may be necessary to prevent the Contractor's equipment from causing erosion of the waterway and tracking of pollutants into the waterway.

2.3.2. Water Quality Control

- 2.3.2.1. The Contractor shall construct wash trough/wash bay complete with water jet as shown on the Drawings unless otherwise directed by the S.O. for cleaning all debris, dirt and mud from the wheels and tyres of the 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..

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- 2.3.2.2. 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 the existing drainage system.
- 2.3.2.3. 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 a disposal site approved by the S.O..
- 2.3.2.4. Water quality standards and monitoring schedule from the silt traps/sedimentation basin/rivers/stream/ water bodies shall comply as specified in JKR/SIRIM 3: 2020 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 events of more than 20mm (For Non-EIA projects) or 12.5 mm (For EIA projects).
- 2.3.2.5. The Contractor shall construct temporary silt fence made of non-woven, synthetic filtration fabric stretched across and parallel to the contours of the Site, attached to supporting wood or steel posts and entrenched, to prevent sediment carried by sheet flow from leaving the Site by slowing storm water runoff and causing the deposition of sediment at the structure. The silt fence shall be inspected after every rain event. The silt accumulated behind the fence shall be removed when it has reached two-thirds of the fence filter height and disposed at the designated site.
- 2.3.2.6. The Contractor shall install check dams 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 channels in steep terrain. The check dams 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 dams 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.
- 2.3.2.7. The Contractor is prohibited from discharging oil, grease, paint and sewage to any watercourse.
- 2.3.2.8. 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 riprap, concrete rubble, gravel, sandbag, wire mesh or trash screen shall be constructed in such a manner that will facilitate cleanout and disposal of trapped sediment/debris and minimizes interference with construction activities.

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2.3.3. Air Quality Control

- 2.3.3.1. The Contractor is not allowed to carry out open burning of cleared vegetation, debris and construction waste etc., shall not be allowed unless prior approval is obtained from the Director General of JAS.
- 2.3.3.2. 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..
- 2.3.3.3. 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, etc. before leaving the Site.
- 2.3.3.4. 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.
- 2.3.3.5. The Contractor's trucks carrying sand, aggregates, earth and other loose construction materials liable to spillage, must use tarpaulin to cover such open trucks when passing through villages and settlements or on all roadways.
- 2.3.3.6. The Contractor shall also ensure dust control at quarry / batching plant (if any) and usage of generator set (genset) complies with environmental requirements as stipulated in the Environmental Quality (Clean Air) Regulations, 2014.
- 2.3.3.7. Any installation of fuel burning equipment (e.g. generator set or boiler) shall comply with the Environmental Quality (Clean Air) Regulations, 2014 and shall be monitored.

2.3.4. Noise and Vibration Control

- 2.3.4.1. 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 minimise the amount of noise generated. The S.O. may require the Contractor to replace any machinery that to his discretion is emitting excessive noise.
- 2.3.4.2. Noise barriers shall be installed at the boundary of the project site adjacent to any sensitive receptor area.
- 2.3.4.3. 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 JKR/SIRIM 3: 2020 or latest edition. No person unless duly authorized by law or carrying out legitimate duties shall use explosives or result in explosions which create a vibration disturbance across a real property boundary or on a public space or right of way.



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2.3.4.4. If blasting work is required, prior approval shall be obtained from relevant authorities and shall comply with the *Garis Panduan Kerja Peletupan Pembangunan, Jabatan Mineral dan Geosains* (JMG).

2.3.4.5. If dynamic replacement and dynamic compaction activities are conducted, the Contractor shall ensure that earth drain/ ditch is constructed to minimise the vibration effect.

2.3.4.6. The Contractor shall comply with the general recommendations set out in Guidelines for Environmental Noise Limits and Control 2019 (JAS) and The Planning Guidelines for Vibration Limits and Control in the Environment (JAS) together with any specific requirements described in the Contract.

2.3.4.7. 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.

2.3.4.8. 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 JKR/SIRIM 3: 2020 or latest edition.

2.3.5. Waste Management

2.3.5.1. The Contractor shall ensure all waste generated on Site shall be managed in accordance with the latest statutes and other related legislation as follows:

Type of waste generated on site	Statutory requirement
Scheduled waste / hazardous waste	• Environmental Quality Act 1974 • Environmental Quality (Scheduled Wastes) Regulations 2005
Construction & demolition waste	• Solid Waste and Public Cleansing Management Act 2007
Domestic waste	• Solid Waste and Public Cleansing Management (Scheme for Construction Solid Waste) Regulations 2018

2.3.5.2. 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:

- a) The Contractor shall submit in the approved format of Construction Waste Management Plan (CWMP) to the S.O. for approval within fourteen (14) days from the date of Site Possession.



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- b) The Contractor shall provide adequate Roll-On Roll-Off (RORO) Bin for construction waste and Mobile Garbage Bin (MGB) for domestic waste.
- c) The Contractor shall provide a minimum of one (1) suitable location on Site for segregation and collection of construction and domestic waste.
- d) The Contractor shall provide proper storage facility(s) and container for Schedule Waste Management in accordance with the Drawings.
- e) 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.
- f) The Contractor shall keep all records relating to disposal of waste from the Site.
- g) The Contractor shall ensure that the bulk fuel tank storage area, including grease trap, shall be properly constructed and sufficiently bunded. The bund wall (concrete or brick) around the storage tanks shall have the capacity to contain the worst spillage condition (110 % of the capacity of the container).

2.3.6. Preservation of flora and fauna

2.3.6.1. The Contractor shall comply with the requirement as specified by *Jabatan Perhutanan Semenanjung Malaysia, Jabatan Perhutanan Sabah, Jabatan Hutan Sarawak* or other relevant Authorities.

2.3.6.2. The Contractor shall comply with the Wildlife Conservation Act, 2010 (Act 716) Amendment 2012, Wildlife Conservation Enactment 1997 for Sabah and other related legislations.

2.3.7. Preservation of coral reef and marine ecosystem

2.3.7.1. Coral reef

The Contractor shall ensure the following:

- a) Prior to site clearing, the Surveyor, assisted by a Marine Biologist and a Marine Park Officer, shall identify any boulder or encrusted coral colony or coral colonies/reefs or immobile endangered species such as giant clams which need to be conserved or translocated. Coral colonies and immobile species which have been identified shall be conserved and marked accordingly in the construction plan.
- b) All coral reefs and immobile marine organisms such as giant clams which are identified to be conserved in the construction area, are transplanted to an approved location and in accordance with the transitional rules set by the *Jabatan Perikanan Malaysia/Sabah Parks*.

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- c) Transplantation of identified coral colonies shall be carried out before any earthworks. For non-transplantable coral colonies (boulder corals, encrusting coral), design of piling location shall be changed accordingly including redesigning of the structures for avoidance.
- d) The approval for the transplant operation of coral reefs and immotile marine organisms shall be obtained from the Director General of *Jabatan Perikanan Malaysia*/Sabah Parks prior to commencement of work as specified by relevant Authorities and/or S.O., and the relocation work shall be monitored by *Jabatan Perikanan Malaysia*/Sabah Parks.
- e) The Contractor shall not collect or possess any coral and marine organisms, whether alive or dead, dredge or extract any sand or gravel, discharge or deposit any pollutant, alter or destroy the natural breeding grounds or habitat of aquatic life, or destroy any aquatic life.
- f) The Contractor is prohibited from anchoring any vessel by dropping any kind of weights, or by attaching any type of rope or chain to any coral, rock or other submerged object.
- g) The sites for translocation of coral shall be 200m away or as specified by the relevant Authorities from the project Site with similar depth profile as original coral population location.

2.3.7.2. Marine aquatic/marine life

Where applicable,

- a) The Contractor shall not fish or attempt to fish, capture, disturb, remove, or possess any aquatic animal or aquatic plant or part thereof, whether alive or dead.
- b) The Contractor shall not construct or erect any building on or over any land or waters within a marine park or marine reserve without specific written permission from the Director General of *Jabatan Perikanan Malaysia*/Sabah Parks/*Jabatan Perikanan Sabah*.
- c) Any activity involving removing, demolishing, damaging and harming marine life is strictly prohibited.

2.3.8. Preservation of man-made and natural heritage sites

For projects located within heritage sites gazetted by *Jabatan Warisan Negara*, the Contractor shall comply to all requirements stipulated by the relevant department as listed in JKR/SIRIM 3: 2020 or latest edition.

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2.3.9. Requirement for waterways

Where applicable, the Contractor shall ensure the following:

- a) Approval shall be obtained from the *Jabatan Pengairan dan Saliran Malaysia* (JPS) and other related agencies for any works related to all types of existing waterways including diversions, modifications, replacements and/or relocation of rivers, watercourses, and related structures during execution of the works.
- b) Coordination for all operations and necessary adjustments shall be made to their programme resulting from the requirements from relevant agencies pertaining to changes made to the natural waterways.
- c) Temporary diversions of rivers and/or waterways shall be capable of sustaining flows throughout the year as specified by JPS or other related agencies.
- d) All the temporary work or structure shall be immediately removed, and waterways shall be reinstated as before, upon completion of activity.

3. Green Rating Tools

3.1. Implementation of Green Rating Tools

- 3.1.1. The Contractor shall abide to implement green rating tool based on the latest SAKPKR used by the JKR.
- 3.1.2. The Contractor is allowed to implement the following green rating tool:
 - a) JKR Standard JKR/SIRIM 2:2020 *Penarafan Hijau (pH JKR) bagi Fasiliti Bangunan Kediaman dan Bukan Kediaman* or latest edition or;
 - b) Any other Green Rating Tools in Malaysia.

3.2. Sustainable Materials and Products

- 3.2.1. The Contractor shall abide to implement green rating tool for products based on the latest SAKPKR used by the JKR.
- 3.2.2. Notwithstanding the materials and products shown on the Drawings or specified herewith, the Contractor shall propose alternative equivalent materials or “Green” products to be used in the Works, subject to the approval of the S.O., such as:
 - a) Environmentally friendly materials or “Green” products that are certified under the SIRIM Eco-Label certification or any labels within the Global Eco-Label Network (GEN) certification.
 - b) Product registered under MyHijau Mark Scheme.
 - c) Products self-declared “Green” by the manufacturer with certification from recognised independent certifying bodies and not a member of GEN.

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- d) Products certified with ISO 14021, ISO 14024 or ISO 14025, or any products that comply with a performance standard including environmental considerations such as indoor air quality and environmental protection.

3.2.3. The Contractor shall refer to JKR Standard JKR/SIRIM 1:2023 Manual for Green Product Scoring System (GPSS) or latest edition for additional information on sustainable materials and products.

3.3. Phases of Submission Requirement

3.3.1. JKR/SIRIM 2:2020 *Penarafan Hijau* (pH JKR)

3.3.1.1. The Contractor shall refer to JKR/SIRIM 2:2020 *Penarafan Hijau* (pH JKR) or latest edition for additional information on the implementation process.

Stages of pH JKR assessment are divided into two (2) stages:

- a) Design Stage: *Penilaian Peringkat Reka Bentuk* (PRB) to be carried out during final design stage
- b) Verification Stage: *Verifikasi Pemarkahan* (VP) to be carried out after six (6) months of Certificate of Practical Completion (CPC) or after 50% occupancy.

3.3.1.2. The Contractor shall provide and submit to the Facilitator through Head of Project Team (HOPT) the following submission requirements for PRB:

- a) Scorecard submittal documents, and proof of calculations.
- b) Submission shall be submitted in softcopy and/or hardcopy format.

3.3.1.3. The Contractor shall provide and submit to the Facilitator through S.O./ HOPT the following submission requirements for VP:

- a) Scorecard submittal documents, and proof of calculations.
- b) Submission shall be submitted in softcopy and/or hardcopy format.

3.3.2. JKR/SIRIM 1:2023 Manual for Green Product Scoring System (GPSS)

3.3.2.1. The Contractor shall refer to JKR/SIRIM 1:2023 Manual for Green Product Scoring System (GPSS) or latest edition for additional information on the implementation process.

3.3.2.2. Stages of GPSS assessment are divided into two (2) stages:

- a) Design Stage: Conduct self-assessment for targeted green products used.
- b) Construction Stage: To complete the green product scoring sheets and the compilation of supporting documents to be submitted and verified by the GPSS Secretariat.

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3.3.2.3. The Contractor shall provide and submit to the Facilitator through the HOPT the Scorecard for the design stage.

3.3.2.4. The Contractor shall provide and submit to the Facilitator through S.O./ Head of Project Team the following submission requirements for Construction Stage:

- a) Scorecard and submittal documents
- b) Submission shall be submitted in softcopy and/or hardcopy format.

3.4. Green Building Material Specification

Green building material shall refer to **APPENDIX B1**.

4. Energy Efficiency

4.1. General Condition

4.1.1. The building shall be designed to be sustainable and green to the extent possible brief current availability of building materials, mechanical and electrical components and systems.

4.1.2. Building Energy Intensity (BEI) calculation shall be proven in the design phase using calculation stated in the latest edition of MS 1525 or simulation programmes tools. The simulation programmes should be a computer-based programme for the analysis of energy consumption in buildings. The simulation programmes should include calculation methodologies for the building components being modelled and subject to the approval and concurrence of JKR.

4.1.3. The building shall be designed according to the relevant standards, guidelines, policies and directives pertaining to energy efficiency and green technology as follows:

- a) Uniform Building By-Laws (Latest Edition)
- b) Latest edition of MS 1525 "Standard for Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings
- c) *Garis Panduan dan Peraturan Bagi Perancangan Bangunan oleh Jawatankuasa Standard dan Kos, Kementerian Ekonomi, Edisi Tahun 2024* or latest edition
- c) *Akta Kecekapan Dan Konservasi Tenaga 2024*
- d) Handbook On Passive Design Strategies for Energy Efficient Building, *Cawangan Arkitek, 2016* (JKR20802-0024-14) or latest edition
- e) Energy Efficiency Needs Statement, *Cawangan Alam Sekitar dan Kecekapan Tenaga, Edisi Tahun 2014* or latest edition

4.1.4. Energy Efficiency shall be achieved, without compromising user comfort.



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- 4.1.5. The cost of incorporating energy efficiency into the design shall be deemed to be included and no separate cost shall be entertained.
- 4.1.6. In addition to this, design criteria specified in this document shall be fulfilled in order to increase energy efficiency of the building.
- 4.1.7. In the event of any contradictions with the specifications outlined in this sub-section (Energy Efficiency), the specifications and technical documents issued by the *Cawangan Arkitek*, *Cawangan Kejuruteraan Mekanikal*, and *Cawangan Kejuruteraan Elektrik* of JKR Malaysia shall take precedence.

4.2. Architectural

4.2.1. Objective

The objective of this Architectural Energy Efficiency is to encourage Architects to apply passive design strategies through creativity, innovation and varying envelope components. This effort in the long run will give high impact reduction and low operational cost in building's energy consumption. By controlling and cutting down on heat transfer shall reduce air-conditioning loads. Similarly, if daylight is optimised, then it can be an important energy saving feature by displacing electric lighting demands.

4.2.2. Requirements

The overall building design shall incorporate and comply with the latest edition of MS 1525: Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings (Section 4 & 5) and Uniform Building By-Laws (Latest Edition) with regards to the Overall Thermal Transfer Value (OTTV) and the Roof Thermal Transfer Value (RTTV).

a) Site planning and orientation;

For the analysis of the local microclimate condition (air temperature, radiant temperature, relative humidity, air velocity and precipitation) reliable climate data for the Site shall be used. The building's main longitudinal orientation shall be on an axis of 5° Northeast.

b) Day lighting;

Daylight penetration must be optimised but glare and heat shall be minimised (refer Table 1 and Table 13 in MS 1525). Daylight Factor Diagram® or Df-TOOL® shall be used as daylight prediction tool.

c) Facade design;

The glass windows/fenestration system shall be protected from direct sunlight during the day's most solar heat gain and hottest months of the year.

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d) Natural ventilation;

The orientation of the building shall be facing the most prevailing wind. Lobby areas, corridors, lift cores, toilets and staircases shall be naturally ventilated.

Alternatively, if a performance-based approach is used, then compliance pertaining to Section 10 (Building Energy Simulation) from the latest edition of MS 1525 shall be met.

- e) The design building annual energy use must demonstrate at least 6% energy savings from the baseline building annual energy use using the same simulation program.
- f) To achieve thermal performance compliance, out of 8,760 hours per year, 60% of the simulated occupied indoor space temperature (without active means) shall be in the range of 24.5 – 28 degree Celsius, typical comfortable indoor temperature in Malaysia.

4.3. Mechanical

4.3.1. Air-Conditioning and Mechanical Ventilation (ACMV) Design

4.3.1.1. Load Calculations

- 4.3.1.1.1. Cooling system design loads for the purpose of sizing systems and equipment shall be determined in accordance with the procedures described in the latest edition of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) handbook, or other equivalent publications.
- 4.3.1.1.2. Design conditions (outdoor and indoor) of air-conditioned space for comfort cooling shall be as recommended by the latest edition of MS 1525.
- 4.3.1.1.3. Alternative ACMV system (air system and refrigeration plant) comparison and its corresponding energy demand shall be conducted. If not specified elsewhere in this document, ACMV system with the least energy consumption shall be selected.

4.3.1.2. System/ Equipment Sizing and Efficiency

- 4.3.1.2.1. Air conditioning systems and equipment shall comply with the latest edition of MS 1525.
- 4.3.1.2.2. Where chillers are used and when the design load is greater than 1000kW_r, a minimum of two (2) chillers or one (1) chiller with multi compressors or one (1) chiller of single compressor with step/variable unloaders shall be provided to meet the required load. Standby chillers shall also be considered.



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4.3.1.2.3. Minimum chiller efficiency Coefficient of Performance (COP) shall be as stipulated in the latest edition of MS 1525 (Table 25 Water chilling packages, electrically driven: Chiller energy performance rating).

4.3.1.2.4. Individual air-cooled or water-cooled direct expansion (DX) units greater than 35 kW_r (reciprocating compressor) or 65kW_r (scroll compressor) shall consist of either multi compressors or single compressor with minimum step/variable unloaders.

4.3.1.2.5. Maximum allowable flow rate in pipes shall follow ASHRAE 90.1 or latest edition.

4.3.1.2.6. Schematic of pipe routing shall be made during the concept design stage to show that the most efficient route has been selected for the chill water pipe system.

4.3.1.2.7. Detailed pump head computation shall be provided together when selecting the pump; i.e.

- a) Friction losses in pipes
- b) No. of bends
- c) Valves and fittings k-value

4.3.1.3. Chiller Efficiency shall be provided as follows:

- a) COP at rated condition.
- b) COP at design condition.

4.3.1.4. ACMV system components shall have minimum energy performance as stipulated in the latest edition of MS 1525.

4.3.2. Separate Air Distribution System

4.3.2.1. Zones which are expected to operate non-simultaneously for more than 750 hours per year shall be served by separate air distribution systems.

4.3.2.2. Separate air distribution systems shall be provided for areas of the building having substantial different cooling characteristics and usage, such as perimeter zones in contrast to interior zones.

4.3.2.3. Zones with special temperature and/or humidity requirements shall be served by independent air conditioning system/separated air distribution system from those serving zones requiring only comfort cooling.

4.3.2.4. For air-conditioned space requiring exhaust air volume in excess of 3400m³/h, heat recovery system shall be provided to recover the coolness of the exhaust air in order to extract heat from the fresh air intake.



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4.3.2.5. Schematic of duct routing shall be made during the detailed design stage to show that the most efficient route has been selected for the duct system.

4.3.2.6. AHUs drainage shall be fitted with tap-off point fitted with valve at highest point possible location. This tap-off point shall be used for measurement of condensate water rate to compute latent load of AHU system.

4.3.3. Energy Recovery / Heat Recovery Wheel (Where Specified)

4.3.3.1. It is recommended that consideration be given to the use of recovery systems which will conserve energy (provided the amount expended is less than the amount recovered) when the energy transfer potential and the operating hours are considered.

4.3.3.2. Recovered energy in excess of the new source of energy expended in the recovery process may be used for control of temperature and humidity. Examples include the use of condenser water for reheat, super heater heat reclaim, heat recovery wheel, heat pipe or any other energy recovery technology.

4.3.3.3. Heat Recovery Wheel (HRW) components shall be utilizing a unique parallel plate energy transfer matrix design that optimizes the energy recovery surface area for a given diameter and depth of a rotary heat exchanger. A polymer film matrix shall be ideal properties that limit counterproductive axial conduction of heat. The combination shall achieve the required performance in a thin, light weight configuration. The constructions shall epoxy painted structural steel frame and powder coated. The rotor is made of alternate flat and corrugated the two air streams, aluminium foil of very uniform pitch and height. Rotor face edges are hardened. The face and radial seals are brush seal HRW desiccant-coated enthalpy wheels are corrosion resistant. They are washable due to patented and proprietary processes that secure the desiccant to the matrix substrate with a permanent mechanical bond without the use of adhesives. HRW capacity shall be as schedule of technical data.

4.3.4. Control

4.3.4.1. Temperature control

Each system should be provided with at least one thermostat for the regulation of temperature. Each thermostat should be capable of being set by adjustment or selection of sensors over a minimum range of between 23°C to 27°C. Multi-stage thermostat should be provided for equipment exceeding 35/65 kW_r.

4.3.4.2. Humidity control

4.3.4.2.1. In a system requiring moisture removal to maintain specific selected relative humidity in spaces or zones, no new source of energy (such as electric reheat) should be used to produce a space relative humidity below 70% for comfort cooling purposes as stated in the latest edition of MS 1525.



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4.3.4.2.2. Air conditioning system for spaces primarily designed for non-comfort cooling purposes, which require precise control of humidity (such as Operation Theatre, Library, Drug Store), reheat system utilizing recovered energy such as from condenser water, de-super heater, heat recovery wheel, heat pipe or other energy recovery technology shall be used. Use of electric reheat can only be considered if the use of above technologies is not technically feasible due to site or building conditions.

4.3.4.3. Zoning for Temperature Control

At least one thermostat for regulation of space temperature shall be provided for each separate system and each separate zone. As a minimum, each floor of a building should be considered as a separate zone. On a multi-storey building where the perimeter system offsets only the transmission gains of the exterior facade, an entire side of uniform exposure may be zoned separately. A readily accessible manual or automatic means should be provided to partially restrict or shut off the cooling input (for the exposure) to each floor. For separate air distribution system refer to MS 1525:2019 para 8.3 or latest edition.

4.3.4.4. Control Setback and Shutoff.

Each system shall be equipped with a readily accessible means of shutting off or reducing the energy consumption during periods of non-use or alternate uses of the building spaces or zones served by the system. The following are examples of these requirements:

- a) Manually adjustable automatic timing devices
- b) Manual devices for use by operating personnel
- c) Automatic control system

4.3.4.5. Off hour control.

- a) ACMV system shall be equipped with automatic controls i.e. weekly timers, usage scheduler during periods of non-use or alternative use of the spaces served by the system. Equipment with connected load less than 2kW each may be controlled by readily accessible manual switch.
- b) Outdoor air supply and exhaust systems with design capacity more than 1800 m³/h shall be provided with motorized dampers interlocked with equipment in operation. Outdoor air supply motorized damper shall be modulated based on level of CO₂ measured in the return air stream. Maximum allowable CO₂ level in the occupied spaces is 1000 ppm. Use of gravity damper is not allowed.

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4.3.4.6. Mechanical Ventilation Control.

Each mechanical ventilation system (supply and/or exhaust) shall be equipped with a readily accessible switch or other means for shut-off or volume reduction when ventilation is not required. Examples of such devices would include timer switch control, thermostat control, duty cycle programming and CO/CO₂ sensor control.

4.3.5. Fan System Efficiency

4.3.5.1. Fan system with air flow rate which exceeds 17,000 m³/h and operates more than 750 hours per year shall have overall fan efficiency of not more than 0.42 W per m³/h of air flow rate.

4.3.5.2. All bare shaft fans shall have Fan Efficiency Grade (FEG) of 71 or higher, certified by an independent third party (Air Movement and Control Association (AMCA) or equivalent) and to bear the FEG certified performance seal. The total efficiency of the fan at the design point of operation should be within 15% points of the maximum total efficiency of the fan.

4.4. High Efficiency Motors/Booster Pumps

All motors used for any mechanical system shall be energy efficient motor in accordance to the latest edition of MS 1525.

4.5. Lift System

4.5.1. The lift shall have control system of Alternating Current - Variable Voltage Variable Frequency (AC-VVVF) thyristor/inverter-converter speed control to achieve optimum performance with stepless acceleration/deceleration and good levelling accuracy in either direction.

4.5.2. The lift motor rooms shall be designed with minimum requirement of cooling (if any) and ventilation system.

4.5.3. All motor used for lift drive shall be of high efficiency motor in compliance with the latest edition of MS 1525 and ISO 25745.

4.5.4. For high rise buildings, regenerative drives shall be considered in designing lift system.

4.5.5. Switch off car lighting and ventilation fan mode shall be incorporated when idling more than 2 minutes.

4.5.6. Energy efficient lighting such as Light Emitting Diode (LED) lighting shall be used for internal and external lift system.

4.5.7. Lifts shall be arranged in single car collective operation and/or in group in automatic group supervisory control operation. The number of lifts to be included under group supervisory control operation shall be based according to the selection criteria of the design taking into consideration the number of lifts provided, types, contract load, contract speed, travel of lift, number of the floors and entrance served, lift car dimensions, etc. The design must give details as to the controls selected for the lift operation and energy efficiency features.

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4.6. Electrical

The energy efficiency criteria shall be incorporated in all design, installation and equipment. The building shall design towards an Energy Efficient Building in accordance with latest edition MS 1525 and shall be referred to the Design and Build Need Statement for Electrical System (for Design and Build project) and/or Energy Efficiency Guideline for *Cawangan Kejuruteraan Elektrik* (CKE) Design.

4.7. Sub Metering

4.7.1. Digital Electrical Energy Meters shall be installed at sub-switch board serving, but not limited to the following:

- a) Central air-conditioning
- b) Lift and escalator system
- c) Major water pump system
- d) General power supply
- e) Lighting supply
- f) Data Centre/Server Room

4.7.2. Digital measuring device such as Digital Power Meter (DPM) shall be installed at main switchboard and sub switchboard. DPM shall be connected to the BAS (if any) for monitoring and control purposes.

4.8. Energy Management Control System in Building Operation (Where Specified)

4.8.1. The Energy Management System (EMS) is a subset of the building automation system function. It should be considered for buildings using central air-conditioning system serving an area $\geq 8000\text{m}^2$. The design shall include a comprehensive energy management component within the building automation system. Continuous monitoring of the energy performance and the comfort perimeter use is vital for achieving energy savings in building.

4.8.2. The Building Management System shall include a comprehensive EMS, comprising both software and hardware, which shall be able to provide monitoring (including graphics interface), control and reporting of the whole building energy status.

4.9. Data Centre, Telecommunications & IT System

The data centre, telecommunications and IT system shall be designed with preference to energy efficiency approach and shall be referred to the latest edition of Design and Build Need Statement for Electrical System (for Design and Build project) and/or JKR Electrical Specification.

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4.10. Building Energy Intensity

The BEI benchmark, BEI_{benchmark} for office building conforming to this standard is 200 kWh/m² /year and is derived using the following equation:

$$BEI_{\text{benchmark}} = \frac{(TBEC - CPEC) \times (52)}{(GFA_{\text{excl carpark}}) \times (WOH)}$$

Where;

TBEC denotes Total Building Energy Consumption in kWh/year

CPEC denotes Car Park Energy Consumption in kWh/ year;

GFA denotes Gross Floor Area in m² ; and

WOH denotes Weighted Weekly Operating Hours of the Office in h/week.

5. Renewable Energy (RE)

5.1. General conditions

- 5.1.1. Renewable Energy (RE) is energy generated from natural resources such as solar, wind, hydro, wave, geothermal and biomass that are sustainable and continually replenished by natural processes.
- 5.1.2. Solar Photovoltaic (PV) system is a system that converts solar energy into electrical energy. Solar PV system shall be considered as the system is reliable and technology ready; as well as to promote the usage of Green Technology in Malaysia.
- 5.1.3. Solar PV modules are commonly installed with the aim to capture solar energy. They can be mounted on roof as roof retrofitted; free-standing on flat roof or ground mounted or thru Building Integrated Photovoltaic (BIPV). The modules can be fully or partially integrated to the building envelope by replacing conventional external building materials such as tiles on roof, sun shading devices or canopies.
- 5.1.4. There are two (2) categories for Solar PV System with respect to the generation and the energy usage, which are:
 - a) Grid Connected PV (GCPV); and
 - b) Off Grid PV (OGPV)
- 5.1.5. The detail requirements shall be referred to the latest edition of Design and Build Need Statement for Electrical System (for Design and Build project) and/or *Garis Panduan dan Peraturan Bagi Perancangan Bangunan by Jawatankuasa Standard dan Kos, Kementerian Ekonomi, Edisi Tahun 2024* and/or Local Authority regulations (if any).
- 5.1.6. In the event of any contradictions with the specifications outlined in this sub-section (Renewable Energy), the specifications and technical documents issued by *Cawangan Kejuruteraan Elektrik* of JKR Malaysia shall take precedence.

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APPENDIX B1

GREEN BUILDING MATERIAL

NO.	CONSTRUCTION WORK	ITEM	DESCRIPTION
1.	General	-	All products and materials used / installed shall prioritised green product specification/requirement in material selection as specified in JKR Standard 1:2023, manual for Green Product Scoring System, (GPSS).
2.	Plastering, Paving, Tiling and Carpet	Paving Work: General	Use paving material with a minimum Solar Reflectance Index (SRI) of 29 (ASTM E1980).
		Interlocking Concrete Paving	Where applicable, the Contractor shall install grass pavers system complete with low maintenance irrigation system.
		Tiling Works: General	Tiling works shall use materials with low VOC content, meeting the required quality and standards, sourced from local manufacturers and certified with eco-friendly labelling.
		Carpet: General	<u>Application for Low VOC Vinyl/Carpet.</u> Floor finishes for vinyl and carpet with low VOC content shall be used, meeting the required quality and standards, sourced from local manufacturers and certified with eco-friendly labelling.
		Carpet: General	<u>General</u> Carpet tiles or broadloom carpet shall be appropriate to the function of areas and shall comply to the latest <i>Pekeliling Perbendaharaan Malaysia</i> or the latest edition related to this item.
3.	Roofing	General	Solar Reflective Index (SRI) ≥ 29 for roof pitch $\geq 10^\circ$ and SRI ≥ 78 for flat roof $\leq 10^\circ$
		General	The U-Value for the entire roof construction layers must achieve the following values: i. Lightweight Roof ($< 50\text{kg/m}^2$) $\leq 0.4\text{W/m}^2.\text{k}$ ii. Heavyweight Roof ($> 50\text{kg/m}^2$) $\leq 0.6\text{ W/m}^2.\text{k}$
		Heat Insulation: General	Use of plastic / foam-based insulation shall be prohibited due to health hazards. Foam based insulation releases toxic substances when heated and burned.
		Heat Insulation: General	Heat insulation material used shall be non-combustible under BS 476 Part 4 or EN13501-1 Class A1.
		Heat Insulation: General	For a roof insulation with a minimum thickness of 50mm used in lightweight roof, the Thermal Resistance shall be: i. Glass Wool $\geq 1.39\text{ m}^2\text{K/w}$ ii. Stone Wool $\geq 1.32\text{ m}^2\text{K/w}$



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NO.	CONSTRUCTION WORK	ITEM	DESCRIPTION
		Heat Insulation: General	For a roof insulation with a minimum thickness of 50mm used in lightweight roof (with air gap), the Thermal Resistance shall be: Stone Wool $\geq 1.39 \text{ m}^2\text{K/w}$
		Green Roof System	Where applicable, all green roof systems shall utilise the following components: - High-quality impermeable waterproofing membrane covering the roof structure as detailed in Vertical Greenery by <i>Jabatan Lanskap Negara</i>. - Drainage layer. - Lightweight growing medium layer (i.e. soil, cocopeat, compost, coconut coir, perlite etc.). - Appropriate Vegetation. - Ease of maintenance and durability which shall be carried out complying to the minimum standard as detailed out in the 'Garis Panduan Pengurusan dan Penyelenggaraan Projek Lanskap'
4.	Wall System	General	<u>Green Wall System</u> Where applicable, all green wall systems shall utilise the following components: - High-quality impermeable waterproofing membrane covering the wall structure. - Drainage layer. - Lightweight growing medium layer. - Appropriate Vegetation. - Ease of maintenance and durability which shall be carried out complying to the minimum standard as detailed out in the Vertical Greenery Guideline by <i>Jabatan Lanskap Negara</i> or the latest edition
		General	<u>Performance Thermal Comfort</u> Where applicable wall material selection for building envelope shall contribute to low U-Value in order to achieve optimal OTTV $\leq 50\text{W/m}^2$
		Type of Finishes to wall and partition	<u>Exterior Shading System</u> Where applicable the Contractor shall install exterior shading system which include shutters, awnings, canopies, blinds, and projecting horizontal and vertical fins according to MS 1525 requirement as mechanism for solar heat gain control in the building. <u>Light Reflector System / Light Shelves</u> Material selection for Light Reflector System shall consider the building structural strength, ease of maintenance, cost and durability.
5.	Painting	General	To achieve good thermal comfort in the building, the albedo which is the fraction of sunlight reflected by a material shall be around 0.4 for walls and above 0.7 for pavement.



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NO.	CONSTRUCTION WORK	ITEM	DESCRIPTION
		General	<u>Low Volatile Organic Compound (VOC)</u> Paints and finishes with low VOC content shall generally be used, ensuring they meet the required quality and standards, sourced from local manufacturers, and certified with eco-friendly labelling.
		Painting Works for Anti-Vandalism	Where building requiring non-stick paint or washable surface in prevention of anti-vandalism, including sticking of notes and tags, application of one coat of acryliccopolymer water-based basecoat and two finishing coats of low VOC vinyl acrylic copolymer emulsion of approved colour all in accordance to manufacturer's recommendation.
6.	Timber Joinery and Ironmongery	Adhesive	Generally, adhesive with Low VOC content shall be used and be of the required quality and standard obtained from local manufacturers and certified with eco green labelling.
		Built-in Furniture	Generally, any furniture material and finishes with Low VOC content shall be used and be of the required quality and standard obtained from local manufacturers and certified with eco green labelling.
7.	Ceiling	Sealants	Generally, sealants with Low VOC content shall be used and be of the required quality and standard obtained from local manufacturers and certified with Eco Green Labelling.
8.	Glazing	Sealants	Generally, sealants with Low VOC content shall be used and be of the required quality and standard obtained from local manufacturers and certified with Green Label.
9.	Sanitary Fittings	Cistern for Water Closet	Where applicable cistern for water closet used in the building shall be certified by Water Efficient Product Labelling Scheme (WELPS), SPAN or other eco labelling.
		Flush Valve for Water Closet	Where applicable flush valve for water closet used in the building shall be certified by WELPS, SPAN or other eco labelling.
		All types of tap	Where applicable the water taps used in the building shall be certified by WELPS, SPAN or other eco labelling.

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1. General Requirement

- 1.1. This specification covers all the required earthworks construction within the limits of the Works. It includes the removal, proper utilization, and hauling, or disposal of all excavated materials, and the construction, shaping, and finishing of all earthworks throughout the entire extent of the Works, in conformity with the Drawings and these Specifications.
- 1.2. The 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 works 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 deemed 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.
- 1.8. 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 at all times are at sufficient gradient to enable them to shed water and prevent water ponding.
- 1.9. 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.
- 1.10. 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.
- 1.11. Should the surface of completed areas be damaged by erosion or by any other causes, the Contractor at his own cost shall make good such areas to the approval of the S.O..
- 1.12. The Contractor shall exercise care in preventing wastage of suitable material needed for embankment or fill construction.
- 1.13. Method of Construction
 - 1.13.1 For the purpose of this clause, the method statement shall include, but is not limited to, the following items unless otherwise specified by the S.O.: -
 - (i) Detailed construction sequences;

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- (ii) Shop drawings showing details of all special requirements for the construction activities;
- (iii) Design calculation of key temporary works endorsed by Professional Engineer;
- (iv) Materials, plants, machineries and labour requirements at each construction stages;
- (v) Rate of production output based on resources allocations; and
- (vi) Other relevant information such as all required testing as specified in this specification, instrumentation (if required) etc..

If requested by S.O., the Contractor shall submit additional information pertaining to the method of construction.

1.13.2 The contractor's method of construction shall comply with more stringent of either the statutory limits imposed on lateral and vertical ground movements, construction noise, vibration and air pollution levels, or such limits necessary for the adequate protection and proper functioning of neighbouring roadways, buildings and their facilities as agreed with the S.O.. The Contractor's compliance with these limits shall not relieve him of his sole responsibility for any consequential damages to adjoining structures, roads and other properties arising from excavation work.

1.13.3 The Contractor shall conduct condition survey prior to excavation at nearby existing structures of the proposed excavation works.

1.13.4 The Contractor shall strictly adhere to construction methods approved by the S.O.. Notwithstanding the S.O.'s approval of the Contractor's proposed methods of construction pursuant to this clause, such approval shall not diminish or absolve the Contractor of any duties or responsibilities under the Contract.

1.14. The Contractor shall prepare and submit an Environmental Management Plan (EMP) as described in Section B. No works shall commence until the S.O. has reviewed and approved the EMP. The Contractor shall execute all works in strict compliance with the approved EMP.

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..

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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 to remain, to be protect as satisfied under SECTION Y: 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, etc., 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 stripping 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 150mm 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 the latest Act and Regulations but not limited to Environmental Quality Act 1974 (Act 127) and the subsidiary legislation under the Act, Solid Waste and Public Cleansing Management Act 2007 (Act 672), Solid Waste and Public Cleansing Management (Scheme for Construction Solid Waste) Regulations 2018 or Local Government Act 1976 (Act 171) and by-laws under the Act.

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4. Timber

- 4.1. The ownership of timber shall be 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 obtain the permission to use unsaleable timber (or saleable timber when permission is granted in writing by the appropriate Government agency or authority) for his own purpose in connection with the Contract, always provided that all requirements set by the S.O. are complied with.

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.
- 5.4. The Contractor shall submit an appropriate method statement to the S.O. for approval. The method statement shall include, but not limited to, protective measures to be taken, methods for handling the structure, and procedures to ensure the safety of the construction site.

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. Earthworks

7.1. Definitions

7.1.1. Formation Level

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

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7.1.2. Common Excavation

Common excavation shall mean excavation in any materials which are not hard mass or rock mass as defined in sub-section 7.1.5. and sub-section 7.1.6.

7.1.3. Unsuitable Materials

7.1.3.1. 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.

7.1.3.2. 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..

7.1.4. Suitable Materials

7.1.4.1. Suitable materials shall mean those materials other than the unsuitable materials defined in sub-section 7.1.3.

7.1.4.2. 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.

7.1.4.3. 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.

7.1.5. Hard Mass

7.1.5.1. This shall mean any cemented sediments, weathered 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 50m³/hour. All machineries shall be in good condition and operated by skilled personnel approved by the S.O..

7.1.5.2. Hard mass shall exclude individual masses less than 0.5m³, which shall be considered as common excavation.

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7.1.6. Rock Mass

7.1.6.1. Rock mass shall mean masses found in ledges or masses which can be excavated using the following machinery with production rate not exceeding 20m³/hour:

(i) Track-type tractor (D8 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.

7.1.6.2. Boulders or detached pieces shall only be regarded as rock if they individually exceed 0.5m³. 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. Confirmation of Hard Mass or Rock Mass Excavation

7.2.1. Confirmation of 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.

(i) Direct method by trial excavation

Trial excavation shall be conducted using the whether the excavated material is categorized as hard mass or rock mass excavation based on its hourly production rate. The trial excavation shall, as far as possible, be carried out on a flat platform to ensure the machinery operates at its rated horsepower with maximum efficiency. All machinery shall be in good working condition and operated by skilled personnel approved by the S.O..

In the event that the Contractor is unable to provide the machinery specified in sub-sections 7.1.5. and 7.1.6., the Contractor may propose similar machine for use at the site for trial excavation, subject to the S.O.'s approval. The equivalent production rate of the proposed machine shall be calculated with reference to **TABLE C1 & C2**.

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

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(ii) Indirect method by point load test

The point load test shall be carried out on excavated material for this purpose by using a portable point load test apparatus. A minimum ten (10) rock samples from the excavated material resulted from the direct method by trial excavation (as described in (i)) shall be tested and the results interpretation are shown in **TABLE C3**. Samples to be tested shall have a size not less than 30mm and not more than 85mm, with the preferred dimension about 50mm in accordance with ASTM D5731.

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

7.2.2. Confirmation test shall be conducted again if, in S.O.'s opinion, the materials differ from those excavated during the trial excavation.

7.3. Excavation Works

Wherever applicable, this sub-section shall be read together with SECTION S: GROUND IMPROVEMENT, for works involved with removal of unsuitable material and/or soft soil layers, and their replacement with suitable material, as indicated in the Drawings.

7.3.1. 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..

7.3.2. 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.

7.3.3. Removal of Excavated Material from Site

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

7.3.3.2 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..

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7.3.4. Removal of Unsuitable Material

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

7.3.4.2. 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..

7.3.5. 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 C4**.

7.3.6. 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.

7.3.7. Widening Cuts

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

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

7.3.8. Excavation of Rock

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

7.3.8.2 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.

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7.3.8.3 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 Polis Diraja Malaysia (PDRM) or any other authority competent to do so under any written law. The Contractor shall comply with 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.

7.3.8.4 Where chemical 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 Jabatan Alam Sekitar (JAS) 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.

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

7.3.8.6 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..

7.3.8.7 Otherwise, excavated rock shall be used in the construction of embankment and fill, to the fullest practical extent, in either of the two following ways:

- (i) 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.
- (ii) 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.

7.3.8.8 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..

7.3.9. 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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7.3.10. Blasting

7.3.10.1 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 Authorities' 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.

7.3.10.2 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.

7.3.11. Safety Measures

7.3.11.1. When blasting is carried out close to properties or roads, safety rules complying with 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.

7.3.11.2. 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.

7.3.11.3. 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.

7.3.12. 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 Class C12/15 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 1,500m³ of fill material to be placed at Site:
- (i) Atterberg limits, MS 1056: Part 2;
 - (ii) Gradation analysis, MS 1056: Part 2;
 - (iii) Compaction Test (4.5 kg rammer method), MS 1056: Part 4.
- 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, etc.. 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: Part 4 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 100m³, 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 1056 or by using other means of testing of comparable accuracy approved by the S.O..

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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 C5**.

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 $\pm 5\%$ shall be rejected.

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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 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 S: 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 C4** 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 S: GROUND IMPROVEMENT. 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..

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

8.7.3.2. Geotechnical instrumentation works shall comply with SECTION S: GROUND IMPROVEMENT.

8.7.4. Monitoring Records

8.7.4.1. All monitoring works and records taken shall comply with SECTION S: GROUND IMPROVEMENT.

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 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 a 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 Y: 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 R: SLOPE STABILIZATION AND RETAINING STRUCTURE.

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, centrosema pubescens, or to the agreement of the S.O..

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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:

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 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) week after cutting/filling works, temporary protection measures such as covering with tarpaulin sheet or artificial cover to control erosion shall be taken.

TABLE C1: EQUIVALENT PRODUCTION RATE OF HARD MASS BASED ON TYPES OF EXCAVATORS

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

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TABLE C2: EQUIVALENT PRODUCTION RATE OF ROCK MASS BASED ON TYPES OF TRACK-TYPES TRACTORS WITH RIPPING EQUIPMENT (BULLDOZER RIPPER)

Dozer	Flywheel Power (kW)	Operating Weight (Tonnes)	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 C3: CATEGORY OF EXCAVATION BASED ON CORRECTED POINT LOAD TEST INDEX $I_{s(50)}$

Type of Excavation	Corrected Point Load Test Index $I_{s(50)} \geq 2\text{MPa}$
Common Excavation	Not applicable (no solid sample can be tested)
Hard Mass	< 80% of the samples
Rock Mass	$\geq 80\%$ of the samples

TABLE C4: 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

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TABLE C5: 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 S.O.. Approval by the S.O on the Contractor's proposed methods of construction shall not, in any way, relieve the Contractor of any of his duties or responsibilities under the Contract.

2.4. Unexpected Ground Conditions

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

2.5. Adjacent Structures

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

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

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

2.6. Existing Services

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

2.7. Disposal of spoil

Soil removed from the excavation shall be removed and disposed of as approved by the S.O. in accordance with the latest Act and Regulations but not limited to Environmental Quality Act 1974 (Act 127) and the subsidiary legislation under the Act, Solid Waste and Public Cleansing Management Act 2007 (Act 672), Solid Waste and Public Cleansing Management (Scheme for Construction Solid Waste) Regulations 2018 or Local Government Act 1976 (Act 171) and by-laws under the Act.

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.

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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 $D/B \leq 3$. Unless otherwise specified, shallow foundations shall conform with MS 1756. On no 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 E: CONCRETING of this Specification.

4.3.2. Reinforcement

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

4.4. Confirmatory of Allowable Bearing Capacity of Soil

4.4.1. The Contractor shall conduct dynamic probing test to confirm the required allowable bearing capacity for all types of shallow foundation. For pad foundation, the probe test shall be conducted at every column position, unless otherwise stated in the Drawings. The Probe test shall be carried out in accordance with JKR 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 150kN/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.

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.

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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.

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 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.
- (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.

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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.
 - 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 aforesaid, 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 D1**.

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
- (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 Drawings or as directed by the S.O.. The trial pile shall not be used as a working pile.

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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 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 16767.

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.

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 ISO 9606-1 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.

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5.2.9. Damage to Piles

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

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

5.2.10. Safety Precautions

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

5.2.11. Records

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

5.2.12. As-built Locations Plan

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

5.3. Precast Reinforced Concrete Piles

5.3.1. Material

5.3.1.1. Reinforced Concrete

- (i) The materials shall be as specified in **TABLE D2** or as in MS 1314.
- (ii) The materials and workmanship for concrete shall be as specified under **SECTION E: 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/mm².

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. Installation of Precast Reinforced Concrete Piles

5.3.4.1. Pitching of Piles

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

5.3.4.2. Driving of Piles

- (i) Each pile shall be installed continuously until the specified set and/or depth has been reached, unless otherwise approved by the S.O.. The installation equipment used shall be of such type and capacity to the approval of the S.O.. A follower (long dolly) shall not be used unless approved by S.O., subject to the following requirements:
 - a) The first pile in each pile system and every tenth pile driven thereafter shall be driven full length, without a follower, to verify that adequate pile length is being attained to develop the desired pile capacity.
 - b) The follower and pile shall be held and maintained in equal and proper alignment during driving;
 - c) The follower shall be of such material and dimension to permit the piles to be driven to the length determined necessary from the driving of the full-length piles;

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- d) The final position and alignment of the first two (2) piles installed with follower in each substructure unit shall be verified to be in accordance with the location tolerances specified in sub-section 5.2.1. before additional piles are installed.
- (ii) Follower shall not be used in driving of raked pile.
- (iii) A detailed record of the driving resistance over the full length of each pile shall be kept. The log shall record the number of blows for every 0.3m of pile penetration. The Contractor shall inform the S.O. without delay if an unexpected change in driving characteristics is encountered. Where required by the S.O. set shall be taken at approved intervals during the driving to establish the behaviour of the piles.
- (iv) A set shall be taken only in the presence of the S.O. unless otherwise approved. The Contractor shall provide all facilities to enable the S.O. to check driving resistances. The final set of a pile other than as friction pile, shall be recorded as the penetration in millimetres per 10 blows. The temporary compression of the pile shall be recorded if required.
- (v) When a set is being measured, the following requirements shall be met:
- The pile shall be in good condition, without damage or distortion;
 - 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;
 - The hammer shall be in good condition, delivering the required energy per blow and operating correctly;
 - 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 1 hour to 2 hours for non-cohesive soils or minimum two (2) days 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 3mm as a result of driving adjacent piles shall be redriven to the required resistance.

5.3.4.3. Repair of Damaged Pile Heads

- (i) If a pile is to be subjected to further driving, concrete in the damaged pile head shall be cut off square at sound concrete, and all loose particles shall be removed by wire brushing, followed by washing with water. Care shall be exercised to ensure that the reinforcement in the pile head is not in any way damaged. Any damaged reinforcement shall be made good to the satisfaction of the S.O.. The head shall be replaced with concrete of similar grade or higher.
- (ii) The new head shall be cast truly in line with the remainder of the pile and be properly cured and allowed to harden sufficiently to develop the strength necessary for further driving. If a pile has been driven to the required set or depth but the level of sound concrete of the pile is below cut-off level, the pile shall be made good to the cut-off level as described above so that the completed foundation will safely withstand the specified ultimate load.

5.3.4.4. Lengthening of Piles

- (i) Where piles have to be lengthened, other than by means of welding of steel plates as detailed on the Drawings, the reinforcement shall be stripped of all surrounding concrete for a distance equal to forty (40) times the diameter of the main reinforcement measured from the pile head for spliced joints and 300mm for butt welded joints and all lateral reinforcement shall be removed.
- (ii) The new concrete shall be of the same grade or higher as the original concrete on pile and shall be adequately compacted.
- (iii) The lengthening bars shall butt on the exposed bars in true alignment and shall be butt welded as specified or shall be spliced with bars of the same diameter as the main pile bars, 60 diameters in length and lapping the main bars for a distance of 40 diameters above and below the joint and shall be securely bound with 1.63mm soft annealed iron wire.
- (iv) New binders of similar size shall be provided and spaced at half the centres of the binders in the main body of the pile and shall be securely bound with 1.63mm soft annealed iron wire and the pile extended by concreting in properly constructed mounds to the length required.

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

5.3.4.5. Pile Joint

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

5.3.4.6. Pile Bending Strength Test

Pile bending strength test shall be performed in accordance with **APPENDIX D1** of this Specification.

5.3.4.7. Cutting and Preparation of Pile Heads

- (i) Piles shall be driven in an approved sequence to minimise the detrimental effects of heave and lateral displacement of the ground. When required, careful levelling from a datum unaffected by the piling shall be made on the pile heads already driven, before and after driving subsequent piles. Piles which have been displaced vertically by more than 3mm 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 D2** or as in MS 1314.
- (ii) The materials and workmanship for concrete shall be as specified under SECTION E: CONCRETING of this Specification.

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 E: 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 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.

5.4.1.5. Pile Plug

If not specified in the drawing, the dimension of pile plug to be used shall be as per manufacturer details.

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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 minimum 2/3 of required design strength in accordance with SECTION E: CONCRETING.

5.4.3. Handling and Storage

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

5.4.4. Installation of Prestressed Spun Concrete Piles

5.4.4.1. Pitching and Installation of Piles

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

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

5.4.4.2. Lengthening of Piles

Where lengthening of piles is required, the details of the joint shall be as shown on the Drawings and in accordance with sub-section 5.6.3. When 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 accordance with sub-section 5.3.4.5.

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..



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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 $\pm 50\text{mm}$ 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 $\pm 2.5\%$.

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 $\pm 50\text{mm}$ 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, 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..

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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 $\pm 50\text{mm}$ in accordance with BS EN 10034.
- (ii) All operations such as handling and transporting of piles shall be carried out in such a manner that damage to piles and their coatings is minimized. Piles that are damaged during handling and transporting shall be replaced by the Contractor at his own expense. All damaged and rejected piles shall be removed from the Site forthwith.
- (iii) Piles within a stack shall be in groups of the same length and on approved supports.

5.5.3. Installation of Steel H-Section Piles

5.5.3.1. Pitching and Driving of Piles

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

5.5.3.2. Lengthening of Piles

- (i) Where lengthening of piles is required, the piles shall be joined by butt welding. Butt welded joints shall be stiffened with plates fillet welded on all four (4) sides as detailed in 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 in the Drawings. The Contractor shall make available full details of the welding procedure and electrodes with Drawings and schedule as requested by S.O..
- (ii) Weld tests shall be performed by radiographic or ultrasonic methods as specified. Provided that satisfactory results are being obtained, one (1) test of a length of 300mm shall be made for 10% or more of the number of welded splices.

5.5.3.3. Cutting and Preparation of Pile Heads

- (i) When a pile has been driven to the required set or depth and before encasing in concrete, the piles shall be cut to within 20mm tolerance of the levels shown on the Drawings. Pile heads shall be constructed to the details as shown on the Drawings.
- (ii) The remaining section which can be reused for lengthening of piles shall be stored and protected as directed by the S.O..



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5.5.3.4. Protective Coatings

Protective coatings of pile shall be in accordance with sub-sections 5.6.4.

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 $\pm 1\%$.
- (iv) The ends of all tubular piles as manufactured shall be within a tolerance on ovality of $\pm 1\%$ 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.

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.

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5.6.2.3. Straightness of Piles

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

5.6.2.4. Fabrication of Piles on Site

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

5.6.2.5. Handling and Storage

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

5.6.2.6. Marking of Piles

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

5.6.3. Workmanship

5.6.3.1. Welding Procedures

- (i) The Contractor shall submit for approval, full details of the welding procedures and electrodes with Drawings and schedules as may be necessary. Tests shall be undertaken as may be required by the S.O. and shall be in accordance with the requirements of BS EN 15614.
- (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..

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: Specification for Line Pipe. 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 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.

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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.

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

5.6.4.7. Part to Be Welded

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

5.6.4.8. Thickness, Number and Colour of Coats

- (i) The minimum dry film thickness of the finished coating, including the minimum dry film thickness of each coat and the minimum number of coats that are to be applied, shall be as specified and shown on the Drawings. Coatings shall be applied in accordance with the manufacturer's instructions.
- (ii) The nominal thickness of the finished coating and each coat shall be as specified. The average coat or finished coating thickness shall be equal to or greater than the specified nominal thickness. In no case shall any coat or finished coating be less than 75% of the nominal thickness. Each coat shall be applied only after an interval that ensures the proper hardening or curing of the previous coat.
- (iii) Where more than one (1) coat is applied to a surface, each coat shall be different colour from the previous coat. The colour sequence and final coating colour shall be established prior to application of coatings.

5.6.4.9. Inspection of Coatings and Acceptability

- (i) The finished coating shall be generally smooth, of a dense and uniform texture and free from sharp protuberances or pin holes.
- (ii) Any coat damaged by subsequent processes or which has deteriorated to an extent such that proper adhesion of the coating may not be obtained or maintained, shall be recleaned to the original standard and recoated with the specified sequence of coats.
- (iii) The completed coating shall be checked for thickness and continuity by an approved magnetic gauge or detector. Areas where the thickness is less than that specified shall receive approved additional treatment.
- (iv) When specified, the completed coating shall be checked for adhesion by means of an adhesion test to BS EN ISO 2409, BS 3900-E6, carried out on 10% of the piles. The adhesion of any completed coating shall not be worse than Classification 2. If adhesion tests on the initial batch are satisfactory, then on further batches only 1% of the piles shall be tested. Adhesion tests shall not be carried out until seven (7) days after coating.

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5.6.5. Installation of Steel Pipe Piles

5.6.5.1. Pitching and Driving of Piles

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

5.6.5.2. Lengthening of Piles

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

5.6.5.3. Cutting and Preparation of Pile Heads

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

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 with 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 E: 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 E: CONCRETING of this Specification. The details of the steel reinforcement shall be as shown on the Drawings.

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.
- (iii) Where bored piles are constructed in ground which is likely to deteriorate with time and it is not possible to finish the bored pile by the end of the working day, a depth equivalent to at least twice the shaft diameter, but not less than 1.5 m shall be bored the following working day immediately before concrete placement in accordance with BS EN 1536.

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 Contractor 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.

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- 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 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 Drawings 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 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 E: 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 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 D6** for bentonite and **TABLE D7** for polymer drilling fluids.

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(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 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 6 hours. Where prolonged delay in construction arises, the bore may have to be backfilled with lean concrete as specified in SECTION E: 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 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 55°. 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 5573:1. For wet boreholes, i.e. holes filled with drilling fluid or water, a suitable probe shall be provided to ascertain the evenness and cleanliness of the pile base.

5.7.3. Placing of Reinforcement

5.7.3.1. Joints in Longitudinal Bars

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

5.7.3.2. Positions of Reinforcement

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

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

5.7.4. Concreting Operations

5.7.4.1. Placing Concrete

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

5.7.4.2. Workability of Concrete

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

The suggested slump details for typical concreting situations shall be as specified in **TABLE D3** of this Specification. The slump shall be measured at the time of discharge into the borehole.

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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 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.
- (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

- (i) 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.
- (ii) The extraction shall be carried out while concrete is still of the required consistency.
- (iii) During the continued extraction a sufficient quantity and head of concrete shall be maintained inside the casing to balance the external pressure so that the annular space vacated by the removal of the casing is filled with concrete.
- (iv) The speed of extraction of the casing shall be such that no inflow of soil or water occurs into the freshly placed concrete, even if a sudden drop of concrete level should occur when a cavity outside the casing is uncovered.

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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.
 - 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.

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.

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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 continuous operation as soon as possible and in no case more than half an hour after mixing.
- (iii) Micropile shall be grouted in one continuous process. If there is significant loss of grout, the Contractor may choose to carry out pre-grouting in stages as necessary to prevent further loss of grout for the construction of micropile. Method statement of pre-grouting including details of equipment, materials and procedures have to be reviewed and approved by the S.O.. If after the process of pre-grouting and re-drilling of the hole is required, the Contractor has to bear the cost and the time of the pre-grouting and re-drilling.

5.8.3.2. Testing Grout

- (i) Grout shall be tested in accordance with BS EN 445 and ASTM C939.
- (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 E: 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 E: 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 E: CONCRETING of this Specification. The grade of the concrete shall be as shown on the Drawings.

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

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5.9.2.3. Method statement

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

5.9.2.4. Minimum clear working space

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

5.9.2.5. Method of excavation

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

- (i) Obtain approval from relevant Authorities and comply with the requirement of statutory Authorities,
- (ii) The position of blast holes and the size of charges shall be such that shattering of rock beyond the caisson is minimized,
- (iii) The rock face shall not be shattered within the toe-in or bell-out zone at the bottom of the caissons, and
- (iv) The caisson opening shall be covered to prevent the projection of fragments of material.

5.9.2.6. Rock Proving

- (i) Rock proving load test machine shall be provided at site for testing of recovered rock sample for shaft and base selected by S.O.
- (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. 0o, 90o, 180o and 360o 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 24 hours after each increment of excavation is complete.
- (iv) Voids between the lining and face of excavation shall be filled with concrete of the same grade as the lining or with others material as agreed by the S.O..
- (v) Any unstable layers of subsoil encountered shall be stabilized by grouting or similar methods. No further excavation will be permitted to proceed until the stabilization 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.

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- (iii) As a minimum measure, individual caissons shall be kept dry during excavation and inspection by pumping from a sump or pilot hole within each caisson as necessary. Submersible pumps shall be used and placed in a sump not more than 0.6m deep and approximately 0.5m diameter sunk in advance of the main excavation. Pump operation shall be continuous until the caisson is concreted.
- (iv) The Contractor shall at all times use, to a minimum degree, of dewatering that is required for the works to proceed. It will be the Contractor's responsibility to ensure that draw down outside the site does not exceed the limits as specified by the S.O.. The Contractor's method statement shall include details of measures proposed to meet this requirement. All such measures shall be subject to approval by the S.O..

5.9.2.10. Water pumped from caissons

- (i) The Contractor shall at all times use, to a minimum degree, of dewatering that is required for the works to proceed. It will be the Contractor's responsibility to ensure that draw down outside the site does not exceed the limits as specified by the S.O.. The Contractor's method statement shall include details of measures proposed to meet this requirement. All such measures shall be subject to approval by the S.O..
- (ii) Water sample pumped from caissons shall be screened through sedimentation or settling tank and quantities of sediment shall be monitored to ensure that excessive fines are not removed from the soil. Should excessive fines be observed from any caisson, pumping from that caisson shall cease and the S.O. notified immediately.
- (iii) When required by the S.O., the Contractor shall record the rate of pumping from the individual caissons and shall submit two copies of the records on the following day. The Contractor shall report immediately to the S.O. any marked change in the rate of flow of water from any caisson.
- (iv) Water pumped from caissons or the ground shall not be discharged directly onto the ground surface without suitable and adequate provisions for drainage being made.
- (v) The Contractor shall be responsible for obtaining all necessary permissions from statutory authorities for discharging water into the public drainage system.

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 of in accordance with sub-sections 2.7.

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 Precautions in the Construction of Large Diameter Boreholes for Piling and Other Purposes.

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

5.9.3. Placing of reinforcement

5.9.3.1. Joints in longitudinal bars

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

5.9.3.2. Positions of reinforcement

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

5.9.4. Concreting operations

5.9.4.1. Placing concrete

- (i) All subsoil and debris shall be removed from the caisson to the satisfaction of S.O.. No concrete shall be placed without approval of the S.O..
- (ii) The method of placing and the workability of concrete shall be such that a continuous monolithic concrete shaft of the full section is formed.

5.9.4.2. Workability of concrete

- (i) The workability of the concrete shall be determined by the slump test as described in MS EN 206.
- (ii) The suggested slump details for typical concreting situations shall be as specified in **TABLE D3** of this Specification. The slump shall be measured at the time of discharge into the borehole.

5.9.4.3. Compaction

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

5.9.4.4. Placing concrete in dry borings

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

- (ii) Concrete may be poured through a funnel with a length of tube so that the flow is directed and does not hit reinforcement bars or the side of the hole.

5.9.5. Construction of pile heads

5.9.5.1. Water levels

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

5.9.5.2. Cutting and preparation of pile heads

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

5.9.5.3. Temporary backfilling above pile casting level

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

5.9.6. Piling records

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

- (i) Signed records of all piles as the work proceeds. Individual pile record shall be submitted not later than noon of the next working day after the pile is installed. The signed records shall form documented record of the work. Any unexpected installation condition shall be noted in the record.
- (ii) Upon completion, compile a record of the work as carried out and provide As-built Drawings. The Drawings shall be prepared and endorsed by the Licensed Surveyor.

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

- (i) Caisson number.
- (ii) Level of top of concreted caisson shaft referred to Principal Datum.
- (iii) Level of top concrete lining referred to Principal Datum.
- (iv) Depth to base of caisson from top of concreted shaft.
- (v) Date(s) and time(s) of starts and finishes of excavations and concreting.
- (vi) Minimum internal diameter of caisson lining.
- (vii) Full details of any bell-out and minimum diameter of caisson base.
- (viii) Thickness and details of concrete lining.

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- (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.

5.9.7.2. Electrical Equipment

All electrical equipment shall be wired in accordance with 'Low-Voltage Electrical Installations', Latest Edition, published by the International Electrotechnical Commission (IEC).

5.9.7.3. Caisson Shafts

- (i) The Contractor shall ensure that construction of the concrete caisson lining follows the excavation sufficiently closely to ensure the stability of the works.
- (ii) The Contractor shall ensure that the concrete caisson lining extends a minimum of 0.25m above and adjacent surrounding ground at all times.
- (iii) The Contractor shall keep all caissons not being worked covered at all times by a stout safety cover capable of supporting a uniformly distributed load of 1.5kN/m² and preventing entry of water into the caisson. The cover shall be attached rigidly to the top of the concrete lining to fully cover the caisson.
- (iv) If an access platform is provided at the top of the caisson the hole through which access to the caisson is gained shall be equipped with a stout 150mm high kicker board around the full perimeter. The area adjacent to the kicker board shall be kept clear at all times of all loose rubble, tools or other objects which may be knocked into the caisson.

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

5.9.7.4. Ventilation

- (i) The Contractor shall provide sufficient compressors, air pumps, etc. including an adequate number of standby spares, in order to ensure complete ventilation of all shafts whilst work is in progress and prevent the build-up of noxious gases or de-oxygenation.
- (ii) Exhaust pipes from boring machines, winches and other equipment shall be so positioned that no exhaust gas enters the caisson or the intake of the air compressors supplying the fresh air to the base of the caisson.

5.9.7.5. Lighting

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

5.9.7.6. Water in Caisson Shafts

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

5.9.7.7. Access and Communications

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

5.9.7.8. Removal of Persons from Caisson Shafts

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

5.9.7.9. Oxygen

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

5.10. Static Pile Load Testing

5.10.1. General

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

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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 E: 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 in 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

- (i) 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.
- (ii) If not specified in drawings, the pile shall be tested after 28 days of installation subject to S.O. approval.

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.

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5.10.4. Method of Loading

5.10.4.1. Test Load

- (i) The test load shall be applied in one of the following ways:
 - a) By means of a jack which obtains its reaction from kentledge heavier than the required load.
 - b) By means of a jack which obtains its reaction from tension piles or other suitable anchors.
 - 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 1500mm to the surface of the test pile. Kentledge shall not be used for testing raked piles. Refer **FIGURE D1** 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.

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- i) Tell-tale or any other tests to the pile such as sonic logging, the instrumentation pipes or cabling which is located at the jack load unit shall be in such extendable during the split zone gap opening during pressurizations.
 - j) The protection measures such as funnel rebar or other methods as approved by the S.O. shall be fixed to the main rebar cage to protect the jack load unit from damages during concreting.
 - k) The jack load unit shall be fully welded together with the upper steel rebar cage. The bearing plates shall be spot-welded with the load unit. The plate shall be made to receive uniform load distribution prior to testing.
 - l) Minimum two (2) grouting pipes shall be installed together with the jack load unit. The pipes shall be pre-cut at the split zone of the load unit to enable the pipes to split and allow the cement grout to flow and grouting takes place. The sonic logging pipes may also be treated as grouting pipes.
 - m) Post grouting shall be done to fill up the gap at the split zone. Clean water shall be initially pumped to remove the debris left at the split zone after testing. Grouting shall start when the water returned to the nearby grouting pipe becomes clean. Grouting operation shall be terminated when the returned cement grout is most likely similar to previous grout applied.
 - n) The test result shall be plotted as load versus displacement curves for the upward and downward displacement independently. The two (2) component curves shall be utilized to construct an equivalent pile-top load versus displacement curve.
 - o) To simulate compressive load, established correction factor for shaft resistance and reduction of pile weight shall be considered at the pile top section which is formally subjected to tension load behaviour during bi-directional testing. In addition, established correction factor and elastic shortening shall be considered at the pile top section for settlement computation due to the load.
 - p) The test report shall be endorsed by a Professional Engineer with Practicing Certificate prior to submission to the S.O..
- (xiii) Alternatively, the Contractor may propose the use of other types, patented or otherwise, in which case the requirements as below shall be fully complied with.

5.10.4.2. Contractor's Load Test System

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

5.10.4.3. Measurement of Load

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

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5.10.4.5. Primary System

Reference Beams and Displacement Measuring Devices

- (i) At least four (4) Linear Voltage Displacement Transducers (LVDT) and a Readout Unit are to be used for measuring the displacement. DC/DC-type displacement transducer having at least 75mm of travel and a linearity of 0.5% or less shall be used. A Readout Unit having a minimum display of three (3) digits, capable of monitoring output from DC/DC – Type LVDT shall be provided.
- (ii) The measurement devices parallel to the longitudinal axis of the test pile and the axis of load application shall be aligned.
- (iii) An independent reference beam or beams shall be set up to enable measurement of the movement of the pile to be made to the required accuracy and shall not be interfered by the load application system. The reference beam shall have adequate strength, stiffness and cross bracing to support the test instrumentation and minimize vibrations that may degrade the measurement of the pile movement.
- (iv) Reference beams and wirelines shall be supported independent of the loading system, with supports firmly embedded in the ground at a clear distance from the test pile of at least five times the diameter of the test pile (s) but not less than 2.5m, and at a clear distance from any anchor piles of at least five times the diameter of the anchor pile(s) but not less than 2.5m. Reference supports shall also be located as far as practicable from any cribbing supports but not less than a clear distance of 2.5m.
- (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 with the instruments. The pile attachments are angles, about 75mm x 100mm with the 100mm dimension projecting from the pile. For round pile, these attachments shall be placed on the perimeter of the pile at 90 degrees and an equal radial distance. For pile of other cross section, the attachments shall be placed at a convenient location as approved by the S.O..
- (viii) Surfaces on which the gauge stems bear should have a smooth finish, such as glass or sheet acrylic, attached by an epoxy or other suitable material approved by the S.O..

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

Refer **FIGURE D1** 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 rod; or, as alternatives, electrical or optical levels.

- (i) Wire, Mirror and Scale

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

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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 buckling stability shall be provided to the pile to be loaded whenever the ratio of the unsupported height to the least cross-sectional dimension is 20 or more. Horizontal supports shall provide full support without restraining the vertical movement of the pile in any way.

5.10.5.2. Maintained Load Test

The Maintained Load Test shall be carried out as follows:

- (i) The Full Test Load (FTL) on a pile shall be twice the Working Load (WL) noted on the Drawings unless otherwise stated, or directed by S.O..
- (ii) The test shall be carried out in two (2) cycles, with first cycle test up to working load and second cycle test up to full test load as specified in **TABLE D4** 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 aforesaid, 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 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 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 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 aforesaid, 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 D4** for Load Increments and Minimum Holding Time.

5.10.6. Submission of Results

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

- (i) Stage of Loading
- (ii) Period for which the load was held
- (iii) Final load and load increment
- (iv) Maximum settlement

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

5.10.6.2. 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 $[(\text{diameter of pile or diagonal width for non-circular pile} / 120) + 4]\text{mm}$ or 12.50mm whichever is the lower value; or

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

5.10.7. Completion of a Test

5.10.7.1. Removal of Test Equipment

- (i) On completion of a test, all measuring equipment and load application devices shall be dismantled and checked. All other test equipment, including kentledge, beams and supporting structures shall be removed from the test pile location. Measuring and other demountable equipment shall be stored in a safe manner so that it is available for further tests, if required, or removed from Site.
- (ii) Temporary tension piles and ground anchorages shall be cut off below ground level and all cut-off materials removed from the site. The ground shall be made good to the original commencing surface level.

5.10.7.2. Preliminary Test Pile Head

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

5.11. High Strain Dynamic Pile Testing

5.11.1. General

5.11.1.1. The Dynamic pile testing using Pile Driving Analyzer (PDA) equipment is a high strain non-destructive load test method which 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 D4945.

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

5.11.2. Construction of Pile Head to be Tested

5.11.2.1. Driven Concrete piles

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

5.11.2.2. Cast In-Situ Piles

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

5.11.2.3. Steel pile

The pile top shall be flat.

5.11.3. Method of Testing

5.11.3.1. Equipment and Personnel Qualification

- (i) The dynamic monitoring shall be performed using a Pile Driving Analyzer (PDA) system or equivalent approved by S.O.. All equipment necessary for the dynamic monitoring such as sensors, cables or wireless transmitters, etc., shall be furnished by Contractor and well calibrated at the time of testing. The equipment shall conform to the requirements of the latest ASTM D4945.
- (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.

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- (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 D5**.

5.11.3.3. Apparatus for Applying Impact Force

- (i) The driving apparatus shall be positioned so that the impact is applied axially to the head of the pile and concentric with the pile. The device used to apply the impact force should provide sufficient energy to cause pile penetration during the impact event adequate to mobilize the desired capacity.
- (ii) Conventional pile driving hammer, drop weight, or similar impact device based on predictive dynamic analysis, experience, or both shall be approved by S.O.. The impact shall not result in dynamic stresses that will damage the pile. The S.O may require cushions, variable control of the impact energy (drop height, stroke, fuel settings, hydraulic pressure, etc.), or both, to prevent excessive stress in the pile during all phases of pile testing.

5.11.3.4. Gauges for Obtaining Dynamic Measurement

- (i) Dynamic measurement shall be carried out by attaching at least two strain transducers and two accelerometers for pile sizes less than 1000mm and at least four strain transducers 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 D4945. If damage is suspected during use, the gauges shall be replaced.

5.11.3.5. Apparatus for Recording, Processing and Displaying Data

- (i) The Contractor shall provide apparatus for measuring the acceleration and strain of the pile head and the energy transferred to the pile. The signals from the transducers during the impact event, shall be transmitted to the PDA to allow determination of the force and velocity versus time.
- (ii) A cable or wireless transmission which connects the sensors near the pile head with the PDA shall be located at safe distance from the pile, but not more than 100m from the pile.
- (iii) The PDA shall include a screen for displaying the force and velocity, a hard disk for obtaining a record for future analysis, and a means to process the data.
- (iv) The apparatus shall have the capability of making an internal calibration check of force, velocity and time scales. No error shall exceed 2% of the maximum signal expected.

5.11.4. Testing Procedures

5.11.4.1. General

- (i) Dynamic Test shall be conducted on test piles as selected by the S.O.. The test shall be carried out in accordance with sub-section 5.11.4.2.
- (ii) Prior to the performance of any dynamic test, the Contractor shall submit the specialist testing firm company profile and working drawings showing the method statement and equipment proposed to be used in the performance of conducting the test together with all relevant calibration certificates to the S.O. for approval. The S.O. may request additional piles to be dynamically tested if the hammer and/or driving system is replaced or modified, the pile type or installation procedures are modified, the pile capacity requirements are changed, unusual blow counts or penetrations are observed, or any other piling behaviour differing from normal installation. The Contractor shall bear the cost and time for all necessary additional test.

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.

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

5.11.5. Submission of Results

- 5.11.5.1. Full test data, complete field test records and results from the readout unit shall be jointly signed by the S.O.'s representative and the Contractor's authorised agent and submit to the S.O. immediately upon completion of the Dynamic Test.
- 5.11.5.2. The Contractor shall submit preliminary results within three (3) days after completion of the test to the S.O..
- 5.11.5.3. The Contractor shall also submit the raw data file (W01) or equivalent, upon completion of the test at the site.
- 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.

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 1849*.
- 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.

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- 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/m² on all ground floor built-up areas including apron areas, and also on all areas extending 1m 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 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 metre 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.

7. Damp Proof Membrane (DPM)

- 7.1. DPM shall be installed below the ground concrete floor level or as shown on the Drawings to prevent the rise of moisture or damp through the structure flooring.
- 7.2. Unless otherwise specified in the Drawings, the DPM shall be extruded polythene film with a nominal thickness of 0.5mm and the tensile strength shall be not less than 15MPa as approved by the S.O..
- 7.3. Unless the application surface is smooth it shall be blinded with compacted soft sand to guarantee a soft bed, free from any objects that may puncture the membrane during the installation or when concrete is applied.
- 7.4. When laying two (2) sheets of DPM, a minimum of 150mm overlap shall be provided between each of the sheets and sealed with 100mm wide jointing tape.
- 7.5. Any punctures in the membrane shall be patched with sheets of identical thickness lapped at least 150mm away from the perforation edge and sealed with double sided pressure sensitive tape.
- 7.6. The DPM shall be covered with a protective layer or screed as soon as possible after the membrane has been installed. Care shall be taken when applying concrete or screed on top the DPM to avoid stretching or the DPM being displaced.

8. Damp Proof Course (DPC)

DPC shall comply with BS 8215: Code of Practice for design and installation of damp proof course in masonry construction and as specified in SECTION F: 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.

TABLE D1: 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 D2: 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.

TABLE D3: 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 D4: 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.		

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TABLE D5: 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

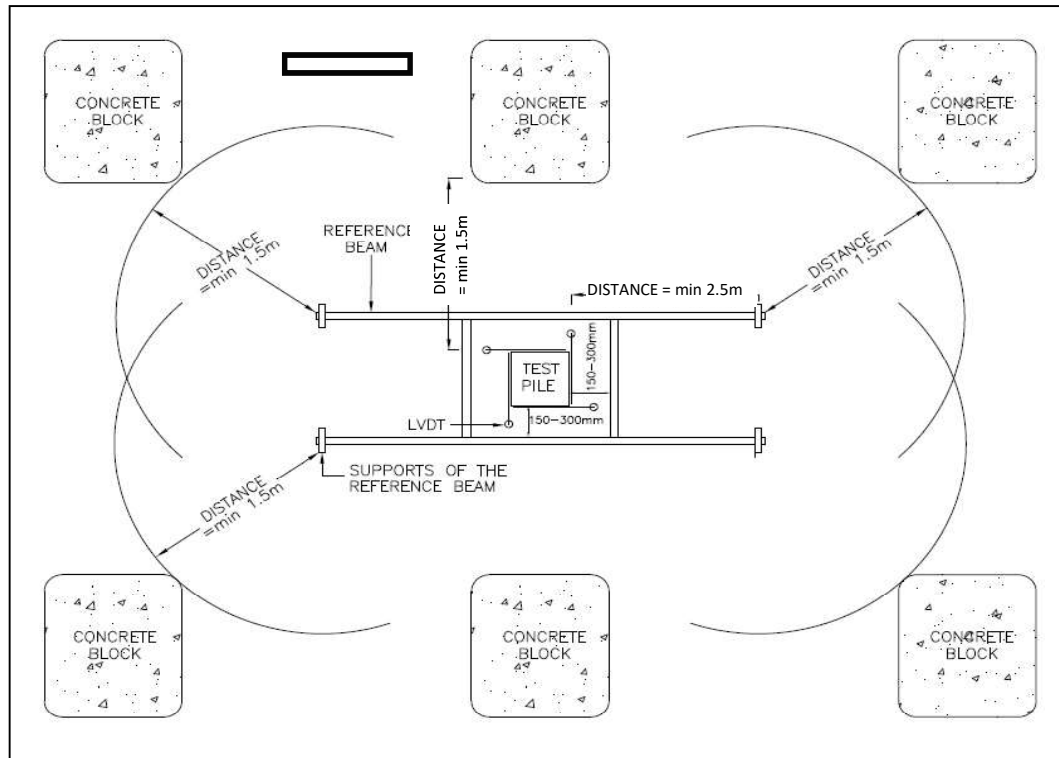
TABLE D6: TESTS FOR BENTONITE DRILLING FLUIDS

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 D7: 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

FIGURE D1: PLAN VIEW OF TYPICAL PILE LOAD TEST SET UP



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APPENDIX D1

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: -

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

Where,

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 D8**. 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 D8** occurs. The calculated values of M_c are given in **TABLE D9**, **TABLE D10** and **TABLE D11**.

TABLE D8: MAXIMUM ALLOWABLE CRACK WIDTH

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

The ultimate bending moment (M_u)

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

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

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

Testing for Static Pile Load Test (Kentledge)

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 D2**.

All rollers shall be manufactured from steel and shall have a circular cross-section with a diameter of 20mm to 120mm; the rollers shall be at least 20mm 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 $\pm 5\text{mm}$. Suitable safety precaution should be taken to ensure that the rollers do not fall off while adjustment is made and during the testing.

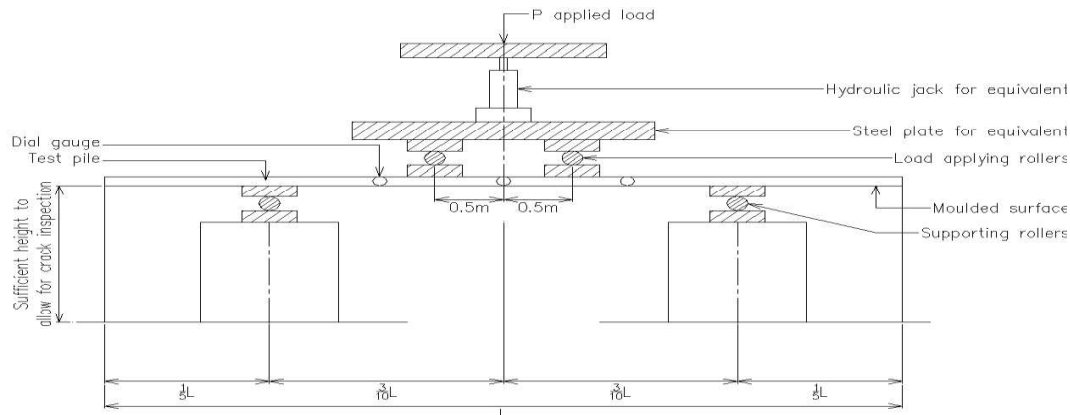


FIGURE D2: LOADING METHOD

Rate of loading

The load shall be applied at the rate of $(0.06 \pm 0.04) \text{ N/mm}^2\text{s}$ 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 1mm represents not more than 100 N/s. Over the operating range of the scale the accuracy shall be within $\pm 5\%$.

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 $\pm 5\%$ 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: -

- Easily read dials or scales; or
- Electrical load indicators, which shall include a visual display.

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

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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 D2**). 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 $(0.06 \pm 0.04) \text{ N/mm}^2\text{s}$. 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/mm^2).
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 D9, TABLES D10** and **TABLES D11** 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 D9, TABLES D10** and **TABLES D11** 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.

TABLE D9: CRACKING BENDING MOMENT (M_c) AND FACTOR ' F ' FOR PRECAST REINFORCED CONCRETE SQUARE PILES (RC PILES)

Nominal Pile Size (mm x mm)	Cracking Bending Moment, M_c (kNm)		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 D10: 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 D11: 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 and proprietary concrete.

1.1.1. Designed Concrete

- 1.1.1.1. Designed concrete shall comply with MS EN 206, MS 523-2, MS 523-3 and the Drawings. The exposure classes, durability recommendations, minimum cement content and maximum free water to cement ratio to be used shall be as shown on **TABLE D5, TABLE D6, TABLE D7** and **TABLE D8**.
- 1.1.1.2. Any types of cement as specified in TABLE D1 can be used for designed concrete.
- 1.1.1.3. Designed concrete shall be produced at a certified concrete plant or a non-certified concrete plant.
 - (i) A certified concrete plant; the plant that is certified by agency that is accredited by Jabatan Standard Malaysia (JSM) or any certification body complying with MS ISO/ IEC 17065; and has certificate of Perakuan Pematuhan Standard (PPS) by CIDB.
 - (ii) A non-certified concrete plant; the plant that is temporarily set up based on the nature of the site, conforming to sub-section 1.1.1.4.
- 1.1.1.4. For sites located in remote areas where there are logistical difficulties in obtaining concrete supply, on-site concrete batching is allowed to be used. Prior approval from the S.O. is required and concrete mix shall conform to sub-section 3.2.3.2.
- 1.1.1.5. The Contractor shall comply with the following requirements:
 - (i) Notify the S.O. the name of the supplier, location of the plant, journey time to transport the concrete to the site and production capacity of the plant.
 - (ii) Submit designed concrete report covering all concrete mixes to the S.O. for approval. The designed concrete shall comply with the requirements specified in **TABLE D5, TABLE D6, TABLE D7** and **TABLE D8** as stated in the Drawings.

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

1.1.1. Proprietary Concrete

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

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

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

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

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

- (i) Verification of product conformity by an agency that is accredited by the Jabatan Standard Malaysia or any certification body complying with MS ISO/IEC 17065, to confirm that the proprietary concrete satisfies the limiting value specified or declared based on project requirement.
- (ii) The proprietary concrete plant shall be certified by an agency that is accredited by the Jabatan Standard Malaysia.

1.2. Production of Concrete

1.2.1. General

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

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

- (i) Selection of materials;

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- (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 adequate documented procedures and instructions. These procedures and instructions shall, where relevant, be established in respect of the control requirement as given in the **TABLE D18**, **TABLE D19** and **TABLE D26**.

1.2.3. Designed Concrete

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

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

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

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

1.2.4. Proprietary Concrete

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

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

1.2.4.3. Proprietary concrete delivered to the Site shall be accompanied by delivery ticket and manufacturer's batching record stating the details of the grade of concrete, name of proprietary concrete, date and time of loading at plant, and other relevant production details. If the Contractor fails to provide the information, the S.O., or his representative shall immediately reject the total load of the concrete. The S.O., or his representative, and the Contractor shall ensure the information provided in the delivery tickets and the manufacturer's batching record complies with the requirement as stated in sub-section 1.1.2 before discharging the concrete.

2. Material

2.1. Cement

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

2.1.2. Certificates of Test

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

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

2.1.3. Transportation and Storage

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

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2.2. Aggregates

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

2.2.2. Coarse Aggregates

Coarse aggregates shall comply with MS EN 12620 and tests shall be carried out according to MS EN 933, BS EN 1744 and MS EN 1097 as specified in **TABLE D3**. For work below ground level, only crushed granite shall be used unless otherwise specified in the Drawings. The maximum nominal size of aggregate shall be as specified in the Drawings.

2.2.3. Fine Aggregates

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

2.2.4. Grading

2.2.4.1. Coarse Aggregates

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

2.2.4.2. Fine Aggregates

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

2.2.5. Sampling and Testing of Aggregates

Where site mixing is performed, samples of fine and coarse aggregates approved by the S.O. shall be kept on Site. These samples shall give a fair indication of the general quality of the aggregates for comparison with the aggregates delivered during the course of executing the Work. Tests shall be carried out on samples of the latter, taken at intervals as required by the S.O., or whenever there is a change of source. The appropriate method of sampling and testing shall be in accordance with the standards as specified in **TABLE D3**. Any batch of aggregate rejected by the S.O. shall be removed from the Site.

2.2.6. Storage of Aggregates

2.2.6.1. Separate storage facilities with adequate provision for drainage shall be provided for each different size of aggregate used.

2.2.6.2. Aggregate shall be handled and stored to minimize segregation and contamination.

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2.3. Water

Water shall comply with the requirements of MS EN 1008. It shall be clean and free from materials deleterious to concrete in the plastic and hardened state and shall be from a source approved by the S.O.. The S.O. may instruct the Contractor to carry out chemical tests at any approved laboratory at the expense of the Contractor. The Contractor shall make adequate arrangement to supply and store sufficient water at the Site for use in mixing and curing of concrete.

2.4. Admixtures

- 2.4.1. The admixtures, the sampling and testing of the admixtures and the information to be provided with the admixture supplied shall comply with MS EN 934.
- 2.4.2. All admixtures shall be used strictly in accordance with manufacturer's recommendation.
- 2.4.3. For admixture to be used in design concrete, the Contractor shall carry out initial test to verify the concrete mix as required in sub-section 3.1.2.

2.5. Requirements for Concrete

2.5.1. Concrete Grade

The Grade of concrete to be used in the Works shall be as stated in the Drawings. 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/mm²) and Y is minimum characteristic cube strength in (N/mm²).

2.5.2. Cement Content

- 2.5.2.1. Cement content in this specification shall refer to the total quantities of cement as approved in sub-section 2.1, or the total quantities of cementitious materials comprising CEM I and other constituents complying to MS EN 197-1.

2.5.2.2. Minimum Cement Content

The minimum cement content shall be in accordance with **TABLE D5, TABLE D6** and **TABLE D7**, unless otherwise shown on the Drawings.

2.5.3. Consistence

- 2.5.3.1. The consistency of the fresh concrete shall comply to MS EN 206 and suitability for the condition of handling and placing so that after compaction, it surrounds all reinforcement, tendons and ducts and completely fills the formwork. Consistency of the concrete shall be within one of the following limits:

- (i) Slump classes (Refer **TABLE D9**)

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(ii) Compacting classes (Refer **TABLE D10**)

(iii) Flow classes (Refer **TABLE D11**)

(iv) Slump Flow Classes (Refer **TABLE D12**)

2.5.3.2. Unless otherwise specified in the Drawings, consistency values expressed as slump and flow classes appropriate to different uses of concrete shall be as given in **TABLE D13**.

2.5.4. Total Chloride Content

The Total Chloride Content of the concrete mix arising from the aggregate or any other source shall not in any circumstances exceed the limits in **TABLE D14** expressed as a percentage relationship between chloride ions and weight of cement in the mix. The tests shall be carried out in accordance with **TABLE D15** for each grade of concrete, to demonstrate that these limits are not exceeded.

2.5.5. Sulphate Content

The sulphate content for aggregate and water shall not exceed the value given in BS EN 12620 and MS EN 1008 respectively. Tests shall be carried out in accordance with BS EN 1744-1 and MS EN 196-2 to demonstrate that this limit is not exceeded.

3. Concrete Conformity and Identity Testing

3.1. Evaluation of Conformity

3.1.1. General

3.1.1.1. The Contractor is only responsible for the conformity evaluation of specified requirements of non-certified concrete. For this purpose, the Contractor shall refer to MS EN 206 to carry out the following task:

(i) Initial test

(ii) Production control including conformity control

3.1.1.2. All tests shall refer to the respective concrete compressive strength test (cube or cylinder).

3.1.1.3. The designed concrete testing flow chart can be referred to **FIGURE D1A** and **FIGURE D1B**.

3.1.2. Initial Test

3.1.2.1. Initial test is required, and the Contractor shall be responsible for the test.

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- 3.1.2.2. In the event of new concrete composition is used, initial test shall be performed to provide a concrete that achieves the specified properties or intended performance with a margin of $1.64 \times$ standard deviation.
- 3.1.2.3. The concrete composition shall be reviewed periodically to provide assurance that all concrete designs are still in accordance with the actual requirements.
- 3.1.2.4. Initial test shall be repeated if there has been a significant change either in the constituent materials, admixtures or in the specified requirements on which the previous test was based on.
- 3.1.2.5. Test Conditions
- (i) In general, initial test shall be carried out on fresh concrete with a temperature 27 ± 3 °C.
 - (ii) For the initial test of single concrete composition, at least three (3) specimens from each of three (3) batches, totaling nine (9) specimens shall be tested at 28 days.
 - (iii) The compressive strength of a concrete composition shall be taken to be the average of the nine (9) specimens.
- 3.1.2.6. Criteria for Adoption of Initial Tests
- (i) The compressive strength of concrete with the composition to be adopted for the actual case shall exceed the values f_{ck} as specified in **TABLE D16** or **TABLE D17**. The margin should be at least 6 N/mm² to 12 N/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 12 N/mm².
 - (ii) The consistency of the concrete shall be within the limits of the consistency class as in **TABLE D13**, at the time at which the concrete likely to be placed or delivered.
 - (iii) For assessing the properties of fresh concrete, the differences between the type of mixer and mixing procedure applied during the initial test and those applied during actual production shall be taken into account.
 - (iv) For other properties that are specified, the concrete shall meet the specified values with an appropriate margin.

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3.1.3. Conformity Control for Designed Concrete

3.1.3.1. General

- (i) For normal-weight and heavy-weight concrete of strength classes from C8/10 to C55/67 or light-weight concrete from LC8/9 to LC55/60, sampling and testing shall be performed on concrete compositions.
- (ii) In the sampling and testing plan, the conformity criteria of concrete shall be distinct in compositions between initial production and continuous production, where:
 - a) Initial production covers the production until at least 35 test results are available.
 - b) Continuous production is achieved when at least 35 test results are obtained over a period not exceeding twelve (12) months.
- (iii) If the production of a concrete composition has been suspended for more than twelve (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 with sub-section 3.2 in order to verify that a defined volume comes from a conforming population.

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3.1.3.2. Sampling and Testing

- (i) Samples of concrete shall be randomly selected in accordance with BS EN 12350. The minimum rate of sampling and testing of concrete shall be in accordance with TABLE D18 at the rate that gives the highest number of samples for initial or continuous production.
- (ii) The samples shall be taken after adding any water or admixtures to the concrete, but sampling before adding plasticizer to adjust the consistence is permitted where there is proof by initial testing that the plasticizer or super plasticizer in quality to be used has no negative effect on the strength of the concrete.
- (iii) The test result shall be obtained from an individual specimen or the average of the results when two or more specimens made from one sample are tested at the same age.
- (iv) Where two or more specimens are made from one sample and the range of the test values is more than 15% of the mean, the result shall be disregarded.

3.1.3.3. Conformity Criteria for Compressive Strength

- (i) Conformity assessment shall be made on test results over a period not exceeding the period given by one of the following options depending on the rate of testing:
 - a) Plants with lower testing rates

Number of test results for designed concrete (less than 35 per three months), the assessment period shall comprise at least 15 results and not more than 35 consecutive results taken over a period not exceeding 6 months.
 - b) Plants with higher testing rates

Number of test results for designed concrete (35 or more per three months), the assessment period shall comprise at least 15 consecutive results and does not exceeding 3 months.
- (ii) Conformity of concrete compressive strength is assessed on specimens tested at 28-days in accordance with:
 - a) Groups of n overlapping consecutive test results f_{cm} (Criterion 1)
 - b) Each individual test result f_{ci} (Criterion 2)

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- (iii) Conformity is confirmed if both the criteria given in **TABLE D19** for either initial or continuous production are satisfied.
- (iv) At the end of initial production, the standard deviation (σ) of the population shall be estimated from at least 35 consecutive test results taken over a period exceeding three months. When continuous production commences, this value of standard deviation shall be used to check the conformity over the first assessment period. At the end of the first and subsequent assessment periods, the standard deviation is checked to determine whether it has changed significantly using the limits given in **TABLE D20**. If it has not changed significantly, the current estimate of the standard deviation applies to the following assessment period. When there is a significant change in standard deviation, a new standard deviation is calculated from the most recent 35 consecutive results and applied to the following assessment period.

3.1.4. Permeability Requirement

For marine structures, Chloride Diffusion Test shall be carried out in accordance with BS EN 12390-11 to assess the potential chloride resistance to chloride ingress for a concrete mix. The precision estimates for calculated chloride content, C_s and non-steady state chloride diffusion coefficient, D_{nss} are given in **TABLE D21**.

3.2. Identity Test

3.2.1. General

- 3.2.1.1. Identity testing indicates whether the defined volume of concrete under review belongs to the same population verified as conforming to the characteristic strength via conformity assessment.
- 3.2.1.2. Identity testing is conducted at the Site upon delivery of concrete.

3.2.2. Sampling and Testing

3.2.2.1. Designed Concrete

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- (i) The sampling rate for identity testing specified in TABLE D22.
- (ii) A sample is made up of three (3) specimens.
- (iii) Samples shall be taken from different batches in accordance with BS EN 12350. Test specimens shall be prepared and cured in accordance with MS EN 12390-2. The compressive strength of the specimens shall be determined in accordance with MS EN 12390-3.
- (iv) One (1) specimen from the sample shall be tested for the 7-days compressive strength. The compressive strength shall not fall below two-third (2/3) of the 28-days compressive strength as given in **TABLE D16** and **TABLE D17**.
- (v) The remaining two (2) specimens shall be tested at 28-days. The compressive strength of the specimens shall be obtained from the average of the results of the two specimens.
- (vi) For 28-days compressive strength test, if the difference between the two (2) test result divided by their mean exceeds 15%, the test result, shall be deemed invalid.

3.2.3. Conformance identity criteria for compressive strength

3.2.3.1. Concrete under production control certification

- (i) Identity of concrete is assessed for each individual strength test result and the average overlapping discrete results as identified in TABLE D23.
- (ii) Concrete is deemed to come from a conforming population if both the criteria in **TABLE D23** are satisfied for n results derived from strength tests on samples taken from the defined volume of concrete.

3.2.3.2. Concrete not under production control certification

- (i) At least three (3) samples shall be taken for testing from the defined volume of concrete.
- (ii) Concrete is deemed to come from a conforming population if both the criteria in **TABLE D24** are satisfied for n results derived from strength tests on samples taken from the defined volume of concrete.

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3.2.4. Identity Testing for Slump and Flow

3.2.4.1. Sampling and Testing

- (i) Sampling of fresh concrete using spot sample shall be obtained from the initial discharge, if concrete is delivered in a truck mixer or agitating equipment. The spot sample shall be taken after a discharge of approximately 0.3 m³ by taking six increments from the moving stream of the concrete. Take at least 1.5 times the quantity required for the tests in accordance with BS EN 12350.
- (ii) The sample shall be remixed on a non-absorbent surface before carrying out the test.
- (iii) For slump test, the test is only valid if it yields a true slump. The slump value (h) is measured in accordance with BS EN 12350 and shown in FIGURE D2.
- (iv) For flow test, the maximum dimension of the concrete spread shall be measured in the two directions as shown in FIGURE D3. The flow value (f) is the average dimension of the two directions in accordance with BS EN 12350.

3.2.5. Conformance Identity Criteria for The Slump and Flow of an Individual Batch

- 3.2.5.1. If the measured slump meets the requirements specified in TABLE D25, the identity test shall confirm that the batch conforms to MS EN 523-2 with respect to its consistency.
- 3.2.5.2. If the measured flow meets the requirements specified in TABLE D11, the identity test shall confirm that the batch conforms to MS EN 523-2 with respect to its consistency.

3.3. Action to be Taken for Non-Conformity of the Product

- 3.3.1. The following actions shall be taken by the Contractor in the event of non-conformity:
 - 3.3.1.1. Check test results and if invalid, take action to eliminate errors.
 - 3.3.1.2. If non-conformity is confirmed e.g., by retesting, take corrective actions including a management review of relevant production control procedures.
 - 3.3.1.3. Where there is confirmed non-conformity with the specification unidentified/ unnoticed at delivery, notice shall be given to the S.O. in order to avoid any consequential damage.
 - 3.3.1.4. Record actions on the sub-sections above.

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3.3.2. In the event that the compressive strength results of the test do not meet the specified requirements mentioned in sub-section 3.2, the S.O. shall determine the action to be taken:

3.3.2.1. If the 7-days concrete strength is less than the specified strength requirements (2/3 of characteristic strength), no more concrete shall be placed on the suspect concrete and no removal of propping on the affected area shall be allowed until the 28-days strength result compliance is available, or unless otherwise approved by the S.O. in writing.

3.3.2.2. For non-compliance of 28- days compressive strength, the S.O. may direct other measures to be taken to rectify the situation to make the work secure.

3.3.2.3. The S.O. may instruct additional tests to be carried out on the hardened concrete to determine the quality of the suspected concrete. The test may include non-destructive and destructive tests. All methods of testing shall conform to MS EN 12504 and results shall be assessed according to MS EN 13791 and MS 1242.

3.3.2.4. If the results from the additional test did not meet the requirements, the S.O. may instruct the Contractor the following actions:

- (i) The section which fails the test shall be removed; or
- (ii) The Contractor shall submit recommendations for remedial work to the suspected concrete. All the recommendations shall be certified by a Professional Engineer.

3.3.3. All works instructed under this sub-section shall be at the Contractor's expense and no extension of time shall be granted for such works.

4. Handling of Concrete

4.1. Supervision

The Contractor shall ensure the required standard of control over materials and workmanship. The S.O. shall be afforded all reasonable opportunities and facilities to inspect the constituent materials and the production of concrete and to take samples for testing.

4.2. Transporting

Concrete shall be transported from the mixer to the formwork as rapidly as practicable by methods, which will prevent segregation or loss of any constituents or ingress of foreign matter or water while maintaining the required workability. It shall be deposited as near as practicable in its final position to avoid rehandling or moving the concrete horizontally by vibration. The concrete shall be conveyed by chutes or concrete pumps only with permission from the S.O..

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4.3. Placement

4.3.1. Placement of Concrete in Dry Condition

- 4.3.1.1. For all concrete whether mixed on or off the site of the Work, each batch shall be placed and compacted within two (2) hours after the time of loading were transported in truck mixers or agitators or within one (1) hour after the time of loading where non-agitating equipment is used, unless a shorter time is specified or a longer time permitted by the S.O.. Concrete shall not be placed in any part of the structure until the approval of the S.O. has been obtained. If concreting is not started within 24 hours of approval given, approval shall again be obtained from the S.O..
- 4.3.1.2. All formwork and reinforcement bar shall be clean and free from standing water immediately before placing of concrete. Concreting shall be carried out continuously between and up to predetermined construction joints in one sequence of operation. It shall be thoroughly compacted by either hand tamping or mechanical vibration or both and shall be thoroughly worked into the corners. After tamping into place, the concrete shall not be subjected to disturbance other than such as incidental to compaction by vibration. In the event of unavoidable stoppage in positions not predetermined, the concreting shall be terminated on a horizontal plane and against vertical surfaces using stop boards. The location for termination shall be subjected to the approval of the S.O..
- 4.3.1.3. Fresh concrete shall not be placed against in-situ concrete which has been in position for more than 45 minutes unless a construction joint is formed in accordance with sub-section 5.1. When in-situ concrete has been in place for 4 hours, no further concrete shall be placed against it for a further 20 hours. Where retarding admixture has been used, the S.O. may approve variation to this limit.
- 4.3.1.4. Unless otherwise approved by the S.O., concrete shall be deposited in horizontal layers to a compacted depth not exceeding 450mm when internal vibrators are used or 300mm in all other cases. The surface of the concrete shall be maintained reasonably levelled during placing.
- 4.3.1.5. Concrete shall not be poured into place from a height exceeding 1.5m. However, higher pouring may be allowed provided the mix has been well designed and proportioned. When trunking or chutes are used, they shall be kept clean and used in such a manner as to avoid segregation.
- 4.3.1.6. The Contractor shall maintain an experienced steel fixer at the Site of reinforced concrete works during the placing of concrete to reposition any reinforcement which may be displaced.
- 4.3.1.7. Where concrete is placed directly against ground, the fresh concrete shall be protected against intermixing with the substrate by a 50mm blinding layer.

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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 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°C.
- 4.4.4. The procedure used to measure the temperature of the fresh concrete shall be as follows:



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- 4.4.4.1. Within 2 min of taking the sample at delivery, insert a Type A 100 mm immersion thermometer having a range of -5°C to +110°C, graduated in intervals of 1°C and conforming to BS 1704, in the sample to a depth of not less than 100 mm. When steady conditions have been maintained for 1 min, record the temperature to the nearest 1°C; and
- 4.4.4.2. Use an alternative form of temperature measurement device with a precision at least that of a thermometer conforming to BS 1704, to record the steady-state temperature to the nearest 1°C.
- 4.4.5. Freshly placed concrete shall be protected from direct sunlight and from loss of moisture by covering, shading or other means.
- 4.4.6. The Contractor shall provide the method statement for temperature control in the case of large volume and/ or continuously concrete pour exceeding 100m³ 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.

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- 4.5.5. Whenever vibration has to be applied externally, the design of formwork and disposition of vibration shall receive special consideration to ensure efficient compaction and to avoid surface blemishes. The vibration shall be such that there will be no excess water on the top surface on completion of compaction.
- 4.5.6. External vibrators shall be firmly secured to the formwork which must be sufficiently rigid to transmit the vibration and strong enough not to be damaged by it. Internal vibrators shall be capable of operating at not less than 10,000 cycles per minute and external vibrators at not less than 3,000 cycles per minute. Sufficient vibrators in serviceable condition shall be on Site so that spare equipment is always available in the event of breakdowns. Vibrators shall be operated by workmen skilled in their use.
- 4.5.7. Concrete shall not be subjected to any disturbance within 24 hours after compaction. No standing or flowing water shall be allowed to come into contact with exposed concrete surfaces during the first two (2) hours after placing and compaction of the concrete.
- 4.5.8. In the event where inadequate or improper compaction is suspected, the S.O. has the right to inspect and to carry out further tests. The tests may include non-destructive and destructive methods. All expenses incurred in carrying out such sampling, testing and remedial works shall be borne by the Contractor irrespective of whether the tests prove the structure to be sound or otherwise.
- 4.6. Curing and Protection
 - 4.6.1. All concrete work shall be cured for the full period of curing which shall not be less than seven (7) days for F1, F2, F3 and F4 surfaces, but not less than five (5) days for F11, F12, F13, F14 and F15 surfaces. Duration of curing for unformed finishes shall not be less than seven (7) days.
 - 4.6.2. Curing and protection shall start immediately after compaction of the concrete to protect it from:
 - 4.6.2.1. Impact damage such as shock, overloading or falling earth which may disrupt the concrete and interface with its bond to reinforcements.
 - 4.6.2.2. Premature drying out from direct sunlight and wind to minimise plastic shrinkage.
 - 4.6.2.3. Leaching out by rain and flowing water.
 - 4.6.2.4. High internal thermal gradients.
 - 4.6.2.5. Harmful contact against aggressive agents e.g., chloride.
 - 4.6.2.6. Harmful weather conditions

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4.6.3. Normal Curing and Protection

4.6.3.1. Concrete, after it is placed and until the expiration of the curing duration, shall not be allowed to dry out. Provision shall be made for adequate protection against direct sunlight and wind to allow the process of curing to complete within the specified period.

4.6.3.2. The following methods are suitable for curing used separately or in sequence after concrete is placed without delay:

- (i) keeping the formwork in place;
- (ii) covering the concrete surface with vapour-proof sheets which are secured at the edges and joints to prevent draughts;
- (iii) placing of wet coverings on the surface and protection of these coverings against drying out;
- (iv) keeping the concrete surface visibly wet with suitable water;
- (v) application of a curing compound of established suitability;
- (vi) Other curing methods of equal effectiveness may be used.

4.6.3.3. The use of other methods of curing may be deemed necessary when the concrete is subjected to high internal thermal gradient, or with large, exposed surface area. The Contractor shall submit method statement to the S.O. for approval.

4.6.3.4. In the event where the Contractor does not do proper curing, the S.O. has the right to inspect and to carry out further tests which may include destructive methods. All expenses incurred in carrying out such sampling, testing and remedial works shall be borne by the Contractor irrespective of whether the tests proved the structure to be sound or otherwise.

4.6.4. Accelerated Curing

4.6.4.1. Steam curing may be used for precast concrete element at the factory.

4.6.4.2. After the completion of the placing of concrete, 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.

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4.6.4.3. The use of accelerated curing methods for concrete containing other types of cement or any admixture or any additional materials shall be to the approval of the S.O..

5. Construction with Concrete

5.1. Construction Joints

- 5.1.1. Construction joints shall be made at the location as shown on the drawing and concreting work shall be carried out continuously up to the construction joints. If the position and detail of any construction joints is not described in the drawings, the Contractor shall propose and obtain the approval of the S.O. prior to commencement of concreting. The construction joints shall be made as few as possible with reasonable precautions against shrinkage. The joints shall be at right angles to the general direction of the member and shall take due account of shear and other stresses.
- 5.1.2. Concrete shall not be allowed to run to a feather edge and vertical joints shall be formed against a stop end. The top surface of a layer of concrete shall be level and flat unless design considerations make this undesirable. Joint lines shall be so arranged that they coincide with features of the 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.
- 5.1.4. Where vertical construction joints are necessary in mass concrete structures, reinforcing bars shall be placed across the joints to make the structure monolithic, all to the approval of the S.O..
- 5.1.5. Prior to recommencement of concreting on a joint, the surface of the concrete against which new concrete will be cast shall be free from laitance and shall be roughened to the extent that the coarse aggregate is exposed but not disturbed. Care shall be taken to avoid damaging the lines of the joint. Care shall also be taken that the joint surface is clean and damp but not wet and the exposed adjoining surfaces shall be of consistent colour. Immediately before the fresh concrete is placed against the joint, fresh rich cement mortar (1:2) shall be applied to the exposed surface.
- 5.1.6. Where the S.O. considers that special preparation is necessary, e.g., for an in-situ structural connection, preparation shall be carried out, preferably when the concrete has set but not hardened, by spraying with a fine spray of air and water or brushing with a stiff brush sufficiently to remove the outer mortar skin and expose the larger aggregates without disturbing them. Where this treatment is impracticable, sand blasting or a needle gun shall be used to remove the surface skin and laitance. Hardened surfaces shall be chipped manually or mechanically to be free from laitance and properly roughened to the extent that the coarse aggregates are being exposed.

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5.2. Fixing Blocks, Brackets, Built in Bolts, Holes, Chases, Etc.

- 5.2.1. All fixing blocks, brackets, built in bolts, holes, chases, etc. shall be accurately set out and formed and carefully sealed prior to the concrete being placed. It is the responsibility of the Contractor to obtain all such information for these sub-sections of work and to obtain the approval of the S.O. before incorporating such work prior to the concrete being placed.
- 5.2.2. Bolts and other inserts to be cast into the concrete shall be securely fixed to the formwork in such a way that they are not displaced during the concreting operations and that there is no loss of materials from the wet concrete through holes in the formwork.
- 5.2.3. Unless otherwise shown on the Drawings or instructed by the S.O., reinforcement shall be locally moved so that the minimum specified cover is maintained at the locations of inserts, holes, chases, etc.. In the event where the minimum cover cannot be maintained, the Contractor shall take the necessary precautions to protect the reinforcements against corrosion by applying an approved coating material to the reinforcements and the concrete cover.
- 5.2.4. Temporary plugs shall be removed and the threads of built-in bolts shall be cleaned and greased before handing over any part of the Work.

5.3. Movement Joints.

- 5.3.1. Movement Joints, Expansion joints, contraction joints or other permanent structure joints shall be provided in the positions and constructed and sealed with waterproofing materials as detailed in the Drawings.
- 5.3.2. When forming movement joints, joint filler shall be fixed firmly to the first-placed concrete. If more than one strip is used within a joint, it is essential to butt the ends tightly or tape them together to prevent grout leakage restricting the closure of the joint.
- 5.3.3. It is essential that the concrete on both sides of the joint, when placed, is thoroughly compacted to form a dense uniform mass. Where stop ends comprise more than one element, particular care is necessary to ensure that joints between elements are sufficiently tight to allow no grout loss through them during compaction of the concrete.
- 5.3.4. Where flexible water stops are used, they shall be fixed to ensure that they are not displaced from their intended position during compaction of the concrete and that the concrete surrounding them is fully compacted. The design of the water stop should be practical and take account of the problems often associated with integral water stop construction in difficult placing conditions.
- 5.3.5. Water stops laid horizontally and located within the concrete mass shall be avoided since they attract the greatest risk of local honeycombing.
- 5.3.6. Unless otherwise shown on the Drawings, all exposed expansion joints shall be covered with 0.7mm thick aluminium cover strips fixed with masonry nails at 300mm centres.

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5.4. Sealants and Special Materials

5.4.1. General

The installation method and the selection, mixing, application and curing of all joint waterproofing materials shall be in accordance with the manufacturer's recommendations. The Contractor may propose to use alternative joint waterproofing materials by submitting supporting technical information, test reports and samples of the proposed waterproofing materials to the S.O. for approval.

5.4.2. Waterproofing Materials

All waterproofing materials used at public access areas shall be protected with non-shrink grout covering.

5.4.3. Water stops

5.4.3.1. The material for water stop can be made of rubber or flexible plastics in accordance with MS 1292.

5.4.3.2. Water stops shall be as specified in the Drawings and shall be installed in accordance with BS EN 1992-3 and the manufacturer's recommendation to the approval of the S.O..

5.4.3.3. Water stops shall be securely positioned in the formwork to 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 $\pm 27.5\%$ of joint width at 27.5°C;
- (iii) Shore 'A' Hardness of 25 $\pm$ at 27.5°C;

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- (iv) Resistance to dilute acids, alkali and all kind of fuel.

5.4.5. Preformed Flexible Strip Sealant

5.4.5.1. Preformed flexible strip sealant shall comply with the following requirements:

- (i) Shall only be used in horizontal joints and be subjected to pressure;
- (ii) Throughout its length;
- (iii) Good adhesion;
- (iv) Water resistant;
- (v) Non-staining.

5.4.6. Bitumen/Rubber Cold Applied Membrane

5.4.6.1. Bitumen/rubber cold applied membrane shall comply with the following requirements:

- (i) Minimum joint movement capacity of $\pm 10\%$ of joint width at 27.5°C;
- (ii) 90% solid content;
- (iii) Resistant to dilute acid and alkali.

5.4.7. Hot-Poured Rubber/Bitumen Sealing Compound.

5.4.7.1. Hot-poured rubber/bitumen sealing compound shall comply with BS 2499.

5.4.8. Bituminous Sheeting

5.4.8.1. Bituminous sheeting with non-asbestos fibre shall comply with the following requirements:

- (i) Resistant to lime water (no visual effect after two (2) weeks immersion);
- (ii) Maximum water absorption of 10% of dry weight;
- (iii) Minimum tensile strength of 50 kg/cm²;
- (iv) Ozone and ultraviolet resistant.

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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 105 kg/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 35 kg/cm³ and 45 kg/cm³;
- (iv) Total resistance to common acids, lubricants and detergents;
- (v) Total resistance to water infiltration by capillary action;
- (vi) Suitability for up to 70°C.

6. Steel Reinforcement

6.1. General

The Work shall consist of furnishing and placing reinforcing steel in accordance with this specification and in conformity with the Drawings or as directed by the S.O..

6.2. Materials

- 6.2.1. The reinforcing steel to be used throughout the Work shall be obtained from the manufacturer that is certified from SIRIM or any certification body that is accredited by *Jabatan Standard Malaysia* and has certificate of PPS by CIDB.
- 6.2.2. 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.
- 6.2.3. Steel fabric reinforcement shall comply with the requirements of MS 145 and shall be delivered to the Site in flat sheets, unless otherwise specified.

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- 6.2.4. 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.
- 6.2.5. 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 E27**.
- 6.2.6. During the course of the Work, any reinforcement found not to be in accordance with the MS or BS may be rejected by the S.O. notwithstanding any previous acceptance on the strength from the test certificates. The S.O. may call for additional tests to be made at the Contractor's expense on samples taken from the batch of the defective reinforcement. If the samples do not comply with the MS or BS, then the S.O. may reject the whole batch and instruct its removal from the Site.
- 6.2.7. 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.
- 6.2.8. Binding wire shall be 1.6mm 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 exceeding 100°C may only be carried out with the S.O. approval and under his supervision. Except where otherwise indicated in the Drawings, bars shall be bent and measured in accordance with MS 1438.
- 6.3.1.3. Cold worked and hot rolled bars shall not be straightened or bent again once having been bent. Where it is necessary to bend the free end of mild steel reinforcement already cast in the concrete, the internal radius of the bend shall not be less than twice the diameter of the bar.



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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 not impair the flow of concrete surrounding the reinforcement bar including the concrete cover.

6.3.4. Spacer Blocks

6.3.4.1. The size of spacer blocks required shall be 50mm x 50mm (LxW) to ensure that the reinforcement is correctly positioned and consistent with their purpose, of a shape approved by the S.O., and designed so that they will not overturn when the concrete is placed. The thickness of spacer will depend on durability design of the structure.

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- 6.3.4.2. Concrete and cementitious spacers should have at least the same strength and should at least give the same corrosion protection as the concrete in the structure. Spacers shall not be made on the construction site. Wires cast in these blocks for the purpose of tying them to the reinforcement shall be free from any corrosion or any other elements that may affect the integrity of the reinforcement bars.
- 6.3.4.3. Spacers left in situ shall not impair the desired appearance or durability of the structure by causing spalling, rust staining or allowing the passage of moisture.
- 6.3.4.4. Plastic chairs and spacers may be used only with the approval of the S.O.. The material of manufacture shall have an equivalent durability when it is in place to that of the concrete itself. Plastic spacers shall satisfy the condition that any cross-section perpendicular to the bar has at least 25% voids within the enclosed perimeter.
- 6.3.4.5. Steel spacers in direct contact with the concrete surface are only permitted in a dry environment i.e. exposure class XC1 of EN 206-1.
- 6.3.4.6. The distance between spacers for each structural component are given in **TABLE E28** and **TABLE E29**.
- 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. 20601-0272-22 or its latest edition.
 - 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.

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7. Formwork and Surface Finish for Structure

7.1. Design and Construction

7.1.1. Description

- 7.1.1.1. Formwork shall include all temporary or permanent forms required for forming the concrete, together with all temporary construction required for their support.
- 7.1.1.2. The Contractor is deemed to have made a study of the Drawings at tender stage and is aware of all areas of construction, requiring heavy and specially designed propping to provide the support and the necessary bracing for the stability of such propping.
- 7.1.1.3. The design and construction of formwork shall be carried out by a competent person. The Contractor shall identify all critical formwork design and submit the strength and deflection calculations and Drawings or the proposed design, certified by a Professional Engineer to the S.O. for prior approval. Notwithstanding any approval by the S.O. with respect to the design submitted by the Contractor, the responsibility or the adequacy and safety of the design shall remain with the Contractor. The Contractor shall also appoint a competent formwork coordinator whose duties would be similar to those outlined in BS 5975.
- 7.1.1.4. When the use of proprietary type of formwork is proposed by the Contractor, the design shall be certified by a Professional Engineer.
- 7.1.1.5. The formwork shall be sufficiently rigid and tight to prevent loss of grout or mortar from the concrete at all stages of construction and shall be appropriate for the methods of placing and compacting.
- 7.1.1.6. Formwork (including supports) shall be sufficiently rigid to maintain the forms in their correct position, shape, profile and dimensions. The supports shall be designed to withstand the worst combination of forces due to self-weight, formwork weight, formwork forces, reinforcement weight, wet concrete weight, construction and wind loads, together with all incidental dynamic effects caused by placing, vibrating and compacting the concrete. Guidance on these loadings is given in The Concrete Society Manual Formwork - Guide to good practice, and in CIRIA Report 108, Concrete Pressure in Formwork, and in BS 5975. Vertical propping to formwork shall be sufficiently constructed to provide the necessary support without overstressing the completed concrete structure.

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7.1.1.7. Metal ties may only be used with prior approval from the S.O.. Where metal ties are permitted, the use of storey height steel soldiers shall be used to reduce the number of tie bolts required. Tie bolts with rubber or plastic cone against the form face are to be used to prevent unsightly grout loss. No metal part of any device for maintaining formwork in the correct location shall remain permanently within the specified concrete cover to the reinforcement. Except for ties used for anchoring void formers, all ties shall be at least 1.2m 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.

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, etc.) 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 200 kPa;
 - b) Maximum pore size of less than 0.030 mm;

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- c) Minimum water retention capacity of 0.35 l/m²;
- d) Result in bleed water from the liner which is free from cement and fine aggregate particles.
- (v) The concrete cast against the CPF liner shall have an even uniformly textured matt finish and shall be free of blowholes and other surface blemishes. The use of the CPF liner shall meet the following performance requirements which should be demonstrated by the supply of test certificate:
 - a) The mean surface strength for the CPF cast face shall exceed that for the control face by at least 70%.
 - b) The mean 10 minutes ISAT result for the CPF cast face shall be not more than 15% of that for the control face.
 - c) The mean depth of carbonation for the CPF cast face shall be not more than 15% of that for the control face.
 - d) The mean concentration of chlorides at a depth of 11mm from the CPF cast face shall be not more than 15% of that for the control face.
- (vi) The CPF liner shall be used once only. Release agents shall not be used with the liner and any residual release agent remaining on forms from previous use shall be removed.
- (vii) To ensure conformity with the performance requirements, the CPF liner is to be used in accordance with the manufacturer's technical guidelines.
- (viii) The CPF liner shall unless otherwise directed, be left in place on the concrete after formwork removal for the curing period specified by the S.O.. It shall be kept wet and covered with plastic sheeting to promote efficient curing.

7.1.3. Projecting Reinforcement, Fixing Devices

Where holes are needed in form to accommodate projecting reinforcement or fixing devices, care shall be taken to prevent loss of grout when concreting or damage when removing forms.

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7.2. Surface Finishes for Concrete

7.2.1. Control of Colour

When specified in the Drawings, the Contractor shall obtain each constituent material from a single consistent source. The aggregates shall be free of any impurities that may cause staining. The mix proportions and the grading, particularly of the fine aggregate, shall be maintained constant. The same type of plywood or timber shall be used in formwork throughout similar exposed areas.

7.2.2. Formed Surfaces

7.2.2.1. Formed concrete surfaces shall have one of the following classes of finish.

7.2.2.2. Unless otherwise specified, all exposed concrete surfaces shall be of Class F12, all unexposed surfaces shall be of Class F1. Other classes of finishes shall be used only where shown on the Drawings:

(i) Class F1

This finish shall be obtained using properly designed forms of closely joined sawn timber or other approved material. Small blemishes caused by entrapped air or water may be expected but the surface shall be free from voids and honeycombing.

(ii) Class F2

This finish shall be obtained using properly designed forms of closely jointed wrought boards, approved plywood or other approved material. Only very minor surface blemishes shall occur, with no staining or discoloration.

(iii) Class F3

a) This finish shall be obtained using properly designed steel forms or plastic-coated plywood or wrought boards or other approved material that can be used not less than 20 times.

b) The surface shall be improved by carefully removing all fins and other projections, thoroughly washing down and then filling the most noticeable surface blemishes with a cement and fine aggregate paste to match the colour of the original concrete. Form release agents shall be carefully chosen to ensure that the surface shall not be stained or discoloured. After the concrete has been properly cured, the surface shall be rubbed down where necessary, to produce a smooth and even surface.

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(iv) Class F4

The requirements for Class F4 are as for Class F3 except that internal ties and embedded metal parts will be permitted. The ties shall be positioned only in rebates, or in other positions as shown on the Drawings or as agreed by the S.O..

(v) Class F11

The requirements for Class F11 surface finish are identical to those for Class F1 except that it shall be achieved using Controlled Permeability Formliners.

(vi) Class F12

The requirements for Class F12 surface finish are identical to those for Class F2 except that it shall be achieved using Controlled Permeability Formliners.

(vii) Class F13

The requirements for Class F13 surface finish are identical to those for Class F3 except that it shall be achieved using Controlled Permeability Formliners.

(viii) Class F14

The requirements for Class F14 surface finish are identical to those for Class F4 except that it shall be achieved using Controlled Permeability Formliners.

(ix) Class F15

The requirements for Class F15 are as for Class F4 except that plywood shutters lined with an approved patterned formliner shall be used to produce a patterned profile finish. Where possible, full height formliners shall be employed so that no horizontal joints in the liners are required. Tie holes shall be spaced so that they occur at overlap joints in the lining sheet.

7.2.3. Unformed surfaces

7.2.3.1. Class U1

The concrete shall be uniformly levelled and screened to produce a plain, ridged or broom roughened surface. No further work shall be applied to the surface unless it is used as the first stage for a Class U2 or Class U3 finish.

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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.

7.2.4. Trial Panels for Exposed Form Finished Surfaces

7.2.4.1. In order to ensure that the specified formed finishes can be obtained by the method of construction proposed and to provide a standard by which the finishes in the Works can be assessed, trial panels shall be cast on Site. These panels shall be subjected to the S.O. approval before similar casting is permitted in the Works.

7.2.4.2. The trial panels shall employ the materials, plant and concrete mix proposed for the Works. They shall be at least a storey height and 1 m wide. They shall be of similar thickness and similarly reinforced as the elements they represent and shall incorporate all features which contribute to the final appearance of the Works.

7.3. Preparation of Forms Before Concreting

7.3.1. Before concreting, all forms shall be thoroughly cleaned out, free from sawdust shavings, dust, mud or other debris. The inside surfaces of forms shall, unless otherwise approved by the S.O., be coated with an approved non-staining form oil or other approved material to prevent adhesion of the concrete. Such release agents shall be applied strictly in accordance with the manufacturer's recommendation and shall not come into contact with the reinforcement or prestressing tendons and anchorages. For any exposed surface only one release agent shall be used throughout the entire area.

7.3.2. All formworks shall be inspected by the S.O. after preparation and immediately prior to depositing concrete and no concrete shall be deposited until approval of the formwork has been obtained.

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7.4. Removal of Forms

- 7.4.1. The Contractor shall inform the S.O. and obtain his approval before striking any formwork, but such approval shall not relieve the Contractor of his responsibilities on the safety of the work.
- 7.4.2. Formwork shall be removed without such shock or vibration that would damage the concrete. A period of time shall elapse between the placing of the concrete and the removal of the formwork for various parts of the structure so as to suit the requirements for its curing.
- 7.4.3. The minimum periods between concreting and the removal of forms are given in **TABLE E30**. The periods stated in this table are based on the use of CEM 1. They may be changed with the approval of the S.O., if other types of cement as described in sub-section 2.1, admixtures as described in sub-section 2.4 are used. The result of the compressive strength obtained from cube strength at 7 days as described in sub-section 3.2 may also be used for early removal of forms. The Contractor shall provide proof of calculation to the S.O for approval prior to removal of forms.
- 7.4.4. For prestressed in-situ components, temporary supports shall not be removed until the components are stressed to the approval of the S.O..
- 7.4.5. Where it is intended the forms are to be reused, they shall be cleaned and made good to the approval of the S.O..
- 7.4.6. Following the removal of forms, no further loads shall be imposed upon the concrete until at least after completion of the curing period or until such later time as in the opinion of the S.O. the concrete shall have attained sufficient strength to safely withstand such loads. Full design loads shall not be applied to any structure until all load bearing concrete is at least 28 days old.

7.5. Inspection and Making Good

- 7.5.1. The surface of the concrete shall be inspected for defects and for conformity to the surface finish specified and where appropriate, with approved sample finishes.
- 7.5.2. Subject to the strength and durability of the concrete being unimpaired, the making good of surface defects may be permitted but the level of acceptance shall be appropriate to the type and quality of the finish specified and ensure satisfactory permanence and durability.
- 7.5.3. Any remedial treatment of surfaces shall be approved by the S.O. following inspection immediately after removing the formwork and shall be carried out without delay.

8. Building Accuracy

After removal of formwork, the Contractor shall take measurements as directed by the S.O. to check the deviation of the reinforced concrete works from specified dimensions shown on the Drawings. All measurements shall be recorded and submitted to the S.O. Any deviation in building accuracy shall comply with BS EN 13670.

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9. Apparatus

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

- 9.1. Concrete slump test apparatus and flow test apparatus complying with BS EN 12350-2. One set of the apparatus shall be provided for each concreting location.
- 9.2. At least twelve (12) numbers of moulds (steel, cast iron or ABS) for casting 150 mm concrete test cubes in accordance with BS EN 12390-1. A minimum number shall be provided such that no stripping of cubes is required prior to 24 hours setting and hardening period.
- 9.3. At least six (6) numbers of prismatic specimen 40 x 40 mm in cross section and 160 mm in length for mortar or grout test moulds in accordance with BS EN 445. A minimum number shall be provided such that no stripping of cubes is required prior to 24 hours setting and hardening period.
- 9.4. Three (3) measuring cylinders of 250 ml capacity, graduated to measure to the nearest 2.0 ml., for determination of silt content (field setting method).
- 9.5. An approved apparatus for measuring moisture content in fine aggregate.
- 9.6. One (1) electronic calculator with statistical functions.
- 9.7. One (1) 300mm steel rule.
- 9.8. One (1) set of sieves in compliance with BS ISO 3310.
- 9.9. Scale or balance 25 kg maximum capacity and weights.
- 9.10. Trowel, shovel, spanner and other tools.
- 9.11. One (1) Electromagnetic Concrete Cover Meter.

10. Precast Concrete Works

- 10.1. The Contractor shall employ manufacturers registered with CIDB to supply or cast on site precast component to the respective project. All precast concrete components to be used in the works shall be approved by the S.O./P.D. prior to installation. The full requirement is outlined in the Specification for Precast Concrete Works (JKR 20601-0251-18) or its latest edition.

10.2. Industrialized Building System (IBS) Requirements

The calculation shall comply based on the latest version of Manual for Industrialized Building System (IBS) Content Scoring System (IBS Score): Construction Industry Standard, CIS 18 published by the Construction Industry Development Board (CIDB) Malaysia.

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10.3. Assembly Drawing

- 10.3.1. All assembly drawing produced by the manufacturer and verified by a Professional Engineer (P.E.) to the S.O. for approval before the commencement of the manufacturing of the component. The list of drawings that needs to be endorsed are as below:

10.3.1.1. Layout drawing;

10.3.1.2. Section drawing;

10.3.1.3. Connection details;

10.3.1.4. Element types;

10.3.1.5. General drawing.

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

10.4. Installation

- 10.4.1. The Contractor shall inform the S.O. at least one month in advance of launching or installation operation and submit the following documents to the S.O. for approval:

10.4.1.1. Method statement including launching systems and transportation;

10.4.1.2. Proposal for traffic diversion, if appropriate;

10.4.1.3. Detailed program of launching and installation operation;

10.4.1.4. Installation operation safety program.

- 10.4.2. Inspection of Precast Unit.

The elements shall be inspected for cracking and other defects or damage. The dimensional properties of the components shall be checked in accordance with the Drawings.

- 10.4.3. Lifting and Handling

A lifting method statement shall be prepared by the Contractor and submitted for approval. The elements shall be lifted from the mould according to the locations of the lifting devices and instructions on the production drawings. The recommended minimum concrete strength for lifting and handling are shown in **TABLE E31**.

10.5. Connection

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

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- 10.5.2. Designed mixes of grout shall be submitted to the S.O. for approval. The grout shall be of high fluidity and cohesive at plastic and shrinkage resistant during hardening.
- 10.5.3. The grout shall be a mixture of blended cement, water and approved admixture. The acceptance strength shall be deemed to be satisfied when the strength is equal or greater than the specified characteristic strength of precast concrete.
- 10.5.4. If the Contractor chooses to use proprietary product, he shall submit to the S.O. 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.
- 10.5.5. The grout shall be tested in accordance with the following method:
 - 10.5.5.1. Fluidity Test by using Cone Method (BS EN 445) or;
 - 10.5.5.2. Fluidity Test by using Grout Spread Method (BS EN 445) or;
 - 10.5.5.3. Flowability Test using Flow Cone Method (ASTM C939) and;
 - 10.5.5.4. Compressive Strength Test (BS EN 445).
- 10.5.6. Placement
 - 10.5.6.1. Vertical Placement (Pressure Grouting)

Grout shall be pumped into each sleeve until grout pours out of the outlet and pumping shall be continued until a pressure of minimum 100 kN/m² is attained. The high-pressure cork shall remain closed and in position for a period of one hour after grouting.
 - 10.5.6.2. Vertical Placement (Gravity Flow)

This method shall only be allowed for shallow sleeve, such as the connection between corbel and precast beam, nib and precast beam. The diameter of corrugated sleeve and the appropriate dowel bar size shall be as shown in **TABLE E32**.
 - 10.5.6.3. Horizontal Placement (Gravity Flow Grouting)

Gravity flow grout shall be applied to areas that convenient and easy for grouting works such as, longitudinal joint between precast components. It can be poured by hand directly along the joint and swept into the gap with suitable tools.

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11. Other Concrete Works

11.1. Foundation

- 11.1.1. All reinforced concrete footings and pile caps shall be constructed according to the Drawings and to the exact depths required. The Contractor shall supply, maintain and remove any necessary planking and strutting, sheet piling and coffer dams, and shall by pumping or other approved means, keep the excavation free from water.
- 11.1.2. The bottom of excavation shall be cleaned or if in loose or disturbed ground shall be well rammed, and the whole shall be approved before it is covered with a blinding layer of lean concrete not less than 50mm thick. The required cover of concrete under the reinforcement shall not be inclusive of the blinding layer's thickness.

11.2. Pile Caps

- 11.2.1. Before commencing to construct pile caps, the Contractor shall check and verify the eccentricities and the cut-off levels of all piling works in the ground are as provided in the Drawings and shall notify the S.O. in the event of any discrepancy.
- 11.2.2. The Contractor shall straighten the steel reinforcement projecting above the piles for anchoring pile caps, carry out excavation, erect formwork and temporary timbering for the construction of pile caps and ground beams.

11.3. Structural Elements Below Ground Level

- 11.3.1. For structural elements, lift shaft and lift pits below ground level, the concrete in the base slab and walls shall be of reinforced concrete with minimum cement content and maximum free water to cement ratio in accordance with the exposure XC3 in **TABLE E5, TABLE E6, TABLE E7** and **TABLE E8** shall be constructed in operations which shall ensure water tightness.
- 11.3.2. All external and internal wall surfaces of lift pits shall be waterproofed with three (3) coats of bitumen solution complying with BS 3416 or any other type of waterproofing material as approved by the S.O.. The concrete surface shall be thoroughly cleaned and dried before application of the waterproofing material.
- 11.3.3. Lift shaft and structural wall enclosures shall be made of reinforced concrete on all sides and constructed using steel formwork to ensure the accuracy of the structure in terms of verticality, shape, profile and dimensions. Refer to **FIGURE E4**.
- 11.3.4. For lift shaft enclosure, all the inner surfaces shall form a continuous flush surface without projection or recesses. Refer to **FIGURE E4**.
- 11.3.5. The lift shaft shall have a high degree of verticality. The limit of accuracy of shaft plumb for the full stretch of the lift shaft shall not exceed ± 30 mm. Refer to **FIGURE E5**.
- 11.3.6. The structural openings shall be vertically aligned one above the other for the full travel of the lift.

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- 11.3.7. The structural opening shall be accurate to the specified dimensions. Deviations from the specified dimensions shall not exceed +12.5mm, -0mm. Refer to **FIGURE E6**.

11.4. Floors

- 11.4.1. After initial set, the upper surface of cast-in-situ reinforced concrete floors shall be trowelled smooth with a steel float to true level and even surface. No screeding of any kind shall be applied to the floor slabs except where specified. Care shall be taken to ensure that the steel reinforcement is not displaced or lowered during trowelling.
- 11.4.2. For areas, which are to receive rendering or other finishes, the fresh concrete shall be trowelled to true level or as required using a long timber trowel. Before it hardens it shall be brushed with a stiff broom in one direction to give a rough and tidy surface.
- 11.4.3. The reinforced concrete ground floor slab shall not be laid directly onto earth surfaces. A blinding layer of 50mm minimum thick of lean concrete shall be laid on well prepared firm ground. Plastic sheeting or other suitable material with sufficient overlaps at joints, shall be laid on the blinding layer before any reinforcement is placed in position.

11.5. Toilet Floors

- 11.5.1. The Contractor shall ensure that all suspended floor for toilet areas are constructed to be watertight and leak proof. All construction method or alternative details proposed by the Contractor must be based on his acceptance of and compliance with the requirements for watertightness. The Contractor shall ensure that holes and fixings are properly constructed.
- 11.5.2. The floor must be concreted in one sequence of operation. No construction joints for toilet floor are to be allowed. All pipes and fittings encased in the concrete floor shall be provided with sleeves to the approval of the S.O and shall be built in-situ. No holes shall be left for later incorporation of fittings and no subsequent hacking of floor shall be made. Notwithstanding whatever shown on the Drawings, all toilet floor slabs shall have a minimum thickness of 150 mm.
- 11.5.3. Testing for Watertightness

The toilet floor areas shall be ponded with minimum 25mm depth of water and shall be maintained continuously over a period of 24 hours. During this period, the exposed soffit shall show no signs of leakage and remain dry. If any area is found not to be watertight, the Contractor must repair at his own expense.

11.6. Roofs

- 11.6.1. Reinforced concrete roofs shall be constructed to fall as shown on the Drawings and finished with steel trowelling, leaving the surface smooth and free from mortar droppings.

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- 11.6.2. The base slab shall be concreted as described for concrete generally, ensuring thorough compactions using a pan vibrator or a vibrating screen. Concrete shall be poured continuously between pre-determined construction joints as decided by the S.O., or as shown on the Drawings. Expansion joints, where applicable, shall be allowed and constructed exactly as indicated in the Drawings.
- 11.6.3. Unless otherwise specified or shown on the Drawings, waterproofing screed to reinforced concrete flat roof shall consist of a 32mm thick screed reinforced with temperature steel.
- 11.6.4. The waterproofing screed shall consist of one (1) part of cement and three (3) parts of clean well-graded sand (1:3) and shall be mixed with an approved waterproofing agent and approved plasticizer in the proportion recommended by the manufacturer.
- 11.6.5. The temperature steel shall consist of a mesh 6mm diameter steel bars at 100 mm centres each way, or alternatively steel fabric of MS 145. The temperature steel shall be placed directly on top of the base slab, and a minimum cover of 20 mm to top bars of the temperature steel shall be maintained.
- 11.6.6. The screed shall be laid after the base slab concrete has sufficiently hardened but not later than 36 hours after the concreting of the base slab, to obtain a thorough bond between the screed and the base slab. The surface shall be finished with a wood float and followed by a steel trowel to a smooth finish.
- 11.6.7. Unless otherwise specified or shown on the Drawings, joints in the screed shall be constructed and located over the main roof beams and shall be filled with approved bituminous compound as soon as possible.
- 11.6.8. After the screed has been placed, the full area shall be properly protected and cured for a period of at least seven (7) days. Alternatively, as soon as the screed has sufficiently hardened to withstand a man's weight without marking, an approved plastic sealing agent shall be sprayed in accordance with the manufacturer's recommendation.

11.7. Drips

Unless otherwise shown on the Drawings or directed by the S.O., a 15mm wide drip shall be formed along edges of soffits to concrete roof slabs, hoods, undersides of balconies, cantilevered beams and slabs and other parts of building where rainwater is likely to adhere in drops.

11.8. Refuse Chutes

Where shown on the Drawings, all cast-in-situ reinforced concrete refuse chutes shall be constructed without bolt holes made through the chute walls. If such holes are unavoidable then they shall be completely grouted with cement mortar or sealed and waterproofed by other means to prevent leakage to the approval of the S.O. Frames which shall not be of asbestos cement, shall be cast into refuse chute walls for fixing chute hoppers. Such frames shall be obtained from the same supplier of chute hoppers.

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TABLE E1: 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	Sulphate-resisting Portland cement	CEM I-SR 0
CEM I-SR 3		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 <i>k</i> -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 E2: 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	MS EN 197-1	IIIA	A
	CEM III/A+SR ^d		IIIA+SR	D
	CEM III/B	MS EN 197-1	IIIB	A
	CEM III/B+SR ^d		IIIB+SR	F
Pozzolan cement ^e	CEM IV/B(V)	MS EN 197-1	IVB-V	E
		or		
		BS EN 14216		
Sulphate-resisting Portland cement	CEM I-SR 0	MS EN 197-1	CEM I-SR 0	G
	CEM I-SR 3		CEM I-SR 3	
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	IIA	A
		MS 523-3		
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	Annex B	IIB-V	A
	CIIB-V+SR ^c	MS 523-3	IIB+SR	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	IVB-V	E
		MS 523-3		
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	IIA	A
		MS 523-3		
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	IIB-S	A
		MS 523-3		
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	CIIA	Annex B	IIIA	A
	CIIA+SR ^d	MS 523-3	IIIA+SR	D

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TABLE E2: 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	CIIB	Annex B	IIIB	A
	CIIB+SR ^d	MS 523-3	IIIB+SR	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	Annex B	IIA	B ^b or C ^b
	CIIA-LL	MS 523-3	IIA	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 <i>k</i> -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 E3: TESTING OF AGGREGATES

Properties	Test Methods
Grading	MS EN 933
Flakiness Index	MS EN 933
Water Absorption	MS EN 1097
Shape Index	MS EN 933
Percentage of Crushed and Broken Surfaces in Coarse Aggregate Particles	MS EN 933
Aggregate Crushing Value	MS EN 933
Chloride Content	BS EN 1744
Sulphate Content	BS EN 1744

TABLE E4: GENERAL GRADING REQUIREMENTS

Aggregate	Size (mm)	Percentage passing by mass					Category G
		2D ^a	1.4D	D ^b	d	d/2	
Coarse	D > 4 d ≥ 1	100	100	90 to 99	0 to 10	0 to 2	G _C 90/10
		100	98 to 100	90 to 99	0 to 15	0 to 5	G _C 90/15
		100	98 to 100	85 to 99 ^c	0 to 15	0 to 5	G _C 85/15
		100	98 to 100	85 to 99 ^c	0 to 20	0 to 5	G _C 85/20
		100	98 to 100	80 to 99	0 to 20	0 to 5	G _C 80/20
		100	98 to 100	85 to 99	0 to 35	0 to 5	G _C 85/35
		100	98 to 100	85 to 99 ^c	0 to 15	0 to 2	G _{CA} 85/15
	d ≥ 1 D ≤ 4	100	95 to 100	85 to 99	0 to 15	-	G _G 85/15
		100	98 to 100	85 to 99	0 to 20	0 to 5	G _G 85/20
		100	98 to 100	85 to 99	0 to 35	0 to 5	G _G 85/35
Natural Graded Aggregates	D = 8 d = 0	100	98 to 100	90 to 99	-	-	G _{NG} 90
Fine	D ≤ 4 d = 0	100	95 to 100	85 to 99	-	-	G _F 85
All-in	D > 4 d = 0	100	98 to 100	90 to 99	-	-	G _A 90
		100	98 to 100	85 to 99	-	-	G _A 85
		100	98 to 100	80 to 99	-	-	G _A 80
		100	-	75 to 99	-	-	G _A 75



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TABLE E5: 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	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	All in Table D1	
	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240		
XC2	-	-	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	All in Table D1	
			0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260		0.65 260
XC3/4	-	C40/50	C32/40	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	All in Table D1 except IVB-V	
		0.45 340	0.55 300	0.60 280	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260		
	-	-	C40/50	C32/40	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	IVB-V	
			0.45 340	0.55 300	0.60 280	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260		0.65 260
Corrosion induced by chlorides other than seawater (XD exposure classes) adequate for any associated carbonation induced corrosion (XC)													
XD1	-	-	C40/50	C32/40	C28/35	C28/35	C28/35	C28/35	C28/35	C28/35	C28/35	All in Table D1	
			0.45 360	0.55 320	0.60 300	0.60 300	0.60 300	0.60 300	0.60 300	0.60 300	0.60 300		0.60 300
XD2	-	-	-	C40/50	C32/40	C28/35	C28/35	C28/35	C28/35	C28/35	C28/35	CEM I, IIA, IIB-S,	
				0.40 380	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	CEM I-SR0, CEM I-SR3
	-	-	-	C35/45	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	IIB-V, IIIA	
				0.40 380	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320		0.55 320
	-	-	-	C32/40	C25/30	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	IIIB, IVB-V
				0.40 380	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	
XD3	-	-	-	-	-	C45/55	C40/50	C35/45	C35/45	C35/45	C35/45	CEM I, IIA, IIB-S	
						0.35 380	0.40 380	0.45 360	0.45 360	0.45 360	0.45 360	0.45 360	0.45 360
	-	-	-	-	-	C35/45	C32/40	C28/35	C28/35	C28/35	C28/35	IIB-V, IIIA	
						0.40 380	0.45 360	0.50 340	0.50 340	0.50 340	0.50 340		0.50 340
	-	-	-	-	-	-	C32/40	C28/35	C25/30	C25/30	C25/30	C25/30	IIIB, IVB-V
							0.40 380	0.45 360	0.50 340	0.50 340	0.50 340	0.50 340	

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TABLE E5: 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	C40/50	C35/45	C32/40	C28/35	C25/30	C25/30	C25/30	CEM I, IIA, IIB-S
				0.35 380	0.40 380	0.45 360	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	
	C40/50	C32/40	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	IIB-V, IIIA
	0.35 380	0.45 360	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	
	C35/45	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	IIB-V ≥ 25 % fly ash,
	0.40 380	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	IIIA ≥ 46 % ggbs
	C32/40	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	IV-B, IIIB
0.40 380	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320		
XS2	-	-	-	-	-	-	C45/55	C40/50	C40/50	C35/45	C32/40	CEM I, IIA, IIB-S
							0.35 380	0.40 380	0.40 380	0.45 360	0.50 340	
	-	-	C35/45	C32/40	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	IIB-V, IIIA
	-	C40/50	C32/40	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	IIB-V ≥ 25 % fly ash,
	-	C35/45	C28/35	C25/30	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25
0.35 380												
XS3	-	-	-	-	-	-	-	-	-	-	C45/50	CEM I, IIA, IIB-S
											0.35 380	
	-	-	-	-	C40/50	C35/45	C32/40	C28/35	C25/30	C25/30	C25/30	IIB-V, IIIA
	-	-	-	C40/50	C32/40	C28/35	C25/30	C25/30	C25/30	C25/30	C20/25	IIB-V ≥ 25 % fly ash,
	-	-	-	C35/45	C28/35	C25/30	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25
0.35 380												



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TABLE E6: 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	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	C20/25	All in Table D1	
	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240	0.70 240		
XC2	-	-	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	All in Table D1	
			0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260		
XC3/4	-	-	-	C40/50	C35/45	C30/37	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	All in Table D1	
				0.45 340	0.50 320	0.55 300	0.60 280	0.65 260	0.65 260	0.65 260	0.65 260	0.65 260	except IVB-V	
	-	-	-	-	C40/50	C35/45	C30/37	C28/35	C25/30	C25/30	C25/30	C25/30	IVB-V	
					0.45 340	0.50 320	0.55 300	0.60 280	0.65 260	0.65 260	0.65 260	0.65 260		0.65 260
Corrosion induced by chlorides other than seawater (XD exposure classes) adequate for associated carbonation induced corrosion (XC)														
XD1	-	-	-	C45/55	C40/50	C35/45	C32/40	C28/35	C28/35	C28/35	C28/35	C28/35	All in Table D1	
				0.40 380	0.45 360	0.50 340	0.55 320	0.60 300	0.60 300	0.60 300	0.60 300	0.60 300		
XD2	-	-	-	-	-	C35/45	C32/40	C28/35	C28/35	C28/35	C28/35	C28/35	CEM I, IIA, IIB-S,	
						0.45 360	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	CEM I-SR0, CEM I-SR3
	-	-	-	-	-	C32/40	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	IIB-V, IIIA	
						0.45 360	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320		0.55 320
	-	-	-	-	-	-	C28/35	C25/30	C20/25	C20/25	C20/25	C20/25	C20/25	IIIB, IVB-V
							0.45 360	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	
XD3	-	-	-	-	-	-	-	-	C45/55	C40/50	C35/45	C35/45	CEM I, IIA, IIB-S	
									0.35 380	0.40 380	0.45 360	0.45 360	CEM I-SR0, CEM I-SR3	
	-	-	-	-	-	-	C40/50	C35/45	C32/40	C28/35	C25/30	C25/30	IIB-V, IIIA	
							0.35 380	0.40 380	0.45 360	0.50 340	0.50 320	0.50 320		
	-	-	-	-	-	-	C32/40	C28/35	C25/30	C25/30	C25/30	C25/30	IIIB, IVB-V	
							0.40 380	0.45 360	0.50 340	0.50 320	0.55 320	0.55 320		



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TABLE E6: 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	C40/50	C35/45	C32/40	CEM I, IIA, IIB-S	
								0.35 380	0.40 380	0.45 360	0.50 340		
	-	C40/50	C40/50	C35/45	C32/40	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	IIB-V, IIIA	
		0.35 380	0.35 380	0.45 380	0.45 360	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320		
	-	-	C35/45	C32/40	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	IIB-V ≥ 25 % fly ash, IIIA ≥ 46 % ggbs	
			0.40 380	0.45 360	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320		
	-	-	C32/40	C28/35	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30		
			0.45 380	0.45 360	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320		
	-	-	C35/45	C30/37	C28/35	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	C25/30	IVB-V
			0.40 380	0.45 360	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320	
XS2	-	-	-	-	-	-	-	-	-	-	-	CEM I, IIA, IIB-S	
	-	-	-		C40/50	C35/45	C32/40	C28/35	C28/35	C25/30	C25/30	IIB-V, IIIA	
					0.35 380	0.40 380	0.45 360	0.50 340	0.50 340	0.55 320	0.55 320		
			C40/50	C35/45	C32/40	C28/35	C25/30	C25/30	C25/30	C25/30	IIB-V ≥ 25 % fly ash, IIIA ≥ 46 % ggbs		
			0.35 380	0.40 380	0.40 360	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320			
			C35/45	C32/40	C28/35	C25/30	C20/25	C20/25	C20/25	C20/25	C20/25	IVB-V, IIIB	
0.35 380			0.40 380	0.45 360	0.50 340	0.55 320	0.55 320	0.55 320	0.55 320	0.55 320			
XS3	-	-	-	-	-	-	-	-	-	-	-	CEM I, IIA, IIB-S	
	-	-	-	-	-	-	C40/50	C40/50	C35/45	C32/40	C28/35	IIB-V, IIIA	
							0.35 380	0.35 380	0.40 380	0.45 360	0.50 340		
	-	-	-	-	-	-	C40/50	C35/45	C32/40	C25/30	C25/30	IIB-V ≥ 25 % fly ash, IIIA ≥ 46 % ggbs	
							0.35 380	0.40 380	0.40 360	0.55 320	0.55 320		
	-	-	-	-	-	-	C35/45	C32/40	C28/35	C20/25	C20/25	IVB-V, IIIB	
0.35 380							0.40 380	0.45 360	0.55 320	0.55 320			

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TABLE E7: MINIMUM CEMENT AND COMBINATION CONTENTS WITH MAXIMUM AGGREGATE SIZES OTHER THAN 20MM

Limiting values given for 20 mm maximum aggregate size		Maximum aggregate size		
Maximum w/c ratio	Minimum cement or combination content (kg/m ³)	≥ 40 mm	14 mm	10 mm
0.70	240	240	260	280
0.65	260	240	280	300
0.60	300	280	320	340
0.60	280	260	300	320
0.55	300	280	320	340
	320	300	340	360
0.50	320	300	340	360
	340	320	360	380
0.45	340	320	360	360
	360	340	380	380
0.40	380	360	380	380
0.35	380	380	380	380

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TABLE E8: EXPOSURE CLASSES

Class designation	Class description	Informative examples applicable in Malaysia
Corrosion induced by carbonation (XC classes) <i>(where concrete containing reinforcement or other embedded metal is exposed to air and moisture)</i>		
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) <i>(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)</i>		
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) <i>(where concrete containing reinforcement or other embedded metal is subject to contact with Seawater or airborne salt originating from seawater)</i>		
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 E9: 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 E10: 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 E11: FLOW CLASSES

Class	Flow Diameter In mm
F1	≤ 340
F2	350 to 410
F3	420 to 480
F4	490 to 550
F5	560 to 620
F6	≥ 630

TABLE E12: SLUMP – FLOW CLASSES

Class	Slump-flow ^a tested in accordance with EN 12350-8 mm
SF1	550 to 650
SF2	660 to 750
SF3	760 to 850

^a The classification is not applicable to concrete with $D_{\max}$ exceeding 40 mm
 $D_{\max}$ = Declared value of D of the coarsest fraction of aggregates actually used in the concrete

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TABLE E13: 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 E14: 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 E15: METHOD FOR DETERMINING THE CHLORIDE CONTENT OF CONSTITUENT MATERIALS

Constituent	Method specified in
Cement, fly ash, ggbs, limestone fines, metakaolin	<i>MS EN 196-2</i>
Aggregate excluding CCA and filler aggregate made from fly ash	<i>BS EN 1744-1</i>
Coarse CCA	<i>BS 1881-124</i>
Admixture	<i>BS EN 480-10</i>
Water ^a	<i>MS EN 196-2^b or BS 6068-2.37^b</i> (ISO 9297)
^a Testing is not required if the water is from a potable supply. ^b MS EN 1008 cites "the relevant clauses of BS EN 196-21" for the determination of chloride ion content. BS EN 196-21 has been superseded by MS EN 196-2. The chemical procedure is the same as that given in BS 6068-2.37 and in this case the starting point is a sample of water. When the chloride ion content is outside the recommended range for the test procedure, dilution and factoring is necessary	

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TABLE E16: COMPRESSIVE STRENGTH CLASSES FOR DESIGNED CONCRETE NORMAL WEIGHT AND HEAVY WEIGHT CONCRETE

Compressive strength class	Minimum characteristic cylinder strength $f_{ck,cyl}$ N/mm ²	Minimum characteristic cube strength $f_{ck,CUBE}$ N/mm ²
C6/8	6	8
C8/10	8	10
C12/15	12	15
C16/20	16	20
C20/25	20	25
C25/30	25	30
C28/35	28	35
C30/37	30	37
C32/40	32	40
C35/45	35	45
C40/50	40	50
C45/55	45	55
C50/60	50	60
C55/67	55	67
C60/75	60	75
C70/85	70	85
C80/95	80	95
C90/105	90	105
C100/115	100	115

TABLE E17: COMPRESSIVE STRENGTH CLASSES FOR LIGHT WEIGHT CONCRETE

Compressive strength class	Minimum characteristic cylinder strength $f_{ck,cyl}$ N/mm ²	Minimum characteristic cube strength $f_{ck,CUBE}$ N/mm ²
LC8/9	8	9
LC12/13	12	13
LC16/18	16	18
LC20/22	20	22
LC25/28	25	28
LC28/31	28	31
LC30/33	30	33
LC32/35	32	35
LC35/38	35	38
LC40/44	40	44
LC45/50	45	50
LC50/55	50	55
LC55/60	55	60
LC60/66	60	66
LC70/77	70	77
LC80/88	80	88

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TABLE E18: MINIMUM RATE OF SAMPLING FOR ASSESSING CONFORMITY

Production	Minimum rate of sampling for assessing conformity		
	First 50m ³ of production	Subsequent to first 50m ³ of production*	
		Concrete with production control certification	Concrete without production control certification
Initial (until at least 35 test results are recorded)	3 samples	1 per 200m ³ or 1 per 3 production days	1 per 150m ³ or 1 per production day
Continuous** (when at least 35 test results are recorded)		1 per 400m ³ or 1 per 5 production days	
Notes:			
* Sampling shall be distributed throughout the production and should not be more than 1 sample within each 25 m ³			
** Where the standard deviation of the last 15 results exceeds 1.37σ, the sampling rate shall be increased to that required for initial production for the next 35 test results			

TABLE E19: CONFORMITY CRITERIA FOR COMPRESSIVE STRENGTH

Production	Number <i>n</i> of test results for compressive strength in the group	Criterion 1	Criterion 2
		Mean of <i>n</i> results (<i>f_{cm}</i>) N/mm ²	Any individual test result (<i>f_{cl}</i>) 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 E20: VALUES OF VERIFICATION OF STANDARD DEVIATION

Number of Test Results	Limits for <i>s_n</i>
15 to 19	$0.63 \sigma \leq s_n \leq 1.37 \sigma$
20 to 24	$0.68 \sigma \leq s_n \leq 1.31 \sigma$
25 to 29	$0.72 \sigma \leq s_n \leq 1.28 \sigma$
30 to 34	$0.74 \sigma \leq s_n \leq 1.26 \sigma$
35 ^a	$0.76 \sigma \leq s_n \leq 1.24 \sigma$
^a In case of more than 35 test results Formula (4) applies	

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TABLE E21: THE PRECISION ESTIMATES FOR CALCULATED CHLORIDE CONTENT, C_s AND NON-STEADY STATE CHLORIDE DIFFUSION COEFFICIENT, D_{NSS}

Parameter	Level	Repeatability conditions [5]		Reproducibility conditions [5]	
		sr	r	sR	R
D_{NSS} (E-12) m^2/s	5.09	1.17	3.27	1.54	4.31
C_s m/m (by concrete mass)	0.45	0.20	0.23	0.20	0.24
Precision expressed in terms of coefficient of variation		CVr (%)	r (%)	CVR (%)	R (%)
D_{NSS} (E-12) $\pm$		23	65	33	92
C_s % $\pm$ (by concrete mass)		13	37	19	54
Note: These estimates are based on a precision exercise undertaken in 2011-2012 [6]. The results shown have involved 12 laboratories using the same concrete samples (2 per test) made fulfilling EN 206 limiting values for concrete composition with two types of cements and two w/c ratios (four variables). These data were obtained by averaging over four concrete type mixes and three exposure type methods the values of D_{NSS} and of C_s obtained by previously averaging over the laboratories involved in each specific mix/exposure combination. There were insufficient data for two of the exposure methods to determine the precision of each of the methods separately and to determine if there was any significance difference between the methods (the data available indicate no significant difference). The values in the table above apply to the three equivalent test methods described in this standard.					

TABLE E22: SAMPLING RATE FOR IDENTITY TESTING

Type of Structure	Volume per sample
Prestressed concrete, masts, cantilevers, columns, footings, pile caps, shear wall, retaining wall	10.0 m^3 or every group of 10 batches
Slabs, beams	20.0 m^3 or every group of 20 batches
Raft foundation, mass concrete	50.0 m^3 or every group of 50 batches

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TABLE E23: 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_{ci}) 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 E24: 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_{ci}) N/mm ²
Consecutive 3	$\geq f_{ck} + 4$	$\geq f_{ck} - 4$

TABLE E25: 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
S1	0	50	0	60
S2	40	100	30	110
S3	90	160	80	170
S4	150	220	140	230
S5*	210	-	200	-
Note: * Due to a lack of sensitivity of the slump test at slump values less than 10 mm or greater than 210 mm, it is recommended to only use the test for slump ≥ 10 mm and ≤ 210 mm.				

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TABLE E26: 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 <i>mixing</i> water (not required for potable water)	Date and place of sampling Test results
Tests on constituents	Date and test results
Composition of concrete	Concrete description Record of masses of constituents in batch or load (e.g. cement content) Water/cement ratio Chloride content Code of family member
Tests on fresh concrete	Date and place of sampling Location in structure, if known Consistence (method used and results) Viscosity, if specified Segregation resistance, if specified Passing ability, if specified Density, if specified Fibre content, if specified Concrete temperature, if specified Air content, if specified Volume of concrete batch or load tested Number and codes of specimens to be tested Water/cement ratio, if specified
Tests on hardened concrete	Date of testing Code and ages of specimens Test results for density and strength Special remarks (e. g. unusual failure pattern of specimen)
Evaluation of conformity	Conformity/non-conformity with specifications of concrete
Additionally for ready-mixed concrete	Name of purchaser Location of work, e. g. the construction site Numbers and dates of delivery tickets related to tests Delivery tickets
Additionally for precast concrete	Additional or different data may be required by the relevant product standard