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6.22.2.2. Load cells shall be provided with calibration certificates and, where appropriate, the effects of sustained loading on the cell shall also be recorded on the certificate. During monitoring period, detective load cells shall be replaced.

6.22.3. Programme

The Contractor shall submit a programme of ground anchor installation to the S.O. for approval prior to commencement of work.

6.22.4. Procedures

6.22.4.1. The Contractor shall inspect the anchor pad, the protection cap, the anchor head and its corrosion protection, and shall report on their condition. A 150ml sample of the grease shall be recovered from the anchor head for subsequent submission to the S.O. for inspection. Upon completion of the inspection, the residual load in the anchor shall be measured. Finally, the corrosion protection and the anchor head protection shall be reinstated in accordance with the requirements of this Specification.

6.22.4.2. Should the variation in the residual load exceed $\pm 10\%$ of that measured immediately after locking-off, the Contractor shall immediately inform the S.O. and await her/his further instructions.

6.22.5. Monitoring Records

A monitoring record shall be submitted to the S.O. within 72 hours of completion of monitoring.

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TABLE R6: PROPERTIES OF GREASE (SHEET 1 OF 2)

Property	Test Method	Acceptance Criterion
Base number	ASTM D 974 – 85 (modified) ⁽²⁾	0.5 min
Water content	ASTM D 95 – 83	0.1% by mass max.
Chloride ion content	ASTM D 4327 – 84 ⁽³⁾	5ppm by mass max.
Nitrate ion content	ASTM D 4327 – 84 ⁽³⁾	5ppm by mass max.
Sulphide ion content	APHA: Part 427:1985 ⁽³⁾	5ppm by mass max.
Cone penetration (worked at 25°C)	ASTM D 217 – 86	175 – 340 units (1 unit = 0.1mm)
Corrosion prevention (48 hrs at 52°C & 100% relative humidity)	ASTMD1743 – 73 (1981)	No corrosion is rated 1. Incipient Corrosion (no more than 3 spots of visible size) is rated 2. Max. rating = 2
Oil separation	ASTM D 1742 – 83	3% by mass max.
Evaporation loss	ASTM D 972 – 86	0.5% by mass max.
Flash point	ASTM D 93 – 85	150°C min.
Drop point	ASTM D 566 – 76 (1982)	60°C min.
Oxidation stability : 100 hrs 400 hrs 1000 hrs	ASTM D 942 – 78 (1984)	Max. loss : 70kPa 140kPa 210kPa
Effects if salt spray testing (1mm thick layer 500 hrs)	ASTM B 117 – 85	No corrosion

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TABLE R6: PROPERTIES OF GREASE (SHEET 2 OF 2)

Notes: (1) Manufacturer's certificates in respect of all the properties listed in the table shall be presented to show compliance with this Specification. (2) Modified procedure for base number determination: (a) Weigh accurately 1 to 1.5g of sample into a 500ml conical flask. Add 20ml isopropanol and 5ml toluene. (b) Place a glass funnel on the top of the flask and heat the flask on a plate until the grease dissolves. (c) Add about 100ml of distilled and de-ionized water and pipette 10ml of 1N sulphuric acid to the flask. Heat the solution for 30 min. at temperature 80 – 90°C. (d) Add a few drops of phenolphthalein indicator solution and titrate with 1N sodium hydroxide solution until the sample solution turns pink. Record the volume of the titre added. (e) Calculate the base number of the grease sample using the following equation: $\text{Base number} = \frac{56.1 (10-V)}{M} \text{ mg KOH/g}$ where V = volume of 1N sodium hydroxide solution used (ml) m = mass of sample (g) (f) Apply correction factors to the volumes of the acid and alkali if they are not exactly 1N. (g) Carry out a blank determination and correct the result accordingly. (3) Procedure for extraction of water-soluble ions from grease for chloride, nitrate and sulphide ions contents determination: (a) Weigh, accurate to 0.001g, about 5g of grease into a separating funnel, add 70ml of xylene and shake the mixture until the grease for chloride, nitrate and sulphide ions contents is determined. (b) Add 30ml of distilled and de-ionized water the funnel, shake for 10 min, and allow the organic and aqueous layers to separate. Run the bottom aqueous layer (and emulsion if present) to a second separating funnel. (c) Repeat step (b) using separately 30ml and 40ml of distilled and de-ionized water for further extraction. (d) Add, to the second separating funnel containing the combined water extract, About 20 – 30ml of xylene, gently swirl the mixture and again allow for complete separation of the 2 layers. (e) To avoid inclusion of the organic solvent in the water extract, collect about $\frac{3}{4}$ of the bottom aqueous layer, filter through a 0.2µm filter paper and reserve the filtrate for determination of the contents of chloride, nitrate and sulphide. (f) Carry out a blank determination, following the same procedure with the same number of reagents.
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TABLE R7: PROPERTIES OF PLASTICS

Property	Test Method	Unit	Acceptance Criterion		
			PVC	PP	HDPE
Density	BS 2782 : Part 6 : 1980, Method 620A	Kg/m³	1350-1400	900-910	950-940
Tensile strength at yield at 23°C (Straining rate 50mm/min)	BS 2782 : Part 3 : 1976, Method 320C	MPa	≥45	≥30	≥29
Softening point (Vicat)	BS 2782 : Part 1 : 1976, Method 120A	°C	≥75	≥150	≥110
Hardness (Shore D)	BS 2782 : Part 3 : 1981, Method 365B	-	≥65		
Brittleness Temperature	ASTM D 746 - 79	°C	≤5°C		
Environmental Stress cracking resistance	ASTM D 1693 – 70 (1980)	hrs	200 (No cracking)		
Fungal resistance	ASTM G 21 – 70 (1980)	-	Rating 1 or less ⁽²⁾		
Bacteria resistance	ASTm D G 22 – 76 (1980) Procedure ‘B’	-	No bacterial growth on surface of specimen		
Water absorption at 23 ± 1°C	ASTM D 570 – 81 (Long term immersion)	% increase in weight	Max. 0.5%		
Hydrostatic pressure resistance	BS 6437 : 1984	-	No localised swelling leaking or weeping		
Note : (1) PVC = polyvinyl chloride ; PP = polypropylene; HDPE = high density polyethylene (2) Observed traces of fungal growth shall not cover more than 10% of the surface area. (3) Manufacturer's certificates in respect of all the properties listed in the table shall be presented to show compliance with this Specification.					

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7. Reinforced Soil Structures and Slope

7.1. General

7.1.1. Scope

This specification covers the general and technical requirements for the construction of reinforced soil structures as described herein. All materials used and the works shall meet the requirements of this specification and details shown on the Drawings.

7.1.2. Contractor's Responsibilities

The Contractor shall provide all necessary resources including materials, skilled workers, and plants/equipment to execute and complete the works as shown on the Drawings. The Contractor shall be responsible for the true and proper setting-out of the areas to which the Reinforced Soil Structure is to be placed and for the correctness of the lines, widths, levels and slopes as shown on the Drawings.

7.2. Materials

7.2.1. Facing Materials

Facing for reinforced soil structures utilising metallic components for reinforcement shall be constructed in units to retain the fill using one or more of the following materials:

7.2.1.1. Reinforced concrete conforming to BS 8110: 1990

7.2.1.2. Carbon steel strips or sheets conforming to BS 1449:1991; BS EN 10025: 1993 or BS EN 10130: 1999. The fabricated components shall be hot-dip galvanised in accordance with sub-section 7.2.3 of this Specification.

7.2.1.3. Structural steel sections conforming to BS EN 10025: 1993. The fabricated components shall be hot-dip galvanised in accordance with sub-section 7.2.3 of the Specification.

7.2.1.4. Segmental block units conforming to the requirements of the Contract.

7.2.1.5. Proprietary product with reinforced fill product certificate.

7.2.2. Reinforcing Elements and Connections

7.2.2.1. Reinforcing elements shall be one of more of the following:

- (i) Metallic reinforcing elements formed from carbon steel conforming to BS 1449: 1991 or BS EN 10130: 1999. The fabricated components shall be hot-dip galvanised in accordance with sub-section 7.2.3 of the Specification.

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(ii) Proprietary polymeric reinforcing products covered by the manufacturer's certificate.

(a) Geogrids and High Strength Woven Geotextiles shall be manufactured from high tenacity polyester encased within polyolefin sheaths. The bond between the sheath and the high tenacity polyester shall be adequate to transfer the required loads to the elements. The geo-linear elements shall consist of continuous high tenacity polyester fibres encased within a polyolefine sheath.

The polyester fibres for geogrids shall be completely encased within a protective polyolefine sheath to completely prevent ingress of moisture. All free ends shall be sealed to completely prevent ingress of moisture. The minimum thickness of the protective cover shall be 1mm.

(b) The weft elements shall be the same quality material as the warp elements.

(iii) Any other materials as specified by the S.O..

7.2.2.2. Connections shall comprise one or more of the following:

- (i) Precision hexagonal bolts, screw and nuts conforming to BS 3692:2001.
- (ii) Black hexagonal bolts and nuts conforming to BS 4190: 2001.
- (iii) Plain washers conforming to BS 4320: 1968.
- (iv) Dowels and rods which shall be made from either steel bar conforming to BS 4449: 1997 or steel conforming to BS EN 10025: 1999.
- (v) Tie strips which shall be made from carbon steel strip conforming to BS 4449: Part 1: 1991; BS EN 10130: 1999 or BS EN 10025:1993.
- (vi) Proprietary connections covered by a reinforced fill product certificate applicable to the polymeric reinforcing elements to be used.

7.2.2.3. Metallic connections between facings, between facings and reinforcing elements and between reinforcing elements shall electrolytically compatible such that corrosion will not be promoted through the use of dissimilar metals.

7.2.2.4. Where components for connections are made from steel, these components shall be hot-dip galvanised in accordance with sub-section 7.2.3 of the Specification.

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7.2.3. Hot-dip Galvanising

Hot-dip galvanising shall be to BS EN ISO 1461, except that the minimum average zinc coating weight for the steel reinforcing elements specified in sub-section 7.2.2 above shall be 610g/m² (85 microns) for land-based structures or slopes and 1000g/m² (140 microns) for structures of slopes that are periodically submerged in water.

7.2.4. Joint Filler and Sealant

7.2.4.1. Joint filler shall be composed of durable, inert material resistant to atmospheric attack and shall comprise the following materials:

- (i) For horizontal joint fillers, resin-bonded cork strip to ASTM D1752-84 Type II.
- (ii) For vertical joint fillers, closed cell polyethylene foam strip or closed cell polyurethane foam strip approved by the S.O..
- (iii) Proprietary joint fillers shall be purpose-made to size for the appropriate location shown on the Drawings.
- (iv) The materials for filling, priming and sealing of joints should be obtained from a single supplier.

7.2.5. Fill Material

7.2.5.1. Fill material shall consist of naturally occurring or processed material which at the time of deposition is capable of being compacted in accordance with the specified requirements to form a stable mass of fill.

7.2.5.2. Fill material shall not contain any of the following:

- (i) Material susceptible to volume change, including marine mud, soil with a liquid limit exceeding 65% or a plasticity index exceeding 35%, swelling clays and collapsible clays.
- (ii) Peat, vegetation, timber, organic, soluble or perishable material.
- (iii) Dangerous or toxic material or material susceptible to combustion, and
- (iv) Metal, rubber, plastic or synthetic material.

7.2.5.3. The grading and index properties of the selected fill shall be in accordance with the requirement specified in **TABLE R8**.

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7.2.5.4. Selected fill for reinforced fill structures or slopes which contain hot-dip galvanised steel reinforcing elements shall comply with the electrical and chemical limits specified in **TABLE R9**.

7.2.5.5. Materials from excavation shall not be used as fill material for a reinforced fill structure of slope unless permitted by the S.O..

Fill materials shall meet any additional requirements given in the Drawings.

TABLE R8: PARTICLE SIZE DISTRIBUTION OF SELECTED FILL

Requirement	Material Type	
	Type I	Type II
Maximum Size (mm)	150	150
% Passing 10mm BS Sieve Size	≥ 25	-
% Passing 600 microns BS Sieve Size	≥ 8	-
% Passing 63 microns BS Sieve Size	0 – 10	10 – 80
% Smaller than 2 microns	-	0 - 10
Coefficient of Uniformity	≥ 5	≥ 5
Liquid Limit (%)	Not applicable	≤ 45
Plasticity Index (%)	Not applicable	≤ 20

TABLE R9: ALLOWABLE ELECTRICAL AND CHEMICAL LIMITS OF SELECTED FILL AND GRANULAR FILTER

Fill Property	Allowable Limits	
	Submerged	Non-Submerged
Resistivity (ohm-m)	≥ 30	≥ 10
Redox Potential (volts)	≥ 0.40 (granular fill) ≥ 0.43 (fine fill)	≥ 0.40 (granular fill) ≥ 0.43 (fine fill)
pH	5 – 10	5 – 10
Chloride Ion Content (% by weight)	≤ 0.01	≤ 0.02
Total Sulphate Content (% by weight)	≤ 0.10	≤ 0.20
Sulphate Ion Content (% by weight)	≤ 0.05	≤ 0.10
Total Sulphide Content (% by weight)	≤ 0.01	≤ 0.03
Note: Submerged structure means a structure that is periodically submerged in water but excluding marine condition and contaminated or saline water.		

7.2.6. Granular Filter

7.2.6.1. Granular filter material for reinforced fill structures or slopes which contain hot-dip galvanised steel reinforcing elements shall comply with the electrical and chemical limits specified in

7.2.6.2. **TABLE R9**.

7.2.6.3. Granular filter material shall any additional given in the Drawings.

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7.3. Submissions

7.3.1. Particulars of Reinforced Fill Structure and Slope

7.3.1.1. The Contractor shall submit to the S.O. a method statement for the construction of reinforced fill structures or slopes. The method statement shall contain proposal on:

- (i) Details of construction plant.
- (ii) Sequence of construction.
- (iii) Programme of work.
- (iv) Details of compaction method including the thickness of compacted fill layers and capacities of the earthmoving and compaction equipment.
- (v) Methods of supporting the facing units during construction.
- (vi) Details of all necessary temporary works for the construction of the reinforced fill structures or slopes.
- (vii) Names and records of experience of the Contractor's supervisory staff to be employed on the works.
- (viii) Arrangements for stockpiling fill material.
- (ix) Methods of controlling the moisture content of fill material.
- (x) Methods of controlling surface water and groundwater.
- (xi) Methods of protecting earthworks and earthworks materials from damage due to water and from weather conditions which may affect the earthworks or earthworks materials.
- (xii) Methods of monitoring groundwater levels.
- (xiii) Methods of monitoring the ground and structures for movements.

7.3.1.2. The particulars shall be submitted to the S.O. at least 6 weeks prior to commencement of construction.

7.3.2. Particulars of Facing Units

7.3.2.1. The following particulars of the proposed facing units shall be submitted to the S.O.:

- (i) Manufacturer's literature on the proposed facing units.
- (ii) Method of construction, including details of corner and facing connections.

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- (iii) A certificate showing the manufacturer's name, the date and place of manufacture and showing that the facing units comply with the requirements stated in the Contract and including the results of tests specified in the certificate or as specified by the S.O..

7.3.2.2. The particulars, including certificates, shall be submitted to the S.O. at least 14 days before the first delivery of the material to the Site. Certificates shall be submitted for each batch of the material delivered to the site and at least 14 days before the installation of the facing units starts.

7.3.3. Particulars of Reinforcing Elements and Connections

7.3.3.1. The following particulars of the hot-dip galvanised coatings to reinforcing elements and associated connection elements shall be submitted to the S.O..

- (i) Name and location of the galvanising plant
- (ii) A certificate from the manufacturer showing the date and place of application of the zinc coating and showing that the galvanisation conforming to the requirements stated in the Contract and including results of tests for:
 - (a) Weight of coating
 - (b) Uniformity of coating

7.3.3.2. The particulars, including certificates, shall be submitted to the S.O. for each batch of galvanised reinforcing element delivered to the Site and at least 14 days before placing of the reinforcing element in the structure or slope starts.

7.3.4. Particulars of Joint Filler and Sealant

7.3.4.1. The following particulars of the proposed joint fillers and sealant shall be submitted to the S.O.:

- (i) Manufacturer's literature on the material and the proposed method of installation.
- (ii) A certificate for the manufacturer shows the date and place of application of the zinc coating and showing that the galvanisation conforming to the requirements stated in the Contract and including results of tests specified by the S.O..

7.3.4.2. The particulars, including certificates, shall be submitted to the S.O. at least 14 days before the first delivery of the material to the Site. Certificates shall be submitted for each batch of the material to the Site and at least 14 days before placing of the joint filler and sealant in the structure or slope starts.

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7.3.5. Particulars of Fill Material

7.3.5.1. The following particulars of the proposed fill material shall be submitted to the S.O. for approval:

- (i) A statement identifying each source of supply and showing that sufficient suitable materials are available for the works.
- (ii) For material from borrow areas, a plan showing the location and extent of each proposed borrow area, and the location, depth and the test results of each sample obtained and each in-situ test carried out.
- (iii) Certification from a laboratory approved by the S.O. which show that each material proposed for use complies with the requirements of the Contract and has been tested in accordance with the appropriate test methods given in this Specification.

7.3.5.2. On receipt of the above particulars, the S.O. may require the Contractor to carry out additional sampling and testing to demonstrate that the properties of the proposed sources of fill meet the requirements of the Contract.

7.3.5.3. The particulars, including certificates, shall be submitted to the S.O. at least 14 days before the first delivery of the material to the Site. Certificate shall be submitted for each batch of the material delivered to the Site and at least 14 days before the placement of the material in the structure or slope starts.

7.4. Handling, Delivery and Storage of Materials

7.4.1. Handling and Storage of Facing Units

Facing units shall be stored and handled in such a manner as to eliminate the possibility of any damage. They shall be stored flat and supported on firm blocking. The use of porous blocks to stack facing units shall be avoided.

7.4.2. Handling and Storage of Reinforcing Elements

7.4.2.1. Reinforcing elements shall not be subjected to rough handling, shock loading or dropping from a height.

7.4.2.2. Reinforcing elements shall be stored in such a manner to eliminate the possibility of any damage and shall be clearly labelled to identify items with different dimensions and properties.

7.4.2.3. Nylon, rope or padded slings shall be used for lifting galvanised reinforcing elements; bundles of reinforcement shall be lifted with a strong back or with multiple supports to prevent abrasion or excessive bending.

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7.4.2.4. Polymeric reinforcing elements shall be properly stored and protected from precipitation, extended ultraviolet radiation, direct sunlight, chemicals that are strong acids or strong bases, flames including welding sparks, temperatures in excess of 50°C, and any other environmental condition that may damage the physical property values.

7.4.3. Handling and Storage of Fill Material

7.4.3.1. Fill material shall not be handled or stored in a manner that will result in segregation, deterioration, erosion or instability of the material.

7.4.3.2. Different types of fill materials shall be kept separate from each other. Fill material shall not be contaminated and shall be maintained in a suitable condition for deposition and compaction.

7.5. Foundation Preparation

7.5.1. Unless otherwise specified by the S.O., all existing vegetation and all unsuitable foundation material shall be removed in those areas where the reinforcing element is to be placed.

7.5.2. Surfaces on which reinforcing elements are to be placed shall be uniform, smooth and free of abrupt changes in slope, debris and irregularities that could damage the reinforcing elements.

7.5.3. During periods of heavy rainfall, the Contractor shall be responsible for protecting exposed surfaces of the foundation and the associated temporary cut slopes with heavy duty impermeable sheeting.

7.5.4. Surface water flowing over exposed surfaces of the foundation and the temporary cut slopes shall be intercepted and diverted away to a safe discharge point. All drainage works shall be kept free of debris to avoid blockage. Temporary conduits shall be provided to discharge water safely from partially completed surface drainage works.

7.5.5. During excavation for the foundation of a reinforced fill structure or slope, a method of working shall be adopted in which the minimum of bare soil is exposed at any time. The method of working shall be agreed with the S.O. before the commencement of work.

7.5.6. The Contractor shall remove all the soil and rock spoil spilled onto any sloping terrain during excavation for the foundation of a reinforced fill structure or slope prior to the commencement of the filling works.

7.6. Erection of Facing

7.6.1. Erection of Elemental Facing

7.6.1.1. Elemental facing units shall be placed in successive courses unless otherwise specified. The spacing, level and alignment of each unit shall be checked immediately after its placement and again at the completion of each course.

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7.6.1.2. Adequate support for the facing units shall be provided at each stage of erection. The bottom course of facing units shall be shored to prevent movement during the placement and compaction of fill material.

7.6.1.3. As placed, all elemental facing units except those at the bottom course shall be inclined towards the fill to compensate for outward movement during or subsequent to compaction of the fill material. The degree of inclination shall be adjusted where necessary as placement and compaction of the fill material proceeds to ensure that the tolerances specified in sub-section 7.11 of this Specification are met.

7.6.2. Erection of Full Height Facing

7.6.2.1. Full height facings shall be properly placed and propped during construction. The level and alignment of each facing shall be checked immediately after its placement and again after the compaction of filling. The foundation for the props shall be adequate to support the propping loads.

7.6.2.2. The degree of inclination of the full height facing shall be adjusted to ensure that the tolerances specified in sub-section 7.11 of this Specification are met.

7.6.3. Erection of Segmental Block Facing

7.6.3.1. Segmental block units shall be properly placed to ensure that all units are in contact. The level and alignment of the block shall be checked immediately after its placement and again at the completion of each course.

7.6.3.2. The top of each course of segmental blocks installed shall be cleaned before the next course of segmental blocks is placed.

7.6.3.3. Maximum stacked height of segmental block units, prior to backfill placement and compaction, shall not exceed two courses unless otherwise approved by the S.O..

7.7. Placement of Reinforcing Elements

7.7.1. Placement and Connection of Reinforcing Elements

7.7.1.1. The reinforcing elements shall be placed on the compacted fill material and connected to the facing units in accordance with the Drawings. They shall be placed at right angles to the facing units or the place face of the slope unless otherwise shown on the Drawings. Bends in steel reinforcing elements shall be to a minimum radius of 300mm.

7.7.1.2. For reinforced fill slopes, in which the overfill and cut back technique is proposed to ensure proper compaction of the slope face, the construction method shall ensure that the reinforcing elements are exposed on the final slope face.

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- 7.7.1.3. Polymeric reinforcing elements shall be pulled tight to eliminate waves and wrinkles and secured in place as necessary by staples, pins, sandbags, backfill or as directed by the S.O after placement.
- 7.7.1.4. After a layer of polymeric reinforcing element has been placed, the next succeeding layer of fill material shall be placed and compacted as soon as practicable to prevent potential damage or extended exposure to direct sunlight. No polymeric elements shall be left exposed for more than 8 hours after placement unless approved by the S.O..
- 7.7.1.5. Unless otherwise specified in the Drawings or as approved by the S.O., no splices or seams shall be made in the primary direction of tensile strength in the polymeric reinforcing elements. When splices are approved, they shall be made for the full width of the polymeric reinforcing elements by using a similar material with similar strength. Spices shall not be placed within 1.5m of the facing unit or slope face, with 1.5m below top of structure or slope, nor within 1.5m horizontally adjacent to another splice.
- 7.7.1.6. Unless otherwise specified, adjacent rolls of polymeric reinforcing elements in reinforced fill slopes shall be butted together to maintain 100% horizontal coverage. When used in a wrap-around facing system, adjacent rolls of polymeric reinforcing elements shall be overlapped with a minimum width of 150mm.
- 7.7.1.7. Reinforcing elements at corners and radii shall be placed in accordance with the Drawings.
- 7.7.2. Installation of Geogrid and Polymeric Materials for Reinforced Soil Slope
 - 7.7.2.1. At each level of geogrid reinforcement, backfill shall be roughly levelled before placing the geogrids. Compaction shall be carried out to the requirements of the Specifications.
 - 7.7.2.2. During backfill placement, trucks and heavy vehicles shall be kept back at least 2m from the face of the Geogrid Reinforced Slope.
 - 7.7.2.3. The deposition, spreading, levelling and compaction of the fill shall be carried out generally in a direction parallel to the facing and shall be executed in stages to alternate with the placing and fixing of the reinforcing elements and the facing.
 - 7.7.2.4. Care shall be taken to ensure that the reinforcing elements and facing are not damaged or displaced during deposition, spreading, levelling and compaction of the fill. The program of filling shall be arranged so that no machines or vehicles run on the reinforcing elements.
 - 7.7.2.5. The fill within 2m of the face of the Geogrid Reinforced Slope shall be compacted using one of the following:

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- (i) Vibro tamper
- (ii) Vibrating plate compacter having a mass not exceeding 1000kg, and
- (iii) Vibrating roller having a mass per metre width of not more than 1300kg and a total mass of not more than 1000kg

7.7.2.6. The rear of the Geogrid Reinforcing Slope shall be adequately supported either by temporary shoring or by phasing the work in order to ensure the contemporaneous deposition of the retained fill material.

7.8. Installation of Joint Filler and Sealant

- 7.8.1. Horizontal joint filler conforming to sub-section 7.2.4 of this Specification shall be placed on the cleaned top edge of each facing unit prior to the placing of the mating facing unit. No joint filler is required between the strip footing and the bottom course of the facing units.
- 7.8.2. Vertical joint filler conforming to sub-section 7.2.4 of this Specification shall be inserted only from the fill side on the structure.
- 7.8.3. Sealants shall be used to protect joint filler from the ingress of external materials. They shall not be used for joints which will be below the finished ground level.

7.9. Deposition and Compaction of Fill Material

7.9.1. Deposition and Compaction of Fill Material

- 7.9.1.1. Fill shall be placed and compacted in near horizontal layers of the thicknesses required to achieve the specified end product and shall, as far as practicable, be brought up at a uniform rate so that all parts of the Site reach finished formation level at the same time.
- 7.9.1.2. The fill material beyond 1.5m of the back face of the structure may be raised in thicker layers than that within the 1.5m zone provided that this is compatible with the arrangement of the reinforcing elements and the difference is compacted levels does not exceed 300mm.
- 7.9.1.3. The fill material shall be deposited, spread, levelled and compacted in layers of thickness appropriate to the compaction methods to be used and so that each reinforcing element can be fixed at the required level on top of the compacted fill material without any voids forming directly underneath the reinforcing element. Unless otherwise permitted by the S.O., layers of fill material shall be horizontal, except for any gradient required for drainage, and the thickness of each layer shall be uniform over the area to be filled.

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- 7.9.1.4. The placement and compaction of fill material shall be carried out in a direction parallel to the face of the structure and shall be completed in stages to follow closely the erection of facing units and the placement of the reinforcing elements.
- 7.9.1.5. The fill material shall be compacted as soon as practicable after being deposited and in a manner appropriate to the location and to the material to be compacted. The in-situ dry density of the compacted fill material shall be at least 95% of the maximum dry density. Compaction shall continue until the whole layer of fill material has attained the minimum in-situ dry density specified above.
- 7.9.1.6. Cobbles, boulders, rock or waste fragments whose largest dimension is greater than two-thirds of the loose layer thickness shall not be incorporated into the fill.
- 7.9.1.7. The Contractor shall ensure that the reinforcing elements and facing units are not damaged or displaced during placement and compaction of the fill material. Tracked machines or vehicles shall not be operated on top of reinforcing elements which are not covered by at least 150mm of fill material.
- 7.9.1.8. No fill shall be placed and left uncompacted at the end of a working day. Compacted fill shall be graded to falls to ensure free runoff of rainwater without ponding.
- 7.9.2. Moisture Content of Fill Material
 - 7.9.2.1. The fill material shall be at optimum moisture content during compaction. The tolerance on the optimum moisture content shall be $\pm 3\%$ provided that the fill material is capable of being compacted in accordance with the specified requirement to form a stable mass of fill. All necessary measures shall be taken to achieve and maintain the specified moisture content. The moisture content of the compacted surfaces shall be controlled to prevent cracking due to drying.
 - 7.9.2.2. The Contractor shall take all necessary steps to ensure that the fill is placed at the moisture content necessary to achieve the specified level of compaction and shall, where necessary, add water to or dry the fill, in order to obtain this value. Where it is necessary to add water, this shall be done as a fine spray and in such a way that there is time for the water to be absorbed into the fill before being rolled by the compaction plant.
 - 7.9.2.3. The Contractor shall examine the placed fill and remove any deteriorated material prior to recommencement of filling.
- 7.9.3. Compaction Plant
 - 7.9.3.1. All vehicles and all construction equipment weighing more than 1000kg shall be kept at least 1.5m away from the face of the structure.

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7.9.3.2. Compaction plant and compaction method shall be selected having regard to proximity of existing trenches, excavations, retaining walls or other structures and all work shall be performed in such a way as to ensure that their existing stability is not impaired. In particular, great care should be taken to limit the compactive effort close to reinforced fill facing panels to prevent damage to connections or produce displacement of the facing.

7.9.3.3. Unless otherwise permitted by the S.O., the fill material within 1.5m of the face of reinforced fill structures or slopes supported by facings shall be compacted using:

- (i) Vibro tamper.
- (ii) Vibrating plate compactor having a mass not exceeding 1000kg, or
- (iii) Vibrating roller having a mass per metre width of not more than 1300kg and a total mass of not more than 1000kg.

7.9.3.4. In the case of reinforced fill slopes, compaction plant shall be restricted to that which does not cause distortion and settlement of the edge of the slope. No sheepsfoot, grid rollers or other type of equipment employing a foot shall be used.

7.9.4. Compaction Adjacent to Structures

During construction, the fill material retained at the rear of the reinforced fill block, defined as the position coinciding with the ends of the reinforcing elements, furthest away from the facing units, shall be maintained at the same level as the adjoining structure. Where the retained material is an existing earthwork or natural slope which requires temporary support by shoring, the shoring shall be removed progressively as the selected fill or filter material is compacted. The shoring shall be removed in such a manner to ensure that the stability of the adjacent ground is maintained, the compacted fill material is not disturbed, and the formation of voids is prevented.

7.10. Damage to Components

7.10.1. Damage to Components

7.10.1.1. In the event of any facing units, reinforcing elements, joint filler or sealant sustaining damage during erection or installation, it shall be set aside until it has been inspected by the S.O., who shall decide whether the Contractor can use it and if so under what conditions.

7.10.1.2. The cost of any repair and the cost of replacing rejected components shall be borne entirely by the Contractor.

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7.10.1.3. Protection of Completed Geogrid Reinforced Slopes from Erosion

The Contractor, where instructed by the S.O., shall carry out Hydraulic Mulch Grass Seeding in the erodable area before Hydraulic Mulch Grass works commence in other areas.

7.11. Tolerances

- 7.11.1. Reinforced fill structures constructed using elemental facing units, full-height facings, cast-in-place facings and segmental facings shall be within the tolerances stated in **TABLE R10** for the specified lines and levels.
- 7.11.2. The location of referencing elements shall be within $\pm 50\text{mm}$ of the specified lines and levels.

**TABLE R10: TOLERANCES OF REINFORCED FILL
STRUCTURE**

Designation	Tolerances
Location of place of structure	$\pm 50\text{mm}$
Overall height	$\pm 50\text{mm}$
Verticality	$\pm 5\text{mm}$ per metre height
Bulging (vertical) and bowing (horizontal)	$\pm 20\text{mm}$ over 4.5m straight edge
Steps in joints	$\pm 10\text{mm}$
Crest alignment	$\pm 15\text{mm}$ from reference
Rotation from wall batter	$\pm 2^\circ$

7.12. Testing: Reinforcing Elements – General Requirements

7.12.1. General

- 7.12.1.1. Prior to the procurement of materials, the Contractor shall provide a sample and the Manufacturer's Independent Test Report (ITR), showing full compliance of the proposed geogrid to all the above-specified property values corresponding to their respective test methods, for the approval of the S.O..
- 7.12.1.2. All tests shall be carried out in accordance with the codes of Practices and Standards as provided within this specification, unless otherwise approved by the S.O.. The independent test report and tests shall be prepared and carried out at reputable institutions or accredited independent laboratories approved by the S.O..

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7.12.1.3. Routine sample testing, when required and specified, shall be carried out at factory or at independent laboratory witnessed by the S.O.'s representative. Test certificates from reputable or accredited laboratories approved by the S.O., showing the material's compliance to the specification, shall be submitted to the S.O. for verification and approval.

7.12.2. Batch: Reinforcing Elements

A batch of reinforcing elements or reinforcement connections is any quantity of reinforcing elements or reinforcing connections of the same type, size and grade, manufactured by the same plant, covered by the same testing certificates and delivered to the Site at any one time.

7.12.3. Samples: Reinforcing Elements

7.12.3.1. Samples of reinforcing elements or reinforcement connections shall be provided from each batch of the material delivered to the Site and at least 14 days before installation of the reinforcing elements or reinforcement connections starts.

7.12.3.2. For strip reinforcing elements, either 3 samples from each batch of the reinforcing elements or samples taken at the rate of 1 sample per 100m² of area of facing shall be provided for testing, whichever is the larger.

7.12.3.3. For grid of sheet reinforcing elements, either 0.5m² of sample from each batch of the reinforcing element or samples taken at the rate of 0.5m² per 100m² of area of facing shall be provided for testing, whichever is the larger.

7.12.3.4. For reinforcement connections, either 3 samples from each batch of the reinforcing element or samples taken at the rate of 1 sample per 100m² of area of facing shall be provided for testing, whichever is the larger.

7.12.4. Testing: Reinforcing Elements

7.12.4.1. Metallic reinforcing elements and the associated connections with hot-dip galvanising for reinforced fill structures shall be tested for the following:

- (i) Tensile strength
- (ii) Weight and uniformity of galvanised coating

7.12.4.2. Polymeric reinforcing elements for reinforced fill structures shall be tested for the following:

- (i) Tensile strength
- (ii) Elongation
- (iii) Weight

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7.12.5. Non-Compliance: Reinforcing Elements

If the result of any test of a reinforcing element does not comply with the specified requirements for the property, additional samples shall be provided from the same batch and additional tests for the property shall be carried out. The number of additional samples shall be in accordance with sub-section 7.12.3 of the Specification.

7.13. Testing: Reinforcing Element – Tensile Test

7.13.1. The tensile strength of metallic reinforcing elements and reinforcement connections shall be determined in accordance with BS EN 10002-1: 2001.

7.13.2. The tensile strength of polymeric reinforcing elements shall be determined in accordance with BS EN ISO 10319: 1996. The tensile strength of polymeric reinforcement connections shall be determined in accordance with BS EN ISO 10321: 1996.

7.14. Testing: Fill Material – General Requirements

7.14.1. Samples: Fill Material

7.14.1.1. The maximum dry density and optimum moisture content tests shall be carried out for each source of fill material when it is first used and thereafter at the same time as every set of in-situ dry density and moisture content tests where required by the S.O.. Samples of fill material to be tested shall be delivered to the S.O. at least 48 hours, or such shorter period as agreed by the S.O., before deposition of the fill material commences. The Contractor shall inform the S.O. of the exact location in which the fill material from which each sample is taken is to be deposited.

7.14.1.2. The location and frequency of in-situ dry density and moisture content tests shall be as required by the S.O. but shall not be less than that given in this sub-section. Testing shall be carried out for each layer of compacted fill material in the reinforced fill structure, in which there shall be a minimum of one test on the filter material and two tests on the fill material and, where the plan area of the structure exceeds 800m², one additional test on the filter material and two additional tests on the fill material shall be carried out for each additional 800m² or part thereof. Samples of the fill material to be tested for moisture content shall be taken during deposition and compaction of fill material and shall be delivered to the S.O. not more than 1 hour after the fill material has been deposited in its final position.

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7.14.1.3. The location and frequency of all other tests specified in sub-section 7.14.2 or sub-section 7.14.3 of this Specification shall be as required by the S.O. but shall not be less than that given in this sub-section. Testing shall be carried out for the top and bottom compacted layer of fill in reinforced fill structures which are up to 5m high, and also for the middle-compacted layer in reinforced fill structures higher than 5m. In each of these layers, a minimum of one (1) sample of filter material and two (2) samples of selected fill material shall be tested; for structure with plan area exceeding 800m², on additional sample of filter material and two additional samples of selected fill material shall be tested for each additional 800m² or part thereof.

7.14.1.4. Sampling and testing shall be in positions specified by the S.O..

7.14.2. Testing: Fill Material for Reinforced Fill Structures or Slopes with Metallic Components

Fill material for reinforced fill structures or slopes with metallic components shall be tested for the following:

- (i) Compaction tests, comprising the determination of maximum dry density, optimum moisture content, in-situ dry density and moisture content.
- (ii) Particle size distribution.
- (iii) Liquid limit and plasticity index of the fill material
- (iv) Coefficient of uniformity
- (v) Resistivity
- (vi) Redox potential
- (vii) Ph
- (viii) Chloride ion content
- (ix) Total sulphate content
- (x) Sulphate ion content
- (xi) Total sulphide content
- (xii) Any other tests as specified by the S.O..

7.14.3. Testing: Fill Material for Reinforced Fill Structure or Slope without Metallic Components

Fill material for reinforced fill structures or slopes without metallic components shall be tested for the following:

- (i) Compaction tests, comprising the determination of maximum dry density, optimum moisture content, in-situ dry density and moisture content

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- (ii) Particle size distribution
- (iii) Liquid limit and plasticity index for the fill material
- (iv) Coefficient of uniformity
- (v) Any other tests as specified by the S.O..

7.14.4. Non-Compliance: Fill Material

If the result of any tests for fill material does not comply with the specified requirements for the property, additional samples shall be provided from the same batch and additional tests for the property shall be carried out. The number of additional samples shall be in accordance with subsection 7.14.1 of this Specification.

7.15. Testing: Fill Material - Resistivity

- 7.15.1. Each sample of fill material as stated in sub-section 7.14.1 of this Specification shall be tested to determine resistivity.
- 7.15.2. The method of testing shall be in accordance with the method as specified in ASTM G187-05: Standard Test Method for Measurement of Soil Resistivity using the Two-Electrode Soil Box Method.

7.16. Testing: Fill Material – Redox Potential

- 7.16.1. Each sample of fill material as stated in sub-section 7.14.1 of this Specification shall be tested to determine redox potential.
- 7.16.2. The method of testing shall be in accordance with the method as specified in ASTM G200-09: Standard Test Method of Oxidation-Reduction Potential of Soil.

7.17. Testing: Fill Material – Total Sulphide Content

Total sulphide content of the fill material shall be determined in accordance with APHA: Part 427: 1985.

7.18. Testing: Fill Material – Shear Strength

The shear strength of the fill material shall be determined using triaxial apparatus or shear box apparatus in accordance with BS 1377: 1990. For shear strength test using shear box apparatus, the test specimen shall be sheared under drained conditions under a normal stress equal to the theoretical maximum vertical earth pressure in the reinforced fill structures or slopes.

7.19. Testing: Fill – Reinforcement Interaction – General Requirement

7.19.1. Samples: Fill – Reinforcement Interaction

Each sample of reinforcing element tested in accordance with sub-section 7.12.3 of this Specification shall also be tested for fill – reinforcing element interaction. Samples for testing shall be delivered to the Site at least 14 days before installation of the reinforcing element in the structure or slope starts.

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7.19.2. Testing: Fill – Reinforcement Interaction

Reinforcing elements shall be tested for the following:

- (i) Pull out resistance
- (ii) Direct sliding resistance

The method of testing shall be in accordance with the method stated in sub-section 7.20 and 7.21 of this Specification.

7.19.3. Non-Compliance: Fill–Reinforcement Interaction

If the result of any tests for fill – reinforcement interaction does not comply with the specified requirements for the property, additional samples shall be provided from the same batch and additional tests for the property shall be carried out. The number of additional samples shall be in accordance with sub-section 7.14.1 of this Specification.

7.20. Testing: Coefficient of Friction between Fill Material and Reinforcement - Pullout

The pullout resistance of reinforcing elements shall be determined in accordance with BS EN ISO 10319: 1996.

7.21. Testing: Coefficient of Friction between Fill Material and Reinforcement – Direct Sliding

The coefficient of friction between the fill material and the reinforcing elements shall be determined by the direct shear test in accordance with BS1377:1990 with the following modification:

- 7.21.1. The weight of fill material required to prepare a compacted test specimen 300mm x 300mm x 75mm shall be calculated.
- 7.21.2. For strip reinforcing elements, the strips shall be cut to tightly fit the interior plan shape of the lower half of the shear box. Ribbed strips shall be cut so that the ribs can be placed as far away from the edge of the box as possible. For plane strips, the top surface and for ribbed strips, shall be at least 1mm and not more than 3mm below the top edge of the lower half of the shear box. The reinforcing elements shall be aligned so that shearing can occur in a direction parallel to their longitudinal axes. The strips shall then be placed and secured in the lower shear box by filling the lower shear box with plaster of Paris so that the strips remain fixed at all stages of the test.
- 7.21.3. For grid or sheet reinforcing elements, the fill material shall be compacted into the lower shear box in accordance with BS1399:1990, except that the surface of the second compacted layer shall be between 1mm and 2mm below the top edge of the lower shear box. The grid or sheet shall then be cut and fitted to match the width of the shear box and to allow it to be secured below the top edge of the lower shear box. The reinforcing elements shall be aligned so that shearing can occur in a direction parallel to their longitudinal axes.

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- 7.21.4. The fill material shall be placed over the reinforcing element and compacted in two equal layers until about 20mm of the compacted fill projects above the top edge of the upper box, if vibratory compaction is used; or in two equal layers until the top of the compacted surface is approximately 20mm below the top of the shear box, if static compaction is used.
- 7.21.5. Shearing shall be carried out until the horizontal displacement is twice the displacement recorded at peak shear stress or until ant rib comes into contact with the edge of the shear box, whichever occurs first.
- 7.21.6. The result of the test shall be taken as the maximum ratio between the shear stress and the normal stress.

8. Tieback Works

8.1. General

This chapter contains recommendations for the specification of permanent tieback works. Since some of the tieback systems or corrosion protection methods are patented, and many contractors have developed unique installation methods, it is virtually impossible for the designer to be familiar with all the various tieback systems which are used. Therefore, the designer needs to prepare a specification that will establish a quality level without eliminating suitable proprietary systems or methods. The specifications should enable qualified Contractors to use their experience gained on previous jobs.

8.2. Performance Specification

- 8.2.1. A performance specification which establishes a quality level and describes the desired end-results enables the designer and the contractor to use their experience and expertise. The designer establishes those things which affect his design, and he specifies a tieback testing procedure and monitoring requirements to verify performance. The installation methods and the development of the tieback capacity should be the responsibility of the contractor. This enables the Contractor to provide his most economical tieback and still satisfy the requirements of the design. The designer and the contractor will share the responsibility for the work.
- 8.2.2. The designer is required to:
 - (i) Provide a detailed geotechnical site investigation.
 - (ii) Determine the design load.
 - (iii) Specify a testing procedure and acceptance criterion.
 - (iv) Estimate the settlement of adjacent structures and establish permissible deformations.
 - (v) Specify the tieback clearance around utilities.
 - (vi) Provide installation tolerances.
 - (vii) Rate the risk associated with the work, and establish the safety factors.

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- (viii) Determine the un-bonded length, and minimum total length.
- (ix) Determine the lock-off load.
- (x) Determine the monitoring requirements.
- (xi) Describe the level of corrosion protection required and evaluate the contractor's proposed corrosion protection system.

8.2.3. The contractor is required to:

- (i) Design the tendon.
- (ii) Select the installation method.
- (iii) Select the anchor length.
- (iv) Propose the corrosion protection system.
- (v) Be responsible for the contract compliance of the materials used.
- (vi) Guarantee the tieback capacity.
- (vii) Obtain the required un-bonded length.
- (viii) Provide the required records.

8.3. Prequalification

The designer may require the prequalification of the tieback contractor. The prequalification may be based on experience, or a list of acceptable Contractors may be included in the specification. An alternate type of prequalification should be tried and evaluated for permanent tieback work. The specification would require the submission and approval of the tieback system design, and the corrosion protection method prior to bid. The submission must be detailed enough for the designer to determine whether or not his design is satisfied. This method would enable the Contractor to know if his proprietary techniques would be acceptable, and to provide the most economical installation. Preparation and review of the submittal would not require a substantial effort, and this contracting practice would encourage alternate tieback types, continued tieback development, and most economical tieback.

8.4. Permanent Tieback Specification

8.4.1. Scope of the Work

This section of the specification describes the materials, labor and equipment required for the installation and monitoring of the permanent tiebacks shown on the Drawings.

8.4.2. Tieback Capacity

The Contractor shall be responsible for obtaining the desired tieback capacity in accordance with the tieback testing section of this specification. (The engineer can use one of the following alternatives):

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- 8.4.2.1. Alternative A: The Drawings contain a loading diagram which the contractor shall use to determine the number and capacity of the tiebacks. The anchor zones of the tiebacks shall be at least 1.5m apart.
- 8.4.2.2. Alternative B: The Drawings contains tieback loadings per linear foot of wall. The Contractor shall use these loadings to determine the number and capacity of the tiebacks. The anchor zones of the tiebacks shall be at least 1.5m apart.
- 8.4.2.3. Alternative C: The contract drawings indicate the location and capacity of tiebacks.
- 8.4.3. Minimum Un-bonded Length and Tieback Angle
- Each tieback shall have a minimum un-bonded length of 4.5m. The Drawings shall indicate the un-bonded length required for each tier of tiebacks. The tieback shall be installed at an angle varying between 10° and 30° downward from the horizontal.
- 8.4.4. Total Tieback Length and Minimum Anchor Length
- The minimum total tieback lengths shall be indicated on the Drawings. In no case shall the anchor length be less than 3m. The tieback must not extend beyond the easement shown on the Drawings.
- 8.4.5. Prequalification
- Twenty (20) working days prior to the bid date, the tieback Contractor shall submit a proposal describing the tieback system he intends to provide to the S.O. for review and approval. The submission shall include:
- 8.4.5.1. Qualifications if required.
- 8.4.5.2. A description of the tieback installation includes drilling, grouting and stressing information.
- 8.4.5.3. Estimated tieback capacity.
- 8.4.5.4. Tendon type and capacity.
- 8.4.5.5. Anchorage type.
- 8.4.5.6. Corrosion protection details-shop drawings required.
- 8.4.5.7. Exceptions to the specification and reasons for exceptions.
- 8.4.5.8. The S.O. will review the submission and give written comments to the prospective Contractors within five (5) working days after receipt of the submission. Within five (5) working days, the Contractor can resubmit a revised proposal. The S.O. will notify the Contractor by writing within five (5) working days before bid date whether or not his tieback system and corrosion protection meets the requirements of the specification.

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8.4.6. Materials

8.4.6.1. Tieback tendons shall be fabricated from single or multiple elements of the following:

- (i) Steel bars conforming to ASTM Designation A 722, "Uncoated High-Strength Steel Bars for Prestressed Concrete"
- (ii) Seven-wire strand conforming to ASTM Designation A 416, "Uncoated Seven Wire Stress-Relieved Strand for Prestressed Concrete"
- (iii) Wires conforming to ASTM Designation A 421, "Uncoated Stress-Relieved Wire for Prestressed Concrete"
- (iv) Compact seven-wire strands conforming to ASTM Designation A 779-80, "Uncoated Seven-Wire Compacted, Stress-Relieved Steel Strand for Prestressed Concrete"

8.4.6.2. Anchorages shall be capable of developing 95% of the guaranteed minimum ultimate tensile strength of the prestressing steel. (The S.O. shall indicate if the anchor head must be restressable and/or capable of load adjustment).

8.4.6.3. The bearing plate shall be fabricated from mild steel and it shall be capable of developing 95% of the guaranteed minimum ultimate tensile strength of the pre-stressing steel. Pre-stressing steel couplers shall be capable of developing 100% of the ultimate strength of the prestressing steel.

8.4.6.4. Centralisers shall be fabricated from material which is nondetrimental to the prestressing steel. (Steel or plastic is commonly used. Wood should not be used.) The centralisers shall position the tendon in the drill hole so a minimum of 0.5 inch (12.7cm) of grout cover is provided. (Pressure-injected tiebacks do not require centralisers)

8.4.6.5. Spacers shall be used to separate elements of multielement tendons. They shall be fabricated from material which is nondetrimental to the prestressing steel. A combination centraliser spacer can be used.

8.4.6.6. Type I, II, or III Portland cement conforming to ASTM C-150 specifications shall be used for grout. (If the soluble sulfate content of the soil or the groundwater is greater than 2,000mg/kg, then Type V cement should be used.) (If the soil or groundwater pH is less than 4.5 or nearby buried concrete structures have experienced chemical attack, then Portland cement grout should not be used. Acid resistant cements may be used in acidic conditions.) Cement should be fresh and should not contain any lumps or other indications of hydration.

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- 8.4.6.7. Water for mixing grout should be potable.
- 8.4.6.8. Grout additives should be avoided. Accelerators should not be used. Expansive admixtures should only be used for secondary grouting, and filling trumpets and anchorage covers. Admixtures which control bleed and retard set may be used. Additives shall be mixed and placed in accordance with the manufacturer's recommendations.
- 8.4.6.9. The sheath or bond breaker shall be either a steel, PVC, polyethylene, or polypropylene pipe or tube. The sheath may surround individual tendon elements or the entire tendon. The material shall be capable of withstanding damage during shipping, handling, and installation. The material is subject to the approval of the S.O..
- 8.4.6.10. Grease injected under the sheath shall be formulated to provide lubrication and inhibit corrosion. The chlorides, nitrates, and sulfides present in the grease shall not exceed the following limits:
- (i) Chlorides 10ppm
 - (ii) Nitrates 10ppm
 - (iii) Sulfides 10ppm
- 8.4.6.11. The contract documents should indicate if simple or encapsulation corrosion protection is required. A simple protected tieback tendon shall be provided. Details of the protection system shall be submitted to the S.O. for review and approval. The Drawings shall show details of a simple corrosion protected tieback. The ends of the grease filled sheath shall be sealed with tape, heat shrinkable tubes, or other means subject to the approval of the S.O.. A plastic trumpet shall be used to make the transition from the bearing plate to the corrosion protection over the unbonded length. A tight-fitting seal shall be provided at the end of the trumpet. Insulating bearing strips shall be provided under the bearing plate. The bearing strips material must:
- (i) Be an electrical insulator
 - (ii) Be resistant to attack from cement, grease or aggressive environments
 - (iii) Be non-detrimental to the prestressing steel
 - (iv) Have compressive strengths greater than concrete
 - (v) Not be susceptible to significant creep deformations
- 8.4.6.12. Manufacturer's literature describing the bearing material shall be submitted to the S.O. for review and approval.

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8.4.6.13. The insulation over the anchorage and bearing plate shall be fabricated from a heat shrinkable cap with an elastic adhesive, a mouldable sealant, or other suitable material. Manufacturer's literature describing the insulation shall be submitted to the S.O. for review and approval. The anchorage insulation must be:

- (i) An electrical insulator
- (ii) Resistant to attack from cement, grease, or aggressive environments
- (iii) Nondetrimental to the prestressing steel
- (iv) Capable of withstanding atmospheric exposure and ultraviolet light if the-anchor head is intended to remain exposed

8.4.6.14. An encapsulated tieback tendon is required. Details of the proposed encapsulated protection system shall be submitted to the S.O. for review and approval. The Drawings shall show details of encapsulated tendon. The anchor length shall be encapsulated in a corrugated plastic or deformed metal tube. The capsule must be:

- (i) Capable of transferring stresses from the encapsulation grout to the anchor grout
- (ii) Accommodate movement during testing, and after lock-off
- (iii) Resistant to chemical attack from aggressive environments, grout, or grease
- (iv) Fabricated from materials nondetrimental to the tendon
- (v) Capable of withstanding abrasion, impact, and bending during handling and installation
- (vi) Leak proof

8.4.6.15. The tendon shall be centralized inside the capsule. Cement grout shall be used to secure the tendon inside the capsule. A leak tight transition shall be provided between the anchor length capsule and the unbonded length capsule. A heat shrinkable sleeve, or other suitable splices, subject to the approval of the S.O., shall be used. A smooth plastic or metal tube can be used over the unbonded portion of the tendon. If the tendon is greased and sheathed within the smooth portion of the capsule, then grout should be used to fill the annular space between the tendon and the plastic or metal tube. If the tendon is not sheathed, grease shall be used to fill the annular space between the smooth tube and the steel. The smooth tube must:

- (i) Accommodate movement during testing and after lock-off
- (ii) Resistant to chemical attack from aggressive environments, grout or grease

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- (iii) Fabricated from materials non detrimental to the tendon
- (iv) Capable of withstanding abrasion, impact and bending during handling and installation
- (v) Leak proof

8.4.6.16. A steel or plastic trumpet shall be used to make the transition from the bearing plate to the protection over the unbonded length. A tight-fitting seal shall be provided at the end of the trumpet. The anchorage shall be encased in, concrete if possible. Exposed anchorages shall be covered with grease or grout filled cover. The Contractor shall ensure that the grease or grout fully covers the anchor head.

- (i) Tendon Fabrication
 - (a) Prestressing steel shall be protected from dirt, rust, or deleterious substances. A light coating of rust on the steel will not affect its function. Heavy corrosion or pitting shall be cause for tendon rejection. If there is a question about the extent of the corrosion, the steel can be tested to determine if it still meets the appropriate ASTM specification.
 - (b) Tendons can be either shop or field fabricated.
 - (c) Tendons shall be stored and handled in such a manner as to avoid damage or corrosion.
- (ii) Installation
 - (a) Core drilling, rotary drilling, or percussion drilling can be used to drill rock foundations. Auger drilling, rotary drilling, or percussion driven casing can be used for soil tiebacks. The drill hole shall be located within 76mm of the desired location.
 - (b) The engineer may specify water-tightness test for rock tiebacks. The test is not necessary for every tieback. Cavernous limestone formations, open jointed or fractured rock, and formations where water loss or gain was observed during exploratory drilling should be checked for water-tightness. The engineer should determine the number of tests to be performed. If the need for water-tightness testing is uncertain, then the initial drill holes need to be tested. If it is certain that the formation is open, then water-tightness testing may be required for each tieback. Pressure grouting the anchor zone using the casing or a packer to seal the hole can be used in lieu of water-tightness test. If pressure grouting is used in rock, the engineer should specify a minimum refusal pressure.

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- (c) After drilling the permanent rock tieback hole to the desired depth, water-tightness test shall be performed to determine the tightness of the drill hole. If the unbonded soil, a packer or casing shall be used to isolate the anchor length so it can be tested. The hole shall be filled with water and subjected to a pressure of 34.5kPa in excess of the hydrostatic head measured at the top of the drill hole. If the leakage rate from the drill hole exceeds 19l in a 10-minute period, then the hole should be consolidated grouted, re-drilled or water flushed, and retested. If the second water-tightness test fails, the process should be repeated. The water level in adjacent drill holes should be observed during the test.
 - (d) The water cement ratio of the consolidation grout may be adjusted as required to seal the hole.
 - (e) If flowing water is observed in the drill hole or artesian water flows out of the hole, then the consolidation grout should be pressurized.
 - (f) The Contractor shall submit for review and approval a description of the water-tightness test procedures and equipment.
- (iii) The anchor grout shall have a water cement ratio between 0.35 and 0.50. The grouting equipment should include a mixer capable of producing a grout free of lumps and undispersed cement. A positive displacement grout pump shall be used. The pump shall be equipped with a pressure gauge to monitor grout pressures. The grouting equipment shall be sized to enable the tieback to be grouted in one continuous operation. Neat cement grouts should be screened to remove lumps. The maximum size of the screen openings shall be 6.4mm. Mixing and storage times should not cause excessive temperature build in the grout. The mixer should be capable of continuously agitating the grout.
- (a) The anchor grout shall be injected from the lowest point of the tieback. The grout may be placed using grout tubes, casing, or drill rods. The grout can be placed before or after insertion of the tendon. The quantity of the grout and the grout pressures shall be recorded. The grout pressures and grout take shall be controlled to prevent excessive heave in cohesive soils or fractured rock.
 - (b) The tieback shall remain undisturbed for a minimum of 3 days or until the grout has cured.

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8.4.6.17. Testing

The S.O. should select the appropriate tests and specify the number of each type to be performed.

8.4.6.18. Monitoring

Permanent load cells and extensometers shall be provided where indicated on the Drawings. The Contractor shall read the instrumentation biweekly during construction. Upon completion of construction, the contractor shall turn over to the S.O. the readout equipment required to continue monitoring. The S.O. shall monitor the tiebacks for additional year.

8.4.6.19. Records

The Contractor shall provide the S.O. with the following records:

- (i) Drawings showing the location of the tiebacks, total tieback length, anchor length and unbonded length
- (ii) Steel and grout certifications and/or mill reports
- (iii) Grouting records indicating the cement type, quantity injected and the grout pressures
- (iv) Tieback test results
- (v) Monitoring results

9. Gabions

9.1. Description

This work shall consist of the construction of miscellaneous erosion protection and retaining structures to be composed of stone filled wire mesh gabions. The work shall be carried out all in accordance with this Specification and as shown on the Drawings and/or as approved by the S.O..

9.2. Materials

9.2.1. Wire Mesh Gabions

9.2.1.1. Gabions shall be rectangular baskets of the required dimensions as shown on the Drawings or ordered by the S.O. unless otherwise specified, they shall be of the following standard dimensions:

- (i) Width – 1.2m
- (ii) Length - 1, 2 or 3m
- (iii) Height - 0.5 or 0.8m

9.2.1.2. Gabions longer than 1m shall be divided into compartments of equal length not exceeding 1m by wire mesh diaphragms

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securely tied along all edges. Each gabion or compartment of a gabion shall be provided with at least 4 cross-connecting wires if its height is 0.5m or less, and with at least 8 cross-connecting wires if its height is in the range 0.5m to 1m.

- 9.2.1.3. Gabions shall be fabricated from steel wire manufactured in accordance with BS 1052 and galvanised in accordance with MS 407, or such similar standards as S.O. shall approve. The galvanised wire sizes used shall be in accordance with **TABLE R11**.

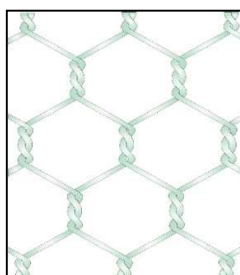
TABLE R11: GALVANIZED WIRE SIZES FOR GABIONS

Type of Wire	Minimum Diameter (mm)
Selvedge (perimeter) wire	3.50
Mesh wire	2.70
Tying and connecting wire	2.20

- 9.2.1.4. Gabions mesh shall be double twisted and shall have a uniform hexagonal pattern with openings of 100mm x 120mm or less. The mesh shall be securely tied to selvedge wires to form rectangular panels which shall be securely wired together to form the completed gabion baskets. The ties and connections for each gabion basket shall comprise not less than 8% of its total weight, and the fabrication shall be all to the satisfaction of the S.O..

Double-twist mesh is demonstrated in **FIGURE R1**:

FIGURE R1: DOUBLE-TWIST MESH



- 9.2.1.5. The tightness of the twisted joints shall be such that a force of not less than 1.7kN is required when pulling on one wire to separate it from the other wire, provided each wire is prevented from turning under the applied forces, and the wire is all in the same plane.

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9.2.2. Zinc Coating

- 9.2.2.1. All wire used in the fabrication of the gabions and in the wiring operations during construction shall be heavily galvanised and exceed MS 407, or such similar standards as the S.O. shall approve. The minimum mass of the zinc coating shall be according to the figures shown in the **TABLE R12**.
- 9.2.2.2. The adhesion of the zinc coating to the wire shall be such that when the wire is wrapped six times around a four-wire diameter size mandrel it shall not flake or crack to such an extent that any zinc can be removed.

TABLE R12: MINIMUM MASS OF ZINC COATING FOR GABIONS

Diameter of Wire (mm)	Weight of Coating (g/m ²)
2.20	240
2.70	260
3.50	275

9.2.3. Polyvinyl Chloride Coating

When specified in the Drawings, all wire used in the fabrication of gabions and in the wiring operation during construction shall, after galvanising, have extruded on to it a coating of polyvinyl chloride (PVC). The PVC coating, not inclusive of galvanising, shall nowhere be less than 0.55mm in thickness.

9.2.4. Geotextile

Non-woven geotextile, as specified in the Drawings and approved by the S.O., shall be placed vertically at the back of each gabion box, and extend backwards into the fill at least 0.5m parallel to the mesh of homogenous lower panel and also 0.5m below the panel directly above the unit, to prevent migration of fines.

9.2.5. Stone

Stone fill for gabions shall be clean, rough quarry stone, or pit or river cobbles, or a mixture of any of these materials, and shall be essentially free from dust, clay, vegetative matter and other deleterious materials. Individual pieces of stone shall have least dimensions not less than 20mm larger than the gabion mesh openings and greatest dimensions not more than 250mm. The stone shall be hard, tough, durable and dense, resistant to the action of air and water, and suitable in all aspects for the purpose intended. The material shall be approved by the S.O..

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9.3. Construction Methods

- 9.3.1. Prior to placing gabions, the surface on and against, which they are to be constructed shall have been prepared and finished in accordance with the relevant provisions of the appropriate Sections of this Specification. Notwithstanding any earlier approval of these finished surfaces, any damage to or deterioration of them shall be made good to the satisfaction of the S.O. before gabions are placed.
- 9.3.2. Each gabion basket shall be put in place in its turn, completely fabricated except for the fastening down of the lid, stretched to the correct shape and dimensions, and fastened securely to all contiguous baskets along each edge with tying wire. The basket shall then be tightly packed with approved stone by hand in such a manner that voids are kept to a practicable minimum and are uniformly distributed in the stone mass. Finally, the lid of the basket shall be securely fastened down with tying wire along all hitherto unfastened edges, all to the satisfaction of the S.O.. In no case shall the weight of the finished gabion be less than 1300kg/m³.
- 9.3.3. As a gabion structure is built up, backfilling against finished gabions shall be carried out as necessary for proper progressive construction, all in accordance with the relevant provisions of the appropriate Sections of this Specification. Unless otherwise specified, vertical joints between gabions shall be staggered in gabion structures in a pattern similar to the joints in running bond brickwork.

10. Gabion Reinforced Earth System

10.1. Materials Specification

10.1.1. Introduction

- 10.1.1.1. The specification below applies to Gabion Reinforced Earth System units and to the materials from which these are manufactured.
- 10.1.1.2. For simplicity the word "GRES" is used.

10.1.2. Definitions

- 10.1.2.1. GRES is defined as PVC coated heavily galvanized steel wire mesh box-shaped basket with a section of the mesh extending into the soil to act as soil reinforcement into the backfill soil. The basket is filled on site with clean-hard stones.
- 10.1.2.2. The selvages of the GRES are the thicker perimeter and edge wires to which the wire mesh is securely tied to withstand sudden or gradual stress from any direction.
- 10.1.2.3. The diaphragms are the internal wire mesh partitions which divide the GRES box into approximately equal sized cells.
- 10.1.2.4. Lacing and bracing wire is the wire used to assemble and join the GRES units.

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10.1.2.5. Connecting wires are the internal wires used to prevent the GRES from bulging during filling.

10.1.3. General Description

10.1.3.1. GRES shall be made from flexible woven wire Heavily Galvanized and PVC Coated 80mm type mesh boxes with integral panels of dimensions as specified in the Drawings or an approved equivalent.

10.1.3.2. All material supplied must be accompanied by a manufacturing certificate from the factory for quality control and quality management purposes. The material shall come from an ISO 9001 certified factory, and every batch supplied shall be accompanied by a manufacturing certificate from the approved supplier.

10.1.3.3. The front face box and the soil reinforcement tail shall be made from one continuous mesh panel.

10.1.3.4. For GRES, the mesh twists are oriented vertically on the gabion face and perpendicular to the front face in the reinforcement panel.

10.1.4. Steel Wire

10.1.4.1. General

All steel wire used in the fabrication of the GRES, and also in the wiring operations during construction, shall be to BS 1052, having a tensile strength of not less than 380N/mm² and not exceed 550N/mm².

10.1.4.2. Wire Diameter

Wire diameters and relevant tolerances shall be in accordance with the **TABLE R13**:

TABLE R13: WIRE DIAMETER AND TOLERANCE

Wire Diameter (mm)	Wire use	Tolerance (mm)
2.20	Lacing Wire	± 0.06
2.70	Body Wire	± 0.08
3.40	Selvedge Wire	± 0.10

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10.1.4.3. Zinc Coating

- (i) All wire used in the fabrication of the GRES and in the wiring operations during construction shall be heavily galvanized and exceed MS 407, or such similar standards as the S.O. shall approve, the minimum mass of the zinc coating shall be according to the figures shown in the **TABLE R14**:

TABLE R14: MINIMUM MASS OF ZINC COATING OF WIRE

Diameter of Wire (mm)	Weight of Coating (g/m ²)
2.20	240
2.70	260
3.40	275

- (ii) The adhesion of the zinc coating to the wire shall be such that when the wire is wrapped six times around a four wire diameter size mandrel it shall not flake or crack to such an extent that any zinc can be removed.

10.1.4.4. PVC Coating

- (i) All wire used in the fabrication of GRES and in the wiring operations during construction shall have extruded onto it (after coating it with zinc in accordance with the foregoing specification) a coating of Poly Vinyl Chloride, otherwise referred to as "PVC", or other plastic material having superior characteristics than PVC as otherwise approved.
- (ii) The coating shall be 0.50mm average thickness with a tolerance of ± 0.05 mm, and nowhere shall be less than 0.40mm thickness.
- (iii) The PVC shall be grey in colour.
- (iv) It shall be capable of resisting deleterious effects of natural weather exposure, immersion in salt water and not show any material difference in its initial characteristics which are:
- Specific Gravity
Shall be 1.30 to 1.35 in accordance with ASTM D 792-91
 - Durometer Hardness
Shall be 50 to 60 shore D, in accordance with ASTM D 2240-91 (ISO 868-1985)

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- (c) Volatile Loss
At 105 °C for 24 hours - Shall not be greater than 5% in accordance with ASTM D 2287-92 E2. Residual Ashes shall be less than 2% according to ASTM D2124-62T
- (d) Tensile Strength
Shall not be less than 210kg/cm² in accordance with ASTM D 412-92
- (e) Elongation
Shall not be less than 200% and not greater than 280% in accordance with ASTM D 412-92
- (f) Modulus of Elasticity at 100% of Elongation
Shall not be less than 190kg/cm² in accordance with ASTM D 412-87
- (g) Resistance of Abrasion
The loss in volume shall be less than 0.30cm³ in accordance with ASTM D 1242-56
- (h) Creeping Corrosion
Maximum penetration of corrosion of the wire core from a square cut end shall not be greater than 25mm when the specimen has been immersed for 2000 hours in a 50% solution of HCL (Hydrochloric Acid 12 BE).

10.1.4.5. Testing for deterioration shall be as described below. Variation of the initial characteristics may be allowed, as specified hereunder, when the specimen is submitted to the following tests:

- (i) Salt Spray
 - (a) According to ASTM B 117-90
 - (b) Period of test = 1500 hours
- (ii) Exposure to Ultraviolet Light
 - (a) According to ASTM D 1499-92 and ASTM G 23(93) apparatus type E.
 - (b) Period of test = 2000 hours at 63°C
- (iii) Exposure at High Temperature
 - (a) According to ASTM D 1203-89, (ISO 176-1976) and ASTM D 2287-(92) E2.
 - (b) Period of test = 240 hours at 105°C.

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- (iv) Brittleness temperature: cold bend less than -30°C test method BS2782-104A; cold flex less than $+15^{\circ}\text{C}$ in accordance with BS2782-151A (84).

10.1.4.6. After the above tests have been performed, the PVC coating shall exhibit the following properties:

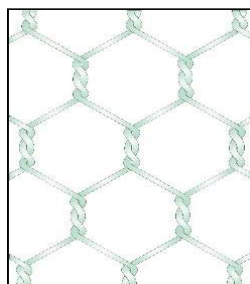
- (i) Appearance
The vinyl coating shall not crack, blister or split and shall not show any marked change in colour
- (ii) Specific Gravity
Shall not show change higher than 6% of its initial value
- (iii) Durometer Hardness
Shall not show change higher than 10% of its initial value
- (iv) Tensile Strength
Shall not show change higher than 25% of its initial value
- (v) Elongation
Shall not show change higher than 25% of its initial value
- (vi) Resistance to Abrasion
Shall not show change higher than 10% of its initial value
- (vii) Brittleness Temperatures
Cold-bend not exceeding -20°C ; cold-flex not exceeding $+18^{\circ}\text{C}$

10.1.5. Wire Mesh

10.1.5.1. Wire mesh shall be mechanically pre-fabricated to become a uniform hexagonal woven mesh wherein the joints are formed by twisting each pair of wires through three half-turns (commonly known as double twist), in such a manner that unravelling is prevented.

10.1.5.2. Double-twist mesh is demonstrated in **FIGURE R2**:

FIGURE R2: DOUBLE-TWIST MESH



10.1.5.3. The tightness of the twisted joints shall be such that a force of not less than 1.7kN is required when pulling on one wire to separate it from the other wire, provided each wire is prevented

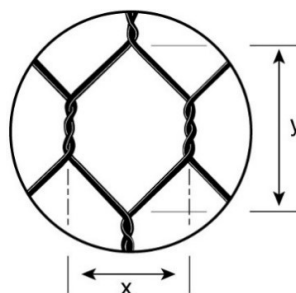
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from turning under the applied forces, and the wire is all in the same plane.

10.1.5.4. The mesh tensile strength, in soil, is to be equal to or greater than 47kN/m. All wire used in GRES units shall be PVC coated.

10.1.5.5. Certain other wire diameters may be utilised if specified by the S.O.. The wire mesh dimensional layout is as per **FIGURE R3**:

FIGURE R3: WIRE MESH DIMENSIONAL LAYOUT



Mesh Type	X (mm)	Y (mm)	Tolerance (%)
80	82	122	± 5

10.1.6. Selvedges

10.1.6.1. The cut edges of all mesh used in the construction of GRES, except the bottom edges of diaphragms and the end of the soil reinforcing tail shall be tightly selvedged with a wire having a diameter of at least 3.40mm.

10.1.6.2. The side selvedge of all and any mesh panels shall be woven integrally with the main mesh as described in the above sub-section 10.1.5 with a selvedge wire of at least 3.40mm in diameter.

10.1.6.3. Where the selvedge is not woven integrally with the mesh but has to be fastened to the cut ends of the mesh, it must be attached by mechanically binding the cut ends of the mesh two and half turns around the selvedge wire or by other approved method, provided that the force of not less than 8.5kN applied in the same plane as the mesh, at a point on the selvedge of a mesh sample one metre long, is required to separate it from the mesh.

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10.1.7. Diaphragms and End Panels

10.1.7.1. The rear/side panels shall be selvedged on the top, bottom and vertical sides as described in sub-section 10.1.6. The diaphragms shall be selvedged on the top and vertical sides.

10.1.7.2. The rear and side panels of the box gabion section of the GRES unit shall be formed by a continuous panel connected to the main panel, along the bottom of the rear panel, either by a spiral wire through the mesh openings or by being mechanically placed with four connecting rings.

10.1.8. Lacing and Bracing Wire

10.1.8.1. Sufficient lacing and bracing wire must be supplied with the gabion cages to perform all the wiring operations to be carried out in the construction of the GRES work.

10.1.8.2. The lacing and bracing wire shall be made from Heavily Galvanized Wire, coated with PVC and have a core diameter of 2.20mm.

10.1.9. Unit Sizes

10.1.9.1. GRES shall be mechanically pre-fabricated in such a manner that the sides, ends and diaphragms can be assembled at the construction site into rectangular baskets of the standard sizes indicated in

10.1.9.2. or as specified and shown on the Drawings.

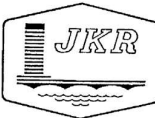
10.1.9.3. All GRES dimensions shall be within a tolerance limit of 5% of the required size.

TABLE R15: STANDARD SIZE OF GRES

Mesh type	80mm
Width (W)	2m
Length (L1)	1m
Length (L2)	To suit design
Depth (D)	0.5m and 1m
Diaphragm	Every 1m

10.1.10. Stone Fill for Facing Box

10.1.10.1. The material used for GRES facing box fill shall be clean, dense hard and durable stone, rounded and angular shape.

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10.1.10.2. No rock shall exceed 250mm and at least 85% by weight of the stone shall have a size equal to or larger than 100mm. No rock shall pass through the mesh.

10.1.11. Structural Embankment

10.1.11.1. The embankment forming the reinforced soil structure should be constructed with material having the soil properties as specified in the design and approved by the S.O..

10.1.11.2. Ideally, the backfill shall be granular, free draining and have the following specification, unless otherwise approved by the S.O.:

- (i) Not more than 15% by mass of total material to be finer than 75 micron sieve opening
- (ii) At least 90% by mass of total material to be finer than the 100mm sieve opening, and
- (iii) Maximum particle size to be limited to 125mm

10.1.11.3. Cohesive frictional fill is permitted provided it is in accordance with the design and internal drainage system is included.

10.1.11.4. The soil should not exhibit any deterioration in these characteristics with time.

10.2. Assembly and Erection Specification for Gabion Reinforced Earth System

10.2.1. Scope

10.2.1.1. This part of the specification details the requirements from the assembly stage through to the final wiring of the completed GRES units.

10.2.1.2. The Contractor shall provide to the S.O., for his approval, full details and specifications of the GRES he proposes to use in this contract. Only those products approved by the S.O. shall be allowed to be incorporated in the works.

10.2.2. Preparation

10.2.2.1. The site shall be surveyed, cleared, trimmed level and the ground compacted accordingly.

10.2.2.2. Prior to assembly, the GRES units shall be opened out flat on the ground and stretched to remove all kinks and bends.

10.2.2.3. The GRES units shall be assembled individually by raising the front panel (with lid), the hinged rear panel, and the two ends vertical ensuring that all creases are in the correct position and that tops of all four sides are even. The diaphragm panel should be located in a vertical plane centrally within the facing box.

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10.2.2.4. The four corner edges of the facing box shall be laced first followed by the edges of the internal diaphragm to the sides.

10.2.2.5. In all cases, lacing shall commence by twisting the end of the lacing wire tightly around the selvedge/s. It shall then pass round the two edges being joined using alternate single and double loops at 100mm intervals and be securely tied off at the bottom. The ends of all lacing wires shall be turned to the inside of the box on completion of each lacing operation. Each loop shall be pulled tight to prevent the joint opening during filling.

10.2.3. Erection

10.2.3.1. Only assembled boxes, or groups of boxes, shall be positioned in the structure. The side, or end, from which work is to proceed, shall be secured either to the completed work, or by rods or stakes driven into the ground at the corner. These stakes must be secure and be high enough to reach at least to the top of the gabion box.

10.2.3.2. Further gabion boxes shall be positioned in the structure as required, each being securely laced to the preceding one along all common corners and diaphragms using the lacing technique described above.

10.2.3.3. Adjacent panels shall be laced longitudinally to provide a homogeneous reinforcement layer.

10.2.3.4. All lacing wire shall be PVC coated.

10.2.4. Geotextile

Non-woven geotextile, as specified in the contract drawings and approved by the S.O., shall be placed vertically at the back of each gabion box section of the GRES units, and extend backwards into the fill at least 0.5m parallel to the mesh of homogeneous lower panel and also 0.5m below the panel directly above the unit, to prevent migration of fines.

10.2.5. Stretching

10.2.5.1. Final stretching of the gabion boxes shall be carried out using a pull-lift of at least one tonne capacity, firmly secured to the free end of the assembled gabion boxes.

10.2.5.2. Whilst under tension, the gabion box section of the GRES units shall be securely laced along all edges (top, bottom and sides) and at diaphragm points, to all adjacent boxes.

10.2.6. Filling

10.2.6.1. Filling shall be carried out whilst gabion boxes are under tension.

10.2.6.2. The front face and all other faces which will be exposed in the completed structure shall be "hand packed" with the stones placed so as to produce a neat face free from excessive bulges, depressions and voids.

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10.2.6.3. Internal bracing wires shall be provided on the exposed faces at the rate of 4/m³ at 330mm centres to prevent distortion of the units during filling and in the completed structure. These bracing wires shall be wrapped around two of the mesh wires and extend from front to back. Additional bracing wires shall be provided on exposed ends at a rate of 4/m² of face.

10.2.6.4. Mechanical filling equipment may be used with the approval of the S.O., provided adequate precautions are taken to protect the PVC coating from abrasion during filling operations.

10.2.6.5. Tension on the gabion boxes shall be released only when fully laced and sufficiently full to prevent the mesh from slackening.

10.2.6.6. All gabions shall be overfilled by 25mm using flat stone to allow for minor settlement and to provide a level surface for subsequent layers.

10.2.7. Structural Embankment Material

Select backfill shall be placed between each subsequent mesh panel layer to the full extent of the mesh reinforcement at each level as specified in sub-section 10.1.11.

10.2.8. Compaction of Backfill

10.2.8.1. The select backfill shall be compacted in lifts not exceeding 250-300mm to 90% of maximum density as determined by Test 12 of BS1377, unless otherwise specified in the Drawings or specified by the S.O..

10.2.8.2. Care shall be taken to ensure heavy compaction equipment does not come into contact with the mesh panels or within 1.0m of the front face. Tracked construction equipment shall not be operated directly upon the mesh reinforcement. A minimum fill thickness of 150mm is required prior to operation of tracked vehicles over the mesh.

10.2.8.3. During construction, the surface of fill should be kept horizontal. A slight sloping surface shall be maintained to facilitate drainage of surface water run-off.

10.2.8.4. Compaction adjacent to the front edge should be done using hand operated rollers or plate compactors.

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11. Hydroseeding

11.1. General

This works shall consist of slope surface preparation and hydroseeding work including supply of all necessary equipment, manpower and materials on location of slopes in cut and fill areas as shown in Drawings or as directed by the S.O.. Method Statement with specific equipment, personnel, materials, works output, sequence and procedure of works plus quality control requirements, etc., showing compliance of the specification shall be sent to the S.O. for prior approval before commencement of work. Equipment with details such as model, type, capacity with catalogue and photos shall be included. Names of key personnel including operator, supervisor manager and their experiences shall be included. Source of supply of materials including material specification, guarantee, expiry dates, test certificates, guide of application shall also be included. Only Contractor with suitable equipment, materials and qualified and experienced personnel plus track records will be considered for approval.

11.2. Seeding

- 11.2.1. Seeding or hydroseeding shall be carried out as soon as practicable on slopes and other areas as shown on the Drawings and/ or directed by the S.O. Unless otherwise approved by the S.O., hydroseeding shall be carried out within 7 days after the slope is cut or filled. The surface before hydroseeding shall be free of loose or soft materials. Cut slope surface shall have some horizontal grooves (about 20mm deep) at about 200mm intervals. Vertical grooves shall be avoided.
- 11.2.2. Seeding shall be carried out by means of a proper hydroseeder where approved slurry of seeds, mulch, fertilisers, binders and organic matter is sprayed on to the prepared soil surface.

11.3. Seed Mixtures

- 11.3.1. Application rate for grass seeds (dry weight) shall be $30 \pm 50\text{g/m}^2$. The seed mixtures shall comprise the following combinations (by dry weight) or similar as instructed by the S.O..

11.3.1.1. Seed Combination A for normal soil at upper cut slopes (Grade 6/5) and lower embankment slope

- | | | |
|-------|---|-----|
| (i) | Japanese millet (<i>Echinochloa Utilis</i>) | 15% |
| (ii) | Bermuda grass (<i>Cynoden dactylon</i>) | 25% |
| (iii) | Signal grass (<i>Brachiaria Desumbars</i>) | 50% |
| (iv) | Centro (<i>Centrosoma pubescens</i>) | 10% |

11.3.1.2. Seed Combination B for normal soil at Lowest cut slope (Grade 3/4/5) and uppermost embankment slope

- | | | |
|------|---|-----|
| (i) | Bermuda grass (<i>Cynoden dactylon</i>) | 50% |
| (ii) | Carpet grass broadleaf (<i>Axonopus compressus</i>) | 50% |

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11.3.1.3. Seed Combination C for hard material of cut slope (SPT N value greater than 50)

- (i) Centro (*Centrosoma pubescens*) 30%
- (ii) Signal grass (*Brachiaria decumbens*) 70%

11.3.1.4. Fertilisers and Soil Amenders

- (i) The amount of lime or other chemicals (if any) to be applied to improve the soil before, during and/or after hydroseeding shall be submitted in advance for S.O. approval.
- (ii) The NPK fertilisers and soil amenders shall be mixed in the hydroseeder and the application rate shall be $100 \pm 5\text{g/m}^2$.
- (iii) Not less than 90% of the GML (Ground Magnesium Lime) soil amender shall pass through a 40-mesh sieve and 50% shall pass through a 100-mesh sieve. (About $\pm 50\text{g/m}^2$).

11.3.1.5. Mulchfibres

- (i) For normal soil, the following mulchfibres shall be mixed in the hydroseeder:

TABLE R16: MULCHFIBRES APPLICATION RATE FOR NORMAL SOIL

Type	Rate of Application (g/m^2)
Coconut or oil palm fibre or paddy straws	60
Newsprint fibre	60

- (ii) For hard material (SPT N value greater than 50) the rate of application of mulchfibres shall be as shown in **TABLE R17**

TABLE R17: MULCHFIBERS APPLICATION RATE FOR HARD MATERIAL

Type	Rate of application (g/m^2)
Coconut or oil palm fibre or paddy straws	90
Newsprint fibre	90

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11.3.1.6. Binder

- (i) The binder must be able to fix all ingredients onto the soil surface and to protect the areas treated against erosion until complete establishment of the vegetation cover. It may be of organic or mineral origin but must be non-polluting and having no delaying action on the germination of the seeds. The binder shall be bio gradable.
- (ii) The Contractor shall submit to the S.O. for his consideration and prior written approval the type and amounts of binding agent to be applied with the seeds, mulch, fertilisers, etc..

11.3.1.7. Mixtures

- (i) All above ingredients shall be mixed with water to form homogeneous slurry and kept agitated until finally applied to the slope surface. All water used shall be free of injurious chemicals and other toxic substances harmful to plant life.
- (ii) The pH value of the water shall be above 6.0. The Contractor shall test the different water points to control the quality.
- (iii) All mixtures shall be used within 4 hours from the time they are mixed.

11.4. Spraying Equipment

- 11.4.1. The equipment shall consist of a water tank or container fitted with an engine; agitator and high-pressure pump with sufficient power to reach the slope surface. The mechanical power drive agitator shall be capable of keeping all ingredients in suspension at all times.
- 11.4.2. All pump passage and pipelines shall be capable of providing a clearance of solids of minimum 15mm.
- 11.4.3. At least two different types of nozzles (long range and close range) shall be supplied so that the mixture may be properly sprayed over distances varying from 5 to 60m. The nozzles shall be connected to the nozzle pipe or to the eventual extension hoses by quick release couplings.

11.5. Biodegradable Mat (BM)

- 11.5.1. Biodegradable Mat shall be from local manufacturers with ISO certification and laboratory test facilities for necessary inspection by the S.O.. Test certificates from reputable or accredited laboratories approved by the S.O., showing the material's compliance to the specification, shall be submitted to the S.O. for verification and approval.

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11.5.2. Biodegradable Mat (BM) should be machine made comprising of paddy straw or coconut/ oil palm coir bonded to a lightweight polypropylene or polyester geogrids with minimum tensile strength 2.0kN/m (ASTM D4595) and should have the following measurements:

11.5.2.1. Nominal mass (ASTM D3776) : Not less than 150g/m² or as shown on the Drawings

11.5.2.2. Thickness (ASTM D1777) : Not less than 3mm or as shown on the Drawings

11.5.2.3. Roll width : 2.0 to 3.5m

11.5.2.4. Roll size : 50 to 200m²

11.5.2.5. The nominal mass of BM shall be determined at oven dry condition as defined in B.S.1377

11.6. Installation of BM Blanket

11.6.1. Prior to installation of BM, the slope or other soil surface shall be prepared as in sub-section 11.6 and seeded as in sub-section 11.2 and 11.3.

11.6.2. To install the BM, unroll the mat with the netting facing upwards and the paddy straw or coconut coir palm fibre in contact with the soil. BM shall be installed immediately after seeding. The mat shall be unrolled vertically to the contour. The ends and the sides of adjoining mats shall be overlapped with a minimum of 50mm.

11.6.3. BM shall be anchored to the ground with the use of U-shaped staples, length 100-150mm, 6mm diameter steel bars. Where the soil is very sandy the steel staples shall be replaced by bamboo sticks of at least 250mm long.

11.7. Preparation of the soil surface prior to hydroseeding

11.7.1. Vertical striations or grooves shall be absent from the final trimmed slope. Instead, a rough textured surface shall be prepared. Where the surface microtopography varies by ± 20 mm from the formation level, an acceptable treatment is to provide horizontal grooving with semicircular or "v" shaped groove, 20mm depth, at an interval of 200mm downslope on all cut slopes comprising soft material. Any surface rills on newly cut slopes in excess of 25mm shall be rectified by retrimming.

11.7.2. Gullies or localized washouts shall be backfilled with suitable material placed in layers of up to 200mm thick, each layer being compacted by hand ramming or by lightweight vibration plate compactors. For localized washout exceeding 1m³ backfilling shall be by sandbags or rock pitching or as shown on the Drawings.

11.7.3. Large clods of earth and stones greater than 50mm shall be removed.

11.7.4. Slopes that have been exposed for a long time must be trimmed and scaled to remove the oxidised layer prior to hydroseeding.

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11.8. Protection of trimmed slopes

- 11.8.1. All cut and fill slopes shall be treated by hydromulching (and BM where specified) within 14 days of initiating the final trim. Any area of cut or fill of over 6m vertical height shall also be protected within 14 days.
- 11.8.2. Temporary and/ or permanent drainage systems shall be installed immediately after the final trim is made to a slope, and before hydromulching and the application of BM.
- 11.8.3. The contractor shall ensure that his sequence of earth moving operations is such that suitable access is available for plant, labour and materials to enable installation of erosion protection measures.

11.9. Maintenance during liability period

The Contractor shall carry out daily watering (except lancing days) for at least 1 week is to ensure the full establishment of rooting and ground cover by taking the necessary maintenance procedures such as regular, fertilising, and reseeding of failed areas. The Contractor shall guarantee the success of the seeding work. Any dead grass spot shall be immediately replaced or resprayed at Contractors' own expenses. In areas where rooting and ground cover cannot be established even after several trials, the Contractor shall report to the S.O. for necessary direction.

11.10. Quality Control

- 11.10.1. The following quality controls and acceptance criteria shall be complied and approved by the S.O.:
 - 11.10.1.1. The rate of application of grass seeds, fertilisers, mulch etc shall be verified at field by 1m x 1m plywood and field records. (minimum 1 test daily or per 3,000m²). The whole slope shall be resprayed if any test result is found below the value specified in sub-section 11.3 pH value of water used shall be checked daily.
 - 11.10.1.2. Certificates related to type, origin, quality and validity of seeds for EACH source or supplier. All seeds and fertilizers shall be from suppliers approved by the S.O..
 - 11.10.1.3. Calibrated weighting machine/balance with 1% or $\pm 2g$ accuracy shall be used for all weighting.
 - 11.10.1.4. Minimum one (1) sample per 5000m² of Biodegradable mat (BM) shall be sampled by the S.O. for measurements/prospective verification at Site to ensure compliance of specification as per sub-section 11.5. All rolls of BM shall be tested if any sample fails any requirement. Rolls of BM below specification shall be rejected and removed from the Site.

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1. General

1.1. This work shall consist of numerous ground improvement technique and instrumentation in regards with general requirement, method of installation and relevant testing to be implemented during construction. This Section shall be read together with SECTION C: EARTHWORKS.

1.2. Method Statement for Construction Operations

1.2.1. The Contractor shall submit to the S.O. a detailed method statement for the works in fourteen (14) days prior to the commencement of the works. The method statement shall contain the following: -

- 1.2.1.1. A detailed construction sequence;
- 1.2.1.2. Shop drawing showing details of all special requirements for the construction activities;
- 1.2.1.3. Design calculation of key temporary works endorsed by P.E.P.C.;
- 1.2.1.4. Material, plant and labour requirement at each construction stage;
- 1.2.1.5. Rate of production output based on resources allocated (if required);
- 1.2.1.6. Environmental Management Plan in related with the Works;
- 1.2.1.7. Precautions against heave and settlement;
- 1.2.1.8. Other information relevant to the Works.

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

1.2.3. The Contractor shall not change the methods which have been approved by the S.O. Approval by the S.O. of the Contractor's proposed methods of construction shall not in any way relieve the Contractor of any of his duty or responsibility under the contract.

2. Removal and Replacement

2.1. General

Removal and replacement shall be used for ground improvement purposes to increase the bearing capacity of the ground. The work involves removal of soft soil layer, hence replaced with suitable material as shown on the Drawings.

2.2. Determination of Depth of Removal

2.2.1. The depth of removal shall be as shown on the Drawings or as determined by trial pits or JKR/Mackintosh Probe test as approved by the S.O. The trial pits or probe test shall be carried out at locations as indicated in the Drawings or as instructed by the S.O..

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- 2.2.2. The apparatus used shall be the standard JKR probes or Mackintosh probes. Procedure of works and details of the JKR probes and Mackintosh probes are as per JKR Standard Specification for Roadworks "SECTION 17: SITE INVESTIGATION".

2.3. Materials for Replacement

- 2.3.1. Where geotextile is specified, it shall be laid as shown on the Drawings before commencement of filling works. The specification of geotextile shall be in accordance with sub-section 4.4.
- 2.3.2. Unless otherwise indicated in the Drawings, suitable materials for fill and method of compaction shall conform to SECTION C: EARTHWORKS.
- 2.3.3. For replacement of excavated material under standing water, the fill material shall be granular material conforming to SECTION C: EARTHWORKS.

3. Pre-loading

3.1. General

- 3.1.1. The execution of surcharging works shall be in accordance with this Specification and details as shown on the Drawings.
- 3.1.2. The scope of works shall cover the following:
- 3.1.2.1. Spread, level and compact surcharging material in accordance with SECTION C: EARTHWORKS and details as shown on the Drawings.
 - 3.1.2.2. Install geotechnical instrumentation to monitor and validate the performance of the works.
 - 3.1.2.3. Removal and disposal of excess material on completion of specified surcharge period or as shown on Drawings or when directed by the S.O..
 - 3.1.2.4. Removal and disposal of excess material of the embankment to the line, level and grade in accordance to details as shown on the Drawings to complete the works.
- 3.1.3. The Contractor shall be responsible for the provision of surcharge material and the removal and disposal of excess material on completion of the specified surcharge period or when directed by the S.O..

3.2. Materials

- 3.2.1. Materials for use in surcharging shall be suitable material conforming to JKR Standard Specification for Building Works SECTION C: EARTHWORKS.
- 3.2.2. The filling material shall be laid in layer and compacted as per SECTION C: EARTHWORKS.

3.3. Surcharge Load and Surcharge Period

The surcharge load shall be applied throughout the surcharge period. The surcharge period specified in the Drawings is subjected to validation from field monitoring results, which may be shortened or extended at the discretion of the S.O. based on interpretation of field monitoring results by means of geotechnical instrumentations installed at Site.

3.4. Stability of Embankment

- 3.4.1. The height of the embankment including the surcharge shall at no time exceed the specified height in the Drawings. The placement of the surcharge materials shall be in uniform layers and care shall be given to ensure stability of the embankment. The Contractor shall check at all times the rate of placement and adjust accordingly in order to avoid instability. Stockpiling of excess earth, machineries or any other materials shall not be permitted on the embankment.
- 3.4.2. Where counterweight berm is designed to enhance the stability of the embankment including the surcharge, the counterweight berm shall be constructed first prior to placement of surcharge material as shown on the Drawings.
- 3.4.3. The width, height and slope gradient of the counterweight berms shall be constructed in accordance with details shown on the Drawings. Any remedial works arising from non-compliance of the requirements of this section which leads to embankment failure shall be borne by the Contractor at his own cost and time.

3.5. Drainage Blanket

- 3.5.1. The drainage blanket layer shall consist of clean sand with less than 10% of fine content passing the 75 μ m sieve having grading within the respective limits specified in SECTION C: EARTHWORKS, **TABLE S4**.
- 3.5.2. The drainage material for depositing in water shall be deposited without the associated use of a compaction plant.
- 3.5.3. The drainage blanket shall be built up evenly in horizontal layers, each not more than 300mm thick up to the design thickness as specified in the Drawings. Filling shall commence from the lowest level, and each layer shall cover the full area of the intended total fill area at that level before deposition of the subsequent layer commences.
- 3.5.4. The drainage system shall include trenches, subsoil drainage etc. as specified in the Drawings.
- 3.5.5. The drainage system shall be regularly maintained throughout the surcharge period to ensure smooth dissipation of water. The outlets of water at the brinks of drainage blanket shall be cleared of any obstruction at all times by way of regular maintenance.

3.6. Instrumentation

- 3.6.1. Surcharge monitoring shall be carried out to monitor stability, settlement, deflection and pore water pressure of the embankment due to surcharging. The types and numbers of instruments and frequency of monitoring shall be in accordance with the Drawings or as specified by the S.O. Specification for instrumentation shall be in accordance with sub-section 10.

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3.6.2. The monitoring results shall be submitted to the S.O. according to the agreed frequency and shall form part of the surcharge control measures. Evaluation and amendments to the surcharging design may be carried out from time to time by the S.O. based on interpretations of the monitoring results.

3.6.3. The Contractor shall be responsible for and shall follow the instructions of the manufacturer in the installation, calibration and testing of all measuring instruments and equipment.

3.7. Removal of Surcharge Materials

3.7.1. Removal of surcharge materials shall only be carried out as instructed by the S.O. upon completion of the specified surcharge period and validated with field monitoring results.

3.7.2. There shall be no unauthorized removal of surcharge materials before the completion of the specified surcharge period and any remedial works arising from such unauthorized removal of surcharge shall be borne by the Contractor at his own cost and time.

3.8. Use of Surcharging in Conjunction with Other Ground Improvement Methods

When surcharging is used in conjunction with other ground improvement methods such as prefabricated vertical drains, the works shall conform to the requirements of the associated ground improvement works.

4. Geosynthetics

4.1. General

4.1.1. Unless otherwise specified elsewhere in the specification or on the Drawings, geosynthetics for use in ground treatment shall conform to requirement as specified herein.

4.1.2. Geosynthetics used shall be manufactured by manufacturer that is ISO 9001 certified.

4.1.3. Geosynthetics shall be durable and resistant to naturally occurring chemical, fungi and bacteria when in contact with soils or materials to be treated. In addition, geosynthetics used shall be resistant against rotting, mildew, insects, salts, alkali, solvent and other constituents of the ground water.

4.1.4. The Contractor shall be responsible for the true and proper setting-out of the areas to which the geosynthetics are to be placed and provide all necessary resources and equipment related to supply and laying of geosynthetics to the correct level and dimension as shown on the Drawings or as instructed by the S.O..

4.2. Packaging, Transportation and Storage

4.2.1. Geosynthetics shall be wrapped in heavy paper or similar heavy-duty protection covering for transportation and storage. If no covered area is available, geosynthetics shall be stored on raised platform and covered with a waterproof canvas. Geosynthetics shall be protected from sunlight, moisture, mud, dirt, dust, debris and other detrimental substances during transportation and storage.



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4.2.2. Each roll of geosynthetics delivered to Site shall be clearly labelled with the following:

4.2.2.1. Product brand name

4.2.2.2. Product type

4.2.2.3. Product grade

4.2.2.4. Date of manufacture or submission of mill certificate

4.2.2.5. Roll width and length

4.2.2.6. Batch serial number

4.2.3. The Contractor is solely responsible for the good condition of the geosynthetics stored at the worksite and in the event of damages or deterioration of the geosynthetics due to improper storage, the Contractor shall be liable to replace the affected materials at his own cost when directed by the S.O..

4.2.4. All materials which are damaged during transportation, handling or storage and do not meet the minimum requirements of the specification shall be rejected by the S.O. and shall be immediately taken off the Site. No payment of any kind shall be made on the rejected product.

4.3. Quality Control and Testing

4.3.1.1. Submission of Material Test Report (MTR)

4.3.1.2. The Contractor shall obtain the S.O.'s approval prior to supplying the geosynthetics to the Site. Prior to the procurement of materials, the Contractor shall provide a sample and Material Test Report (MTR) not more than 2 years old complying with *ISO/IEC 17025* from accredited laboratory by Department of Standards Malaysia with the scope of accreditation referring to geosynthetics, showing full compliance of the proposed geosynthetics to all the specified property values corresponding to their respective test methods for the approval of the S.O..

4.3.1.3. The Contractor shall also submit technical data and samples to verify the physical, mechanical and hydraulic properties of the geosynthetics to be used for S.O.'s approval.

4.3.1.4. All tests shall be carried out in accordance with the Codes of Practices and Test Standards provided within this Specification. All cost associated with the tests and preparation of report shall be borne solely by the Contractor.

4.3.2. Routine Sample Testing

4.3.2.1. Routine sample testing shall be carried out at factory or at an accredited laboratory witnessed by the S.O.'s representative. The Contractor shall submit test report after each routine test showing compliance of the Specification.

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- 4.3.2.2. Prior to installation and at the discretion of the S.O., test samples shall be carried out at the frequency specified in **TABLE S1** and **TABLE S2**. Control testing shall be carried out for each batch of geosynthetics in accordance with the provisions of **TABLE S1** and **TABLE S2**.
- 4.3.2.3. Individual sample shall not be less than two (2) metres in length for non-woven geotextile and one (1) metre in length for high strength woven geotextile and geogrid, times the full width of the geosynthetics. Samples submitted for tests shall indicate the linear metres of the geosynthetics and manufacturer's identifications represented by the sample.
- 4.3.2.4. Should any individual sample selected at random fail to meet the Specification, then that roll shall be rejected, and two additional samples shall be taken at random from two other rolls representing the same batch. If either of these two additional samples fails to comply with the Specification, then the entire batch of geotextile represented by the samples shall be rejected.

4.4. Geotextile

4.4.1. General

Geotextile shall be made of new synthetic polymeric fabric that are stable or stabilized against ultraviolet (UV) radiation such that 3 months exposure to sunlight shall not reduce its specified strength to less than 70%.

4.4.2. Installation

- 4.4.2.1. Prior to the laying of geotextile, Site clearance shall be carried out in accordance with the Specification and Drawings or as directed by the S.O.. All voids shall be filled with suitable material and the area cleared of large stones and exposed tree root systems or other such like protrusions. Geotextile fabric shall be installed to the shape and requirements as specified herein and in the Drawings.
- 4.4.2.2. Geotextile shall be placed just in advance of placement of the specified overlying fill material. Geotextiles laid shall be covered by the fill as soon as possible within seven (7) days of being placed. The counting of this foresaid seven (7) days shall commence immediately upon the geotextile being exposed from its protective wrapping. Installation proposals and trials as deemed required shall be carried out for approval by the S.O. prior to the acceptance of the placement method for the main works.
- 4.4.2.3. The geotextile shall be unrolled smoothly on the prepared ground. In general, high strength woven geotextile shall be placed transversely, across the direction of the slope as shown in **FIGURE S1**, or otherwise as approved by the S.O.. The geotextile shall be laid flat on the underlying surface with no wrinkles or folds and shall extend far enough over the edges of the embankment for a wrap-around as shown on the Drawings.

- 4.4.2.4. Adjacent geotextile rolls shall be overlapped or sewn in accordance with this Specification. Overlapping of geotextile without sewn connections shall only be allowed with the approval of the S.O.. On curves and corners, geotextile may be folded or cut to conform to the direction as approved by the S.O.. The seaming of geotextile is as described in sub-section 4.4.3..
- 4.4.2.5. The specified overlying fill material properties and method of compaction on the non-woven geotextile fabric shall be in accordance with SECTION C: EARTHWORKS. Fill materials shall be and spread simultaneously with the dumping in a manner to prevent any localized distress or failure of the ground.
- 4.4.2.6. No traffic shall travel directly on the non-woven geotextile and there shall be no sudden stops, starts or turns on the fill materials by the construction equipment or other such actions which may cause damage to the geotextile.
- 4.4.2.7. In water logged or swampy areas, the non-woven geotextiles shall be sunk after jointing by ballasting with sufficient sandbags. To control the location of the mattress, buoys shall be fixed with ropes on the edges of the non-woven geotextile or using other method as approved by the S.O. The mattress shall be ballasted as soon as possible after positioning.
- 4.4.2.8. The contractor shall submit a detailed method statement on installation of the non-woven geotextile to the S.O. for approval prior to commencing installation works.

4.4.3. Jointing of Geotextile

- 4.4.3.1. In general, the joints are allowed for both machine direction (MD) and cross direction (CD) of the non-woven or woven geotextile used in separation and filtration application. Jointing of reinforcement geosynthetics such as high strength woven geotextile, geogrid, etc. is only allowed in the CD for reinforced soil structures (reinforced soil wall/soil slope and mechanically stabilized embankment).

4.4.3.2. Methods of Jointing

- (i) There are two common methods to connect the geotextile, which are by overlapping or seaming. The decision to use an overlap or seam shall be based on the following: -
- a) The weakness of the foundation soil upon which the geotextile is directly placed with respect to the potential for mud waving during the backfill operation;
 - b) The material and labour costs of deploying individual geotextile panels with extra material required for the overlap versus the material and labour costs of seaming and installing large, fabricated panels; and
 - c) The feasibility of deploying individual geotextile panels in poor access and/or adverse climatic conditions.

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- (ii) **TABLE S3** provides a guide in determining overlap requirements for separation/stabilization applications based on subgrade strength. When the subgrade soils upon which the geotextile is directly placed provides shear strength less than CBR = 0.5, the adjacent geotextile panels shall be seamed.

4.4.3.3. Sewn Seams

- (i) The geotextile may be jointed using an approved handheld sewing machine by sewing a double thread 'lock stitch' with 'prayer' or 'J' or 'butterfly' seam (minimum lap of 50mm) as shown in **FIGURE S2**. Typically, polyester thread is used for seaming geotextiles. Minimum required density of stitches during sewing of the geotextile is 3 stitches per 25mm. The thread shall have a breaking load of not less than 200N.
- (ii) The expected seam strength shall be more than 70% of the original strength of the non-woven geotextile. For high strength woven geotextiles, the expected seam strength shall be more than 30% of the original strength. Samples of such sewn seam assembly shall be tested in accordance with latest revision of ISO 1032: or ASTM D4884 as requested by the S.O.

4.4.4. Non-Woven Geotextile

- 4.4.4.1. Non-woven geotextile described in this Specification shall be for separation and filtration application of the ground treatment.
- 4.4.4.2. Unless otherwise approved by the S.O., non-woven geotextile shall be needle punched fibres of polypropylene or polyester supplied by an approved manufacturer.
- 4.4.4.3. The physical, mechanical and hydraulic properties of non-woven geotextile shall meet the minimum requirement as given in **TABLE S4**. Minimum roll width shall be 4.0 metres.
- 4.4.4.4. In addition to requirement given in sub-section 4.3., the Contractor shall furnish test certificate from accredited laboratory that includes the following:
- (i) Wide width tensile strength
 - (ii) Elongation
 - (iii) CBR Puncture Resistance
 - (iv) Permeability
 - (v) Effective Opening Size, O_{90} or Apparent Opening Size, O_{95}

4.4.5. High Strength Woven Geotextile

- 4.4.5.1. High strength woven geotextile described in this Specification shall be for basal reinforcement application of the ground treatment.

- 4.4.5.2. Unless otherwise approved by the S.O., high strength woven geotextile shall comprise of woven yarns of high tenacity polyester filaments with properties that meet the requirement as given in **TABLE S5**. The edges of fabric shall be selvedge or otherwise finished in such a way to prevent the outer yarn from unravelling.
- 4.4.5.3. High strength woven geotextile shall be free of any flaws that may have an adverse effect on its physical and mechanical properties. Minimum roll width shall be 5.0 metres.

4.5. Geogrid

4.5.1. General

- 4.5.1.1. Unless otherwise specified elsewhere in the Specification or in the Drawings, geogrid for use as geotechnical reinforcement and in ground treatment shall conform to the requirements as specified herein.
- 4.5.1.2. Unless otherwise approved by the S.O., geogrid shall be made of high tenacity polyester coated with PVC that meets the requirements as given **TABLE S6**. The geogrid shall be formed from cross-laid strips (geo-linear elements) bonded at the cross-over points. The geo-linear elements shall consist of continuous high tenacity polyester fibres coated with PVC.
- 4.5.1.3. Bonding at the cross-over points shall be such that the properties as required by the Contract are not affected. The strength of the bond shall be such as to ensure the function of the geogrid is achieved.
- 4.5.1.4. The polyester fibres shall be:
- (i) Coated with PVC to completely prevent ingress of moisture;
 - (ii) All free ends shall be sealed to completely prevent ingress of moisture;
- 4.5.1.5. The weft (referring to CD) elements shall be the same quality material as the warp (referring to MD) elements.

4.5.2. Durability of Geogrid

- 4.5.2.1. Durability of the geogrid shall be such that a design life of 120 years is achieved. The geogrid shall not deteriorate from exposure to sunlight and due to chemical action or biodegradation when buried in wet soil.
- 4.5.2.2. Information relating to the durability of the geogrid shall be submitted as required by the S.O. for his approval.

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4.5.3. Method of Installation

4.5.3.1. Installation of geogrid shall be carried out by qualified and experienced workers under the supervision of a competent person. The geogrid shall be installed in compliance to manufacturer's instructions utilizing approved plants/equipment. The fill to the lines and levels shall be well-graded granular, dry cohesive soils or other engineered fill as shown on the Drawings.

4.5.3.2. All works related to earthwork shall be referred to SECTION C: EARTHWORKS.

4.5.3.3. Installation of Geogrid for Reinforced Slope

- (i) At each level of geogrid reinforcement, backfill shall be roughly levelled before placing the geogrid. Compaction shall be carried out to the requirements of the Specifications. During backfill placement, trucks and heavy vehicles shall be kept back at least 1.0 metre from the face of the Geogrid Reinforced Slope.
- (ii) The deposition, spreading, levelling and compaction of the fill shall be carried out generally in a direction parallel to the facing and shall be executed in stages to alternate with the placing and fixing of the reinforcing elements and the facing. The geogrid shall be laid whereby machine direction (MD) is in a direction perpendicular to the face of reinforced wall or slope. The overlapping width of adjacent panels of geogrid shall be minimum 150mm.
- (iii) Care shall be taken to ensure that the reinforcing elements and facing are not damaged or displaced during deposition, spreading, levelling and compaction of the fill. The program of filling shall be arranged so that no machines or vehicles run on the reinforcing elements.
- (iv) The fill within 1.0 metre of the face of the Geogrid Reinforced Slope shall be compacted using one of the following:
 - a) Vibro tamper
 - b) Vibrating plate compacter having a mass not exceeding 1000kg
 - c) Vibrating roller having a mass per metre width of not more than 1300kg and a total mass of not more than 1000kg
- (v) The rear of the Geogrid Reinforcing Slope shall be adequately supported either by temporary shoring or by phasing the work to ensure the contemporaneous deposition of the retained fill material.



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4.5.3.4. Protection of Completed Geogrid Reinforced Slopes from Erosion.

The Contractor, as specified in the Drawings or where instructed by the S.O., shall carry out adequate erosion protection measures such as vegetation, etc.

4.5.3.5. Drainage

The Contractor, as specified in the Drawings or where instructed by the S.O., shall carry out adequate water discharge method such as horizontal drain, cascade drain, etc. to ensure the drainage of impounding water on the slope and the surface runoff.

5. Prefabricated Vertical Drains (PVD)

5.1. General

- 5.1.1. This Specification covers the technical requirements for the supply and installation of Prefabricated Vertical Drains (PVD) as described herein. All materials used shall meet the requirements of this specification and all works shall be executed in accordance with the details shown on the Drawings and the procedures described herein.
- 5.1.2. The Contractor shall provide all necessary resources including materials, skilled workers, and plant/equipment to execute and complete the works related to supply and installation of PVD as shown on the Drawings.
- 5.1.3. All materials and workmanship shall be in accordance with the appropriate British Standards current at the time of tender, including those listed in this Specification, except where the requirements of British Standards conflict with this Specification, the latter shall take precedence unless otherwise approved by the S.O..
- 5.1.4. The Contractor shall be responsible for the true and proper setting-out of the areas to which the PVD is to be placed and for the correctness of the lines, widths and levels.

5.2. Soil Investigation Report

A soil investigation report shall be made available at the S.O.'s office for the Contractor's information. The report is intended solely as a preliminary guide and neither the completeness nor the accuracy of the information provided is guaranteed. No responsibility is assumed by the S.O. for any opinion or conclusion given in the soil report. The Contractor shall study the given soil report and make his own interpretation of the information provided and to make due allowance for the effect of Site conditions on his construction operations.

5.2.1. Pre-Treatment Soil Investigation

Cone Penetration Test (CPT) may be carried out to verify the thickness of sub-soil to be treated using PVD. CPT may be carried out if necessary. The CPT results shall be submitted to the S.O. for design verification purpose prior to the commencement of work.

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5.3. Transportation and Storage

- 5.3.1. The PVD materials shall be labelled or tagged for sample identification and other quality control purposes. Each pallet shall be identified by the manufacturer's name, lot number, individual roll number, roll length, date of manufacture or mill certificate, manufacturer and product identification of the jacket and core.
- 5.3.2. During transportation and storage, the PVD shall be wrapped in heavy paper, burlap or similar heavy-duty protection covering. The PVD shall be protected from sunlight, mud, dirt, dust, debris and other detrimental substances during transport and on-site storage.
- 5.3.3. The Contractor shall ensure that the PVD is in good condition and properly stored in a covered area at the worksite. If no covered area is available, the PVD may be stored on raised platform and covered with a waterproof canvas. In the event of damage or deterioration of the PVD due to improper storage, the Contractor shall be liable to replace the affected materials at his own cost.

5.4. Materials

5.4.1. Prefabricated Vertical Drains (PVD)

5.4.1.1. General Requirements

- (i) Prefabricated Vertical Drains (PVD) shall be from an approved manufacturer and consist of a polymer core enclosed within an external non-woven filter jacket and shall comply with the requirements as indicated in **TABLE S7**. The PVD shall be produced by factory with ISO 9001 certification. The manufacturing process as well as the relevant tests required shall be accredited. The filter jacket shall be capable of resisting all bending, puncturing and tensioning subjected during installation and design life of the drain.
- (ii) The core shall be made of continuous plastic material fabricated to facilitate drainage along the axis of the vertical drain.
- (iii) The prefabricated vertical drain shall be resistant against rotting, mildew, bacterial action, insect, salts, acids, alkalis, solvent and other constituents in ground water.

5.4.1.2. Quality Control and Testing

- (i) Submission of Material Test Report (MTR)
 - a) This section shall be in accordance with sub-section 4.
- (ii) Routine Sample Testing
 - a) This section shall be in accordance with sub-section 4.3.2.

- b) Prior to installation and at the discretion of the S.O., individual test sample shall be cut off from at least one (1) roll selected at random to represent each batch or the first 100,000 metres, whichever is lesser. Individual sample shall be not less than 15 metres in length. Samples submitted for tests shall indicate the linear metres of drain and manufacturer's identifications represented by the sample.

5.4.2. Geotextile

This section shall be in accordance with sub-section 4.4.

5.4.3. Drainage Blanket

This section shall be in accordance with sub-section 3.5.

5.5. Installation

Proper method statement for installation shall be prepared and submitted to the S.O. for approval before commencement of works. The method statement shall include the use of all necessary resources such as materials, manpower, machineries and equipments. Also, to include is the sequence of works with diagrammatical illustrations where necessary, workmanship requirements as well as the construction quality controls.

5.5.1. Procedure

The equipment used for the installation of the PVD shall have adequate capacity to install the PVD to the required depth at one go without the need for any withdrawal and re-insertion. The Contractor shall be responsible to ensure that the working platform is stable and safe without risks to workers and nearby buildings or structures.

5.5.2. Geotextile

The installation of geotextile section shall be carried out in accordance with sub-section 4.4.

5.5.3. Drainage Blanket

This section shall be in accordance with sub-section 3.5.

5.5.4. Prefabricated Vertical Drain (PVD)

5.5.4.1. Equipment

- (i) PVD shall be installed with approved equipment of a type which will cause minimum disturbance to the sub-soil during the installation and maintain the mandrel in a vertical position.
- (ii) PVD shall be inserted into the soil using a mandrel or sleeve. The mandrel or sleeve shall protect the drain material from tears, cuts and abrasion during installation and shall be retracted after each drain is installed.

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- (iii) The size and shape of the mandrel or sleeve shall be as close as possible to the size and shape of the drains to minimize disturbance to the soil. The length of the mandrel shall be not less than the maximum length of the drain. The mandrel shall be capable of making a clean puncture through any geotextile if necessary.
- (iv) The mandrel or sleeve shall be provided with an anchor plate or similar arrangement at the bottom to prevent the soil from entering the bottom of the mandrel during the installation of the drain and to anchor the drain tip at the required depth at the time of mandrel withdrawal.
- (v) The installation equipment of PVD shall come with a data log that shows the details of each PVD installed which includes, among others, the tag number and depth depending on what is required by the S.O.. The data log shall be converted into a file that is accessible and readable to the S.O..

5.5.4.2. Method Statement

- (i) This section shall be in accordance with sub-section 1.2.
- (ii) Approval by the S.O. of the method or equipment used to install the drains shall not constitute, necessarily, acceptance of the method for the remainder of the project. If, at any time, the S.O. considers that the method of installation does not produce satisfactory quality and productivity as expected, the Contractor shall alter his method and/or equipment as necessary to comply with these Specifications.

5.5.4.3. Setting Out

The intended positions of PVD shall be marked, numbered and pegged by the Contractor using a baseline and benchmark indicated by the S.O.. The Contractor shall take all reasonable precautions to preserve the pegs and is responsible for any necessary re-pegging.

5.5.4.4. Depth and Positioning

PVD shall be installed from the working surface to the depth shown on the Drawings, or to such depth as directed by the S.O.. The Contractor shall furnish to the S.O. on the next working day a summary of the PVD installed that day. The summary shall include the PVD type, location and length of PVD installed at each location.

5.5.4.5. Verticality

Equipment for installation PVD shall be plumbed prior to installing each PVD and shall not deviate from the vertical more than 1 in 50 during installing of any PVD.

5.5.4.6. Tolerances

The positions of installed PVD shall not vary by more than 150mm from the positions indicated in the Drawings. PVD installed which deviated more than 150mm from design plan positions or are damaged or improperly installed shall be rejected and abandoned in place and replaced accordingly.

5.5.4.7. Installation

- (i) PVD shall be installed using a continuous push using static weight or vibration. Installation techniques using driving will not be permitted.
- (ii) The installation shall be performed, without any damage to the PVD during advancement or retraction of the mandrel. In no case will alternate raising or lowering of the mandrel during advancement be permitted. Raising of the mandrel will only be permitted after completion of an installation.
- (iii) The completed PVD shall be cut off neatly 150mm above the working grade, or as otherwise specified in the contract Drawings.

5.5.4.8. Instrumentation Damage

The Contractor shall observe precautions necessary for protection of any field instrumentation devices. The Contractor shall replace, at his own expense, any instrumentation or equipment that has been damaged or become unreliable as a result of his operations prior to continuing with PVD installation or other construction activities.

5.5.4.9. Pre-Augering

- (i) The Contractor shall be responsible for penetrating overlying fill material as necessary to satisfactorily install the PVD. Satisfactory installation may require clearing obstructions defined as any man-made or natural object or strata that prevents the proper insertion of the mandrel and installation of the PVD.
- (ii) Where obstructions are encountered below the working surface which cannot be penetrated by the installation equipment, the Contractor shall complete the drain from the elevation of the working surface to the obstruction and notify the S.O. prior to installing any more PVD.
- (iii) At the direction of the S.O. and under his review, the Contractor shall attempt to install a new PVD within 600mm horizontally from the obstructed PVD. A maximum of two attempts shall be made as directed by the S.O.. If the PVD still cannot be installed to the design tip elevation, the PVD location shall be abandoned and the installation equipment shall be moved to the next location, or other action shall be taken as directed by the S.O..

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(iv) The Contractor may use augering, spudding, or other approved methods to loosen the soil and any obstructive material prior to the installation of PVD. The obstruction clearance procedure is subjected to the approval of the S.O.; however, such, approval shall not relieve the Contractor of his responsibility to clear obstructions in accordance with the specification.

(v) If augering is the selected method, the augers shall have a minimum outside diameter equal to the largest horizontal dimension of the mandrel, shoe or anchor, whichever is greater.

5.5.4.10. Splicing

Splicing of PVD material shall be done by stapling in a workmanlike manner and so as to ensure structural and hydraulic continuity of the drain. At the splice, the minimum overlap shall be 150mm and the lower portion of the jacket shall be external to the upper portion. A maximum of one splice per PVD installed will be permitted.

5.5.5. Pre-loading

This section shall be in accordance with sub-section 3.

5.6. As-Built Records

The Contractor shall submit to S.O. the daily installation record verified by S.O. representative, specialist Contractor and main Contractor on the next working day. The Contractor shall submit As-built PVD treatment area plan certified by a Licensed Surveyor within fourteen (14) working days of completion of the last PVD. The As-built Drawings and records shall include the as-built position and depth of each PVD point noting any deviation outside specified tolerances.

6. Stone Columns

6.1. General

The work shall consist of the supply of equipment, labour and materials for the execution of stone column works for ground improvement. The stone column described in this Specification shall be carried out by deep vibratory compaction incorporating stone columns formed with imported granular backfill complying with the requirements of the latest version of BS EN 14731. This section shall be also in accordance with sub-section 5.1.

6.2. Soil Investigation Report

This section shall be in accordance with sub-section 5.2.

6.2.1. Pre-Treatment Soil Investigation

This section shall be in accordance with sub-section 5.2.1.

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6.3. Method Statement for Construction Operations

This section shall be in accordance with sub-section 1.2.

6.4. Unexpected Ground Conditions

The Contractor shall report immediately to the S.O. any circumstances which, in the Contractor's opinion, indicate ground conditions that may differ from those expected by him from interpretation of the soil investigation report. The Contractor's report shall be in the form of written notice of which shall be given to the S.O. at the earliest possible time after encountering such conditions and obstructions. The report shall be accompanied by all information available to the Contractor which will materially assist the S.O. in verifying the conditions reported.

6.5. Adjacent Structures

6.5.1. The Contractor shall pay very careful attention to the construction constraints imposed by adjacent structures. The Contractor shall exercise extra care and implement adequate monitoring measures when carrying out the works so as not to disturb or damage the existing adjacent properties and foundations. The Contractor shall provide a proposal for monitoring adjacent properties for any detrimental effects arising out in execution of the works, so that appropriate and timely preventive action can be taken to minimise damage. The Contractor's proposal and monitoring program shall be certified by his Professional Engineer and approved by S.O..

6.5.2. The Contractor shall also carry out a condition survey of adjacent properties to establish the condition of the existing structures and facilities prior to commencement of work. Condition Survey shall be conducted by competent personnel and the result of the survey shall be submitted to the S.O. for record.

6.5.3. The Contractor shall be responsible for and shall bear the cost of such works and any claims of damage to adjacent structure and facilities arising from his execution of the works.

6.6. Existing Services

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

6.7. Workmanship

6.7.1. The Contractor shall satisfy the S.O. regarding the suitability, efficiency and adequacy of the equipment to be employed. The Contractor shall state the type and number of rigs he intends to use.

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- 6.7.2. On completion of each area of stone column the Contractor shall grade debris and surplus material arising from the stone column to leave a reasonable firm and level working surface. On completion of the stone columns to the satisfaction of the S.O., the Contractor shall remove from the Site all plant and unwanted material.
- 6.7.3. Installation of the stone columns shall be carried out by experienced Specialist Contractor approved by S.O.. The Specialist Contractor shall have the following experience and personnel: -
 - 6.7.3.1. The Specialist Contractor shall employ personnel experienced in the construction of stone columns for this part of the Works.
- 6.7.4. For both dry and wet methods, the depth vibrator shall be sufficiently powerful to ensure:
 - 6.7.4.1. The depth indicated in the Drawings may be reached; and
 - 6.7.4.2. Adequate compaction of the stones can be achieved
- 6.7.5. For the avoidance of doubt, any equipment other than a depth vibrator as specified in the latest version of BS EN 14731, is non-complying and precluded.

6.8. Setting Out

Setting out shall be carried out by the Contractor from grid lines provided and maintained by the Contractor. Immediately before installation, the column position shall be marked with suitable identifiable pins, pegs or markers at least 300mm length. The pins, pegs or markers should be driven to ground level and the location marked with contrasting material.

6.9. Materials

- 6.9.1. Material used for forming stone columns shall consist of hard and durable stone so as to remain stable during column construction and the working life of stone columns. The material may be natural or crushed stones or recycled material based on availability at Site, and shall conform to the following requirements:
 - 6.9.1.1. The Aggregate Crushing Value (ACV) shall be not more than 30% (tested in accordance with latest version of MS 30 or equivalent);
 - 6.9.1.2. The Flakiness Index shall be not more than 30% (tested in accordance with latest version of MS 30 or equivalent);
 - 6.9.1.3. The average loss of weight in the sodium sulphate soundness test (5 cycles), shall not be more than 10% (tested in accordance with AASHTO Test Method T104 or equivalent);
 - (i) The gradation shall comply with **TABLE S8** as appropriate.

The above tests shall be carried out on each of every source of material supplied to Site.

- 6.9.2. Material shall be used with a grading appropriate for compaction to form a dense column fully interlocking with surrounding ground. Material shall be compatible with the vibro plant used and flow freely within bottom and through feed delivery systems without arching, which may block these systems.
- 6.9.3. Material with particle size falling in the range of 20-40mm size (dry method) and 50-75mm size (wet method), its appropriate grading limit are as per **TABLE S8**. Quarry dust and other fine stone chippings shall be limited to not more than 5%. The material shall also be free of unsuitable material.
- 6.9.4. Prior to commencement of the works, the Specialist Contractor shall submit samples of the stone backfill from proposed source of supply to the S.O. for his approval.
- 6.9.5. Throughout the period of the works, when directed by the S.O., the Specialist Contractor shall be required to substantiate that the output from the approved sources of stone consistently conforms to the requirement of the Specifications and any conditions stipulated during the initial approval.

6.10. Stone Column Construction

- 6.10.1. The construction method may either be the wet or dry process. Generally, the wet process is suited for sites underlain by very soft to firm soils and a high ground water table. For dry process, it is suitable for soils with undrained shear strength of about 40-60kN/m² with relatively low ground water table. If the dry process is used it shall be demonstrated on Site that the hole made by the machine will remain open to enable the stone to be placed cleanly to the bottom of the hole to form a continuous column to the surface.
- 6.10.2. Working platforms shall be designed, prepared and maintained by the Contractor in a manner suitable for the safe movement and working of the vibro plant. Material used to provide working platforms shall be granular, suitable for the ground conditions on which it is placed and shall not prevent poker penetration. Minimum thickness of the working platforms shall be at least 1000mm to ensure that stone compaction is effectively carried out to the ground surface.
- 6.10.3. Site working levels for the stone column shall be maintained throughout the duration of the Works. Where near surface obstructions occur, they shall be broken out prior to the commencement of the vibro works and the resulting voids shall be filled with granular material that can be penetrated and compacted by the vibrating poker.
- 6.10.4. The stone column shall be formed to the working surface without inclusion of clay or other unsuitable material preventing intergranular contact between stone particles.

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- 6.10.5. When the dry top-feed process is being used, the vibrator may be removed completely from the hole to allow access for the stone. Where the dry bottom-feed process is used, the depth vibrator shall not be removed from the ground during column construction. When the wet process is being used, the vibrator shall be kept in the hole at all times in order to maintain stability of the sides and to ensure that the stone shall reach the required depth via the annular space around the vibrator.
- 6.10.6. The Contractor shall provide a supply of water if the wet process is selected. The Contractor shall indicate the rate of water supply required and be responsible for checking that this is available. The Contractor shall be responsible for supplying any extra storage tanks and pumping as required.
- 6.10.7. Any unnecessary excavation on the stone column construction shall be avoided. Where this is not possible, excavation of the constructed stone columns shall be carried out with prior approval from the S.O. and under his strict supervision to minimize the disturbance on the constructed stone columns. Compaction by rolling or tamping rammer shall be carried out before foundation construction.
- 6.10.8. The Contractor shall be responsible for disposal of effluent from the works and complying with the Environmental Law and Regulations. The Contractor shall provide countermeasures as required by the Environmental Management Plan (EMP) and maintain silt traps required. On completion of the stone column the Contractor shall remove all such equipment and backfill any pits.
- 6.10.9. In ground conditions where pre-boring is deemed necessary, it shall be carried out by a method and to a sequence agreed by the S.O.. Pre-boring shall be carried out immediately before, or as near as practicable, to stone column construction to mitigate any safety issues associated with open excavations and prevent unnecessary deterioration of the underlying ground, for example due to water ingress.
- 6.10.10. Verticality
- The maximum permitted deviation of the stone column from the vertical is 1 in 20.
- 6.10.11. Depth and Spacing
- The depth and spacing of the stone columns shall be as shown on the Drawings and neither the depth nor spacing shall be varied without the prior agreement of the S.O.. Any variations in depth of stone columns due to Site conditions not anticipated in the design shall be reported immediately to the S.O. who shall advise on any action to be taken.
- 6.10.12. Tolerances
- All stone columns shall be located to within 150mm of the plan positions shown on the stone column layout Drawing.

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6.11. Construction Records

- 6.11.1. The Contractor shall keep records each of the stone column carried out as required by the S.O. and shall submit two (2) signed copies of these records to the S.O. not later than at noon of the next working day after the stone column is completed. The duly signed records shall form part of the records for the works. Any unexpected conditions shall be noted in the records.
- 6.11.2. The Contractor shall ensure that the equipment to be used shall be instrumented with sensors and the data processed by a micro-processing unit to enable continuous monitoring and data capture of the following parameters during the construction of each stone column:
 - 6.11.2.1. The depth of vibrator and vibrator movements (depth of penetration); and
 - 6.11.2.2. Power consumption (compaction effort)
- 6.11.3. Data captured shall be continuously displayed on an LCD unit and graphical output (plots of depths versus time and power consumption) generated by an automated computerised recording device throughout the process of the stone column installation. This shall be done for each point and records shall be submitted to the S.O. by the next working day.
- 6.11.4. The records of each completed stone column shall contain but not limited to the following information where applicable: -
 - 6.11.4.1. Identification number and location of stone column point
 - 6.11.4.2. Date and time
 - 6.11.4.3. Method of treatment
 - 6.11.4.4. Equipment and personnel in-charge
 - 6.11.4.5. Depth of penetration
 - 6.11.4.6. Time required to reach maximum depth and withdrawal
 - 6.11.4.7. Vibrator power consumption during penetration and compaction
 - 6.11.4.8. Material consumption
- 6.11.5. Any observed ground heave or settlement during construction shall also be recorded and reported to the S.O..

6.12. Preliminary Stone Columns

Prior to commencement of actual stone column works, the Contractor shall carry out preliminary stone column as shown on the Drawings to establish the installation criteria for the subsequent stone column and for confirming the adequacy of the design, dimensions and working load through load test. The Contractor shall give at least three (3) days' notice of the commencement of construction of any preliminary stone column.

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6.13. Testing of Stone Column Works

6.13.1. To verify the design assumptions and working load, the Contractor shall carry out load test on stone column as shown on the Drawings or as instructed by S.O.. The testing procedures shall be submitted two (2) weeks before the commencement of load test for S.O. approval. Loading of a stone column shall not commence until seven (7) days have elapsed after completion of its installation.

6.13.2. Load testing for stone column can be carried using plate test or zone test as shown on the Drawings or as instructed by the S.O..

6.13.2.1. Plate test: A plate test is a loading test carried out using a plate on treated ground essentially used as a control of workmanship. It can be a single column plate load test or a group of four columns plate load test.

6.13.2.2. Zone test: A zone test is a loading test carried out over a large treated area, intended to test stone columns' performance over a wider and deeper zone than in the plate bearing test. A zone test is usually carried out by placing earth fill to simulate widespread loads, and the fill height will be determined to meet the required test pressures.

6.13.3. During the progress of a test, the testing equipment and all records of the test shall be available for inspection by the S.O..

6.13.4. Load Test Procedures

The plate load test shall be carried out in accordance with the latest version of MS 2038.

6.13.5. Submission of Results

6.13.5.1. Full test data and results shall be jointly signed in duplicate by the S.O.'s representative witnessing the test and the Contractor's authorized personnel immediately upon completion of the test. A copy of this records shall be kept by the S.O..

6.13.5.2. Within seven (7) days of the completion of the test, a complete test report inclusive of all necessary analysis shall be submitted to the S.O.. This shall be as specified below for a plate bearing test or a zone test as appropriate.

6.13.5.3. Information on Tested Ground from Plate Tests

(i) The Contractor shall provide information about the tested ground in accordance with the following schedule where applicable:

a) General

i. Contract identification

ii. Date of test

b) Test area Details

- i. Identification of area relative to Site layout Drawing
- ii. Brief description of position in structure
- iii. Ground level at test position
- iv. Excavated test level

c) Treatment Details

- i. Date and time of treatment
- ii. Unexpected circumstances or difficulties

d) Stone Columns

- i. Identification numbers of stone columns
- ii. Diameter and depth of stone columns exposed
- iii. Spacing of adjacent columns
- iv. Depth
- v. Stone consumption

e) Test Procedure

- i. Approximate weight of kentledge
- ii. Date and times of load application

f) Test Results

- i. Load and settlement with time reported in tabular form, and in graphical form, load and settlement being plotted against time, and load against settlement.

6.13.5.4. Information on Tested Ground from Zone Tests

The Contractor shall provide information about the tested ground in accordance with the following schedule where applicable:

(i) General

- a) Contract identification
- b) Date of tests

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(ii) Test Area Details

- a) Identification of area relative to Site layout Drawing
- b) Size and position of area
- c) Ground level at test position
- d) Excavated test level

(iii) Treatment Details

- a) Date and time of treatment
- b) Unexpected circumstances or difficulties
- c) Identification number of stone columns
- d) Depth of treatment
- e) Stone consumption

(iv) Test Details

- a) Plan showing position and extent of zone test fill in reference to the stone columns and instrumentation layout
- b) Method of load-measurement, if any (e.g. pressure cells, or earth fill field density tests)
- c) Fill height measurements versus time (e.g. rod settlement gauges)
- d) Dates and times of fill application, duration of instrumentation
- e) Other instrumentation measurements over time (e.g. inclinometers, settlement markers)

(v) Test Results

- a) Load and settlement with time reported in tabular form, and in graphical form, load and settlement being plotted against time, and load against settlement

6.13.5.5. Completion of a Test

Upon completion of a test, all temporary structures used in the testing (concrete slab or ground anchor etc.) shall be dismantled and removed from Site. The ground shall be made good to the original commencing surface level.

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6.14. As-Built Records

- 6.14.1. The Contractor shall submit an As-built stone column location plan certified by a Licensed Surveyor to the S.O. within fourteen (14) working days after the completion of the works. Partial as-built plan may be submitted throughout construction of the works for verification by the S.O..
- 6.14.2. The As-built Drawings shall include the following information:
 - 6.14.2.1. The stone column identification number and corresponding As-built depth of each point;
 - 6.14.2.2. Spatial coordinates of reference points delineating the treatment; and where stone columns positions were deviated on Site due to obstructions or other reasons with the knowledge of the S.O., the new position coordinates shall be included.

7. Deep Soil Mixing

7.1. General

The work shall consist of the supply of equipment, labour and materials for the execution of deep soil mixing (DSM) works. Deep soil mixing method shall comply to BS EN 14679. This section shall also be in accordance with sub-section 5.1.

7.2. Soil Investigation Report

This section shall be in accordance with sub-section 5.2.

7.2.1. Pre-Treatment Soil Investigations

- 7.2.1.1. This section shall be in accordance with sub-section 5.2.1.
- 7.2.1.2. The Contractor shall carry out chemical test to determine the types of chemical present in the soil for effective deep soil mixing. The Contractor shall provide Material Safety Data Sheet (MSDS) produced by the Manufacturer for the handling and storage of chemicals used. The use of chemicals shall be in accordance with JKR Standard Specification for Roadworks "SECTION 18: SOIL STABILISATION".

7.3. Method Statement for Construction Operations

This section shall be in accordance with sub-section 1.2. The method statement shall also include precautions against heave and settlement.

7.4. Unexpected Ground Conditions

This section shall be in accordance with sub-section 6.4.

7.5. Adjacent Structures

This section shall be in accordance with sub-section 6.5.

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7.6. Existing Services

This section shall be in accordance with sub-section 6.6.

7.7. Specialist Contractors and Personnel

DSM works shall be carried out by experienced Specialist Contractor approved by the S.O. The Specialist Contractor shall have the following experience and personnel:

- 7.7.1. Personnel experienced in the design, supervision and construction of DSM columns

7.8. Setting Out

This section shall be in accordance with sub-section 6.8.

7.9. Material

7.9.1. Binder

- 7.9.1.1. Cementitious binders to be used shall be an approved variant of Portland cement, complying with JKR Standard Specification for Building Works SECTION E: CONCRETING or as per BS EN 197-1. The cement shall be adequately protected from moisture and contamination in storage on the job site. Reclaimed cement containing lumps or deleterious matter shall not be used. Other binders shall be acceptable if the project requirements can be met with their use. Laboratory tests shall be required to verify the suitability and dosage of the other binder variants.

- 7.9.1.2. If other chemicals are proposed, the material shall be in accordance with JKR Standard Specification for Roadworks "SECTION 18: SOIL STABILISATION".

7.9.2. Water

Freshwater, free of an excessive amount of deleterious substances that adversely affect the properties of the binder shall be used. It is the responsibility of the Contractor that the grout resulting from the water shall always meet the requirements of this Specification.

7.9.3. Grout suspension

Grout suspension shall be prepared on site using binder(s) as described in sub-section 7.9.1. and other additives, wherever required, in water. The grout shall be pumpable and workable with the DSM injection equipment.

7.9.4. Additives

7.9.4.1. Admixtures may be used to enhance the workability or final properties of the treated soil. Conventional additives include bentonite, fly ash, lime, sodium silicate, a set retarder, alkali activator, etc.. Additives may be added to the water or the grout. Notwithstanding, the use of additives is subjected to the approval of the S.O..

7.9.4.2. The Contractor shall provide Material Safety Data Sheet (MSDS) produced by the Manufacturer on the use of chemical additives to ensure the safety of the material used. The Contractor shall be made liable for any discrepancies that occur during the application of chemical additives in the absence of MSDS.

7.9.5. Soil Mixing Material

Soil-mixing material, resulting from the in-site mixing of soil with grout suspension (mainly for a wet method of mixing), should have a compressive strength as specified in the drawing. The factor of safety concerning the maximum characteristic stress acting on a single column shall be not less than 2.0.

7.9.6. Steel Reinforcement

Steel reinforcement, if specified in the Drawings shall comply with SECTION E: CONCRETING, relevant specifications and Malaysian Standards.

7.10. DSM Column Installation

7.10.1. General

The Contractor shall satisfy the S.O. regarding the suitability, efficiency and adequacy of the equipment to be employed based on soil conditions and the requirements defined herein and in the design. The equipment chosen for the installation of works shall be in full compliance with the provision of the BS EN 14679.

7.10.2. Drilling Equipment

7.10.2.1. Deep soil mixing equipment shall be capable of rotating down to the required depth or stiff layer through the weak soil and withdrawing the mixing tool by simultaneous rotation and mixing of the binder with in-situ soil.

7.10.2.2. Deep soil mixing machine shall have a single or multiple shaft(s) with cutting/mixing blades at the lower end.

7.10.2.3. Deep soil mixing machine shall be able to operate at different rotation and withdrawal rates within the required range as in the design to complete the work and produce the required cement columns, and as required by BS EN 14679.

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7.10.2.4. The cutting/mixing blades shall have the minimum diameter as per design. The size of the mixing tool shall define the column diameter.

7.10.2.5. The mixing tools shall consist of a minimum of one nozzle for the binder delivery but shall be demonstrated that it is adequately sized to meet the binder dosage as required by design.

7.10.2.6. Real-time measuring and recording devices shall be provided throughout the mixing operation, to capture data e.g. column number, time, depth, pressure, feed rates, rotation speed, injection rate, injection volume, binder consumption, etc..

7.10.3. Binder Delivery Station

7.10.3.1. Dry Method

In the dry method, the deep soil mixing process shall be carried out by mixing the binder in powder form. The medium of transportation of binder is typically compressed air unless otherwise approved by the S.O.. Binder storage tank(s)/ silo(s) is generally on-board with the DSM machine or on a separate self-propelled chassis connected to the DSM machine.

7.10.3.2. Wet Method

In the wet method, the deep soil mixing process shall be carried out by mixing the binder in slurry form. The medium of transportation of binder usually is water unless otherwise approved. The binder is generally prepared at the separate mixing and holding tanks and pumping station shall be required to deliver the binder to the DSM machine. The mixing and pumping station shall be able to produce enough volume of slurry required and enable continuous supply and controlled delivery of slurry.

7.10.4. Working Platform Preparation

Working platforms shall be designed, prepared and maintained by the Contractor in a manner suitable for the safe movement and working of the deep soil mixing equipment. The material used to provide working platforms shall be suitable for the ground conditions on which it is placed and shall not be detrimental to the drilling operation. Site working levels for the treatment shall be provided and maintained by the Contractor throughout the deep soil mixing works.

7.10.5. Soil Mixing Work

7.10.5.1. Unless otherwise specified, pressure feed of the binder shall be terminated approximately 0.5m to 1.0m below the working platform. Satisfactory quality shall not be relied on in the design over a depth of 1.0m below the working level, i.e. within the working platform material. If the deep soil mixing operation is interrupted for any reason, re-mixing or repositioning may be required upon confirmation from the S.O. on Site.

7.10.5.2. The mixing tool rotation speed shall be adjusted to accommodate a constant rate of mixing as given in the design. The penetration/withdrawal rate of the mixing tool shall be maintained such that the proper amount of binder is added and the proper amount of mixing time is allowed as per design. Both the rotation speed for mixing tool and penetration/withdrawal rate can be adjusted according to drilling difficulty, upon confirmation from the S.O. on Site.

7.10.5.3. The injection rate per vertical metre of column shall be predefined by the Contractor. The injection rate shall be adjusted accordingly, if necessary, with the working parameters in the paragraph above herein, throughout the work to achieve the requirement for the DSM columns. The injection rate of the binder shall be measurable and monitored with the appropriate device as proposed by the Contractor.

7.10.5.4. After completion, the DSM columns shall be left undisturbed for at least fourteen (14) days. The area of DSM columns shall not be driven over with heavy equipment.

7.10.6. Obstruction

In the event of obstructions preventing the drilling and installation of DSM columns, the S.O. shall be informed immediately. Remedial options subject to approval from the S.O. shall include:

7.10.6.1. Reposition the column a short distance from the original position.

7.10.6.2. Additional DSM column(s) around the obstruction, if necessary.

7.10.6.3. Excavate, remove the obstruction, backfill and compact to the requirements of JKR Standard Specification for Building Works SECTION C: EARTHWORKS and reinstall the DSM column.

7.10.7. Verticality

The maximum permitted inclination of the DSM columns is 1 in 75.

7.10.8. Length, diameter and spacing

The length, diameter and spacing of the DSM columns shown on the Drawings shall be adjusted to suit site conditions when deemed necessary as instructed by the S.O..

7.10.9. Tolerances

The maximum permitted deviation of the centre of the DSM column from the centre point shown on the setting out drawing shall be 150mm in any direction.

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7.11. Construction Records

7.11.1. On the same day, a daily record shall be submitted to the S.O. summarizing the points done and depths of DSM column installed. Two (2) copies of signed records for each soil mixing element shall be submitted to the S.O. on the next working day.

7.11.2. The record shall include the following information, but not limited to: -

7.11.2.1. Column ID or reference number;

7.11.2.2. Depth of installation;

7.11.2.3. Column top and toe level;

7.11.2.4. Binder type and composition, injection rate and total injection volume;

7.11.2.5. Time for mixing during penetration and withdrawal;

7.11.2.6. Rotation of mixing tool versus depth and blade rotations by numbers;

7.11.2.7. Weather report;

7.11.2.8. Any other information as may be required by the S.O..

7.12. Preliminary DSM Column(s)

7.12.1. Before commencement of the DSM works, the Contractor shall carry out field trial as shown on the Drawings. A total number of minimum four (4) numbers of preliminary columns shall be constructed to verify the deep soil mixing methodology, suitability of the mixing tool and the design parameters. The quality of DSM columns shall conform to the design requirements and shall be verified using the appropriate testing method, e.g. by the mean of the load test. Loading on the DSM column shall not commence until fourteen (14) days have elapsed after completion of its installation.

7.12.2. Where excavation is possible, assessment of the geometric and mechanical characteristics of the DSM column should be made by visual inspection. Coring can be made on the completed columns. Unconfined Compressive Strength Testing (UCS) on samples recovered by coring or excavation can be made to verify the soil-mixing material compressive strength as specified in the design. At least one of the trial columns shall be sampled and UCS testing shall be carried out on three samples. The sampling and testing frequency may be varied based on project requirements or at the instruction of the S.O..

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7.13. Quality Control and Quality Assurance

7.13.1. Quality Control

- 7.13.1.1. Before the commencement of all works, procedures for verification, control and acceptance shall be established in the method statement with reference to the Drawings and Specification.
- 7.13.1.2. Blade rotation number of soil mixing shall be used as a guide to verify the consistency of mixing and forming homogenous columns. Minimum blade rotation number in cohesionless soils shall be at least 300, whereas for cohesive soils it shall not be less than 400. For peaty and organic soils, the blade rotation number shall be at least 600. These requirements shall be followed unless otherwise stated in the project requirement or instructed by the S.O..
- 7.13.1.3. The construction process shall be controlled and monitored automatically, with the aid of a computerised system. The construction parameters and information as detailed in **TABLE S9** shall be monitored continuously during execution.

7.13.2. Sampling

- 7.13.2.1. The sampling of soil mixing improved ground shall be done by conventional vertical coring. Double tube sampling shall also be acceptable provided the Contractor can demonstrate that good sample recovery can be obtained. Wet grab sampling shall also be permitted, and samples shall be prepared from wet grabs at the instruction of the S.O.. The S.O. shall also instruct at what depth the sampling needs to be taken. Sampling shall ensure that the recovery ratio is at least 80% or otherwise instructed by the S.O..
- 7.13.2.2. At least 1% of the installed columns shall be sampled by coring, double tube or wet grabbing, unless otherwise stated in the Drawings. Minimum three (3) samples from each sampled column shall be tested for UCS. The sampling and testing frequency may be varied based on project requirements or at the instruction of the S.O..

7.13.3. Unconfined Compression Test

- 7.13.3.1. Where necessary, the improvement from the treatment shall be tested by Unconfined Compression Test (UCT) of samples. The Unconfined Compressive Strength (UCS) of samples shall meet the requirements of the design, where the characteristic strength of samples shall be more than the project requirements.
- 7.13.3.2. UCT testing shall be done on cylindrical or cube samples having a minimum dimension of 50mm diameter. Corrections to readings and reporting of values shall be as per BS EN 12504-1.
- 7.13.3.3. Where required the S.O. may specify additional tests to determine other engineering properties of the improved ground.

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7.13.4. Load Test

This section shall be in accordance with sub-section 6.13.

7.13.5. Submission of Test Results

This section shall be in accordance with sub-section 6.13.5.

7.14. As-Built Drawings

7.14.1. The Contractor shall submit an As-built DSM columns location plan certified by a Licensed Surveyor to the S.O. within fourteen (14) working days after the completion of the works. Partial As-built plan may be submitted throughout construction of the works for verification by the S.O..

7.14.2. The As-built Drawings shall include the following information:

7.14.2.1. The DSM column identification number and corresponding as-built depth of each point;

7.14.2.2. Spatial coordinates of reference points delineating the treatment; and where DSM columns positions were deviated on Site due to obstructions or other reasons with the knowledge of the S.O., the new position coordinates shall be included.

8. Dynamic Compaction

8.1. General

The works shall consist of the supply of plant, equipment and specialist personnel for the execution of dynamic compaction (DC) works for ground improvement. This section shall also be in accordance with sub-section 5.1.

8.2. Specialist Contractor

DC works shall be carried out by experienced Specialist Contractor approved by the S.O.. The Specialist Contractor shall have the following experience and the personnel:

8.2.1. The Specialist Contractor shall employ competent and experienced geotechnical engineer who is capable of analyzing existing soil data, obtaining and interpreting additional data as required, performing field testing prior to, during and after DC works.

8.3. Soil Investigation Report

This section shall be in accordance with sub-section 5.2.

8.4. Method Statement for Construction Operations

This section shall be in accordance with sub-section 1.2.

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8.5. Unexpected Ground Conditions

This section shall be in accordance with sub-section 6.4.

8.6. Adjacent Structures

8.6.1. This section shall be in accordance with sub-section 6.5.

8.6.2. At locations where acceptable peak particle velocity or acceleration are likely to be exceeded, cut off trenches or other protective measure shall be taken. Contractor shall demonstrate to the satisfaction of the S.O., by trials, that his proposal will reduce the maximum peak particle velocity or acceleration to acceptable values.

8.7. Existing Services

This section shall be in accordance with sub-section 6.6.

8.8. Workmanship

8.8.1. Contractor shall satisfy the S.O. on the suitability and efficiency of the equipment to be employed.

8.8.2. The dynamic compaction (DC) works shall be performed by a qualified Contractor. The DC works shall be carried out up to the designed depth/compaction energy required to make sure the design criteria are achievable.

8.9. Setting Out

The Contractor shall perform setting out from the temporary bench mark (TBM) provided and shall be maintained by the Contractor. The approximate limits of work shall be shown in the DC shop Drawings and the exact limit shall be determined by the Contractor upon completion of the pre-treatment testing. DC points shall be marked with suitable and identifiable markers.

8.10. Working Platform

The working platform shall be prepared and maintained by the Contractor and suitable for safe movement and working for the DC plant and equipment. The working platform shall be made of granular material and at least 1000mm above the ground water level.

8.11. Spacing

The spacing of the DC point shall be shown in the construction Drawings. This shall be confirmed by field calibration or field trial conducted as approved by S.O..

8.12. DC Field Trial Area

The Contractor shall perform at least one DC field calibration or trial area prior to commencement of the full production DC works. Minimum trial area shall be 20m x 20m. The objective of the field trial is to determine the optimum compaction energy to be applied to the DC point and to confirm the technical data obtained is as per design.

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8.13. Site Records

The Contractor shall keep and submit to the S.O. the following records:

- 8.13.1. Number of blows for each DC point for each phase of DC works.
- 8.13.2. DC pounder free fall height for each blow for each phase of DC works.
- 8.13.3. Ground level before and after DC works.
- 8.13.4. Any other record as required by the S.O..

8.14. Testing

8.14.1. Pre-Treatment Testing

8.14.1.1. The Contractor shall undertake soil testing prior to commencement of DC works to provide data for the purpose of refining the preliminary design to comply with the acceptance criteria as specified. The field testing shall include the following:

- (ii) Pressure Metre Tests (PMT) shall be performed at every metre vertical interval and at changes in strata in accordance with the method outlined in ASTM D4719 or the latest version of BS EN ISO 22476-4.
- (iii) Cone Penetration Tests (CPT) shall be performed in accordance with ASTM D5778 or the latest version of BS EN ISO 22476-1.

8.14.1.2. The Contractor shall determine the total number of locations of pre-engineering tests necessary to analyse the soil conditions and to delineate the areas requiring DC works. Pre-engineering testing shall include the following as a minimum:

- (i) A minimum of one PMT for every 2000m² of area marked for improvement in the Drawing.
- (ii) A minimum of one CPT for every 2000m² of area marked for improvement in the Drawing.

8.14.1.3. The Contractor shall determine locations of any additional testing that may be required if conflicting test results are indicated by two adjacent tests or to delineate areas for ground improvement.

8.14.2. Final Acceptance Testing

8.14.2.1. The Contractor shall verify the ground improvements works for compliance with the acceptance criteria by in-situ tests of the improved soils and by analysis of the test results. The final testing shall be conducted at a minimum of one (1) week after completion of the ground improvement works.

8.14.2.2. The final tests shall generally be at the locations of the pre-engineering test locations and shall include the following field tests:

- (i) PMT shall be performed at every metre vertical interval and at changes in strata in accordance with the method outlined in ASTM D4719 or the latest version of BS EN ISO 22476-4.
- (ii) Cone Penetration Tests (CPT) shall be performed in accordance with ASTM D5778 or the latest version of BS EN ISO 22476-1.

8.14.2.3. Final testing shall include the following as a minimum:

- (i) A minimum of one PMT for every 2000m² of area marked for improvement in the Drawing.
- (ii) A minimum of one CPT for every 2000m² of area marked for improvement in the Drawing.

8.14.2.4. Areas in which the specified criteria are not met shall be reworked by the Contractor until the specified requirements are met. The S.O., at his/her discretion, may check the Contractor's test results by conducting additional and independent testing.

8.14.2.5. If necessary, correlation between the CPT results with PMT results can be conducted to obtain the limit pressure and pressure metre modulus required for the engineering calculations.

8.15. Documents Submission

8.15.1. The Contractor shall submit to S.O. documents regarding the DC works as follows:

- 8.15.1.1. Pre-treatment testing proposal – this document is a plan and schedule for pre-treatment testing and shall be submitted at least seven (7) days before the pre-treatment testing is scheduled to begin.
- 8.15.1.2. Pre-treatment testing report – this document shall be submitted not later than fourteen (14) days after completion of pre-treatment testing.
- 8.15.1.3. Interim progress report – this document stated the DC works operations, including pre-treatment testing, final acceptance testing, elevation measurements, quantities completed during month, cumulative quantities to date and a forecast of remaining work.

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8.15.1.4. Final technical report – this document shall be submitted at the completion of the DC works. The report shall contain graphical presentation of all parameters used by the Contractor to accomplish the acceptance criteria including all pre-treatment testing and final testing results together with As-built Drawings. The report shall be submitted in five (5) copies duly endorsed by a Professional Engineer.

9. Piled Embankment

9.1. General

- 9.1.1. The works shall consist of all labour, materials, tools, transportation, instrumentation, etc. necessary to construct piled embankment in accordance to the Drawing and SECTION D: FOUNDATION AND WORKS BELOW LOWEST FLOOR LEVEL.
- 9.1.2. The works shall cover the following:
 - 9.1.2.1. Mobilization and demobilization of all labour, plants, piling and drilling equipment on Site.
 - 9.1.2.2. Supply, handling, pitching and installation of piles to the pile lengths as specified in the Drawings.
 - 9.1.2.3. Lengthening of piles by jointing to detail.
 - 9.1.2.4. Strip pile to cut-off level and check pile eccentricity.
 - 9.1.2.5. Construct reinforced concrete slab as per the details in the Drawings.
 - 9.1.2.6. Carry out pile testing in accordance with SECTION D: FOUNDATION AND WORKS BELOW LOWEST FLOOR LEVEL on working piles as specified.

10. Geotechnical Instrumentation

10.1. General

- 10.1.1. Instrumentation shall be installed to measure horizontal and vertical displacement of the subsoil or structures supported by the subsoil and water pressures within the works and shall remain operational both during and after the construction period specified in the Contract.
- 10.1.2. The Contractor shall be responsible for and shall follow the instruction of the manufacturer and the requirements of this Specification in the installation, calibration and testing of all measuring instruments and equipment, which shall be carried out under the direct supervision of the S.O.. The Contractor shall inform the S.O. at least two (2) days prior to undertaking installation of the equipment. The Contractor shall make due allowances in his construction programme for any delays which may arise on account of the installation of the instruments.



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10.1.3. Protection and Maintenance of Instruments

The Contractor shall take all necessary precautions to protect the instruments and maintain the instruments in good working order after commissioning. For all instruments which project through and above the fill, special precautions shall be taken to provide protection from vehicles and plant including substantial and readily visible barriers at a radius of 750mm around each instrument. Heavy compaction equipment shall not approach within 1.0m of projecting instruments. Damaged instruments shall be replaced or repaired by the Contractor at his own expense within seven (7) days.

10.1.4. Stabilising Electronic Readout Devices

All electronic readout devices and transducers shall be shaded from direct sunlight during use. Probes which are used inside access tubes shall be placed inside the tube and allowed to come to a stable temperature for at least 10 minutes before use. Zero or starting values shall only be taken once temperature stabilization is complete. All readout units shall be calibrated at least once a year and the calibration certificates submitted to the S.O..

10.1.5. Personnel

10.1.5.1. The Contractor shall submit names and curricular vitae of personnel including Instrumentation Engineer and Instrumentation Technician to carry out the instrumentation and monitoring and a programme of their attendance for the approval of the S.O.. Deviation from the approved programme of attendance or the requirements given in this clause shall only be permitted with the approval of the S.O..

10.1.5.2. The Instrumentation Engineer shall be responsible for the overall planning, implementation and monitoring of the instruments. He shall be on Site throughout installation, commissioning and initial monitoring. He shall be on Site for the remaining monitoring on a basis to be agreed with the S.O..

10.1.5.3. All instrumentation and monitoring works shall be carried out by an experienced Instrumentation Technician. Instrument data obtained shall be verified by an Instrumentation Engineer.

10.1.6. Boreholes for Instruments

10.1.6.1. Boreholes for instruments may be drilled by any method provided that it results in a clean and stable hole of the required diameter to the correct depth. The method of forming boreholes, including the procedure for advancing casing, shall be submitted to the S.O. for approval before commencement of the works.

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10.1.6.2. Boreholes shall be cased to their full depth unless strata are sufficiently competent for the hole to stay open under dry condition. If boreholes are drilled using water as a flushing medium, clean water shall be used. Drilling mud or polymer additives shall only be used with the approval of the S.O.. In the case of installation of piezometers, drilling mud or polymer additives shall not be permitted.

10.1.6.3. During drilling care shall be taken to ensure that minimum material is lost from outside the casing. Surging of the casing shall not be allowed and flushing of drilling water outside the annulus of the casing shall be minimized.

10.1.7. Grouting of Boreholes

For all instruments placed in boreholes, grouting is required for part or the entire borehole during installation. The grout shall be a bentonite: cement mixture with sufficient water to achieve a pumpable mix. The proportions of the mix shall be such as to imitate as closely as possible the strength or consistency of the natural soils present. Unless otherwise stated in the Drawings, the Contractor shall propose the suitable bentonite: cement mixture to S.O.'s approval. Grout shall be pumped into boreholes using a tremie pipe.

10.1.8. Labelling and Marking of Instruments

All instruments shall be labelled with their reference numbers at the location where readings or measurements are taken. The labelling shall be permanent using a method or material to be agreed with the S.O..

10.1.9. Survey Equipment and Survey Reference Station

10.1.9.1. The Contractor shall be responsible for establishing survey reference station at locations selected by the S.O. to monitor settlement markers, settlement plates, displacement markers and other instruments deemed necessary.

10.1.9.2. All survey equipment used in conjunction with the monitoring of instrumentation, including measuring tapes, levels and total stations shall be maintained and calibrated as required by the manufacturers and good surveying practice.

10.1.9.3. The survey reference station provides a reference for levelling or horizontal measurement to other points. The location of the survey reference station, shall be agreed by the S.O.. The coordinates and elevation of the survey reference station shall be surveyed in and submitted to the S.O..

10.1.9.4. The survey reference station shall be established on undisturbed ground clear of the embankment. The survey reference station shall be located on stable ground not affected by the Works, preferably away from the construction activities. The survey reference station is to be located on structures free of settlement and lateral movement or as agreed by the S.O..

10.1.9.5. The survey reference station may comprise of a steel rod of 20mm diameter, which shall be driven vertically into the undisturbed ground for a minimum distance of 1.0m and shall project approximately 75mm above ground surface. The rod shall be surrounded by not less than 0.03m³ of concrete at surface level, and the top of the rod shall be carefully centre-punched.

10.1.9.6. The survey reference station shall be checked at intervals to be established by the S.O. to ensure that it is stable during the course of the monitoring works.

10.1.10. Deep Levelling Datum

10.1.10.1.A deep datum is required to provide a reference for measurement of ground levels in areas of soft ground.

10.1.10.2.The Contractor shall propose the location and depth of the deep levelling datum for the approval of the S.O.

10.1.10.3.The datum itself shall be fixed into hard ground with Standard Penetration Test (SPT) value more than 50 or rock and isolated from soft and compressible overlying strata. If the SPT value of more than 50 is not achievable at great depths, the Contractor and the S.O. shall mutually agree on the termination depth.

10.1.10.4.A deep levelling datum shall consist of a 25mm galvanized iron (GI) pipe fixed into hard ground with cement grout. The datum pipe shall be isolated from the overlying soft ground by a 75mm GI pipe bedded into the top of the cement grout. The upper part of the 75mm pipe shall be surrounded by a square concrete plinth of not less than 0.03m³ of concrete. The details of the deep levelling datum including its protective measures are as shown on the Drawings. The concrete shall be scored with the reference number of the datum.

10.1.10.5.The level of a deep levelling datum shall be established by standard levelling techniques from agreed benchmark in the vicinity. Levelling shall be closed back to the benchmarks to check for accuracy. The level shall be measured three times soon after installation of the datum and shall be checked at intervals to be agreed by the S.O..

10.1.11. Instrumentation Equipment References

Details of equipment shall be submitted to the S.O. for approval. If the S.O. considers it necessary, demonstrations shall be arranged by the Contractor. Any supplier of geotechnical instrumentation shall demonstrate that the manufacturer operates an adequate system of product quality assurance.

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10.2. Displacement Marker/Settlement Marker

- 10.2.1. Displacement marker/Settlement marker is required to monitor the horizontal and vertical movement of the ground or embankment surface. The Contractor shall be responsible for establishing settlement markers at locations as shown in the Drawing or as determined by the S.O..
- 10.2.2. The marker shall comprise of a steel rod of minimum 20mm diameter which shall be driven vertically into the embankment or undisturbed ground for a minimum depth of 1.0m and shall project approximately 75mm above the ground surface. The rod shall be surrounded by not less than 0.03m³ of concrete at ground level, and the top shall be domed and centre-punched. The details of the installation are shown on the Drawings. The concrete shall be scored with the reference number of the marker.
- 10.2.3. For the settlement markers, the level of the top of the rod shall be measured using standard precise levelling techniques, referencing and closing back to the survey reference station with instrument to a minimum of +1mm accuracy.
- 10.2.4. For the displacement marker, the lateral movement shall be measured using a total station or other survey techniques agreed by the S.O..

10.3. Building Settlement Marker

- 10.3.1. Vertical deformation of adjacent structures shall be determined by means of precision devices to an accuracy of +1.0mm. The Contractor shall install building settlement points at location as specified by the S.O..
- 10.3.2. The precise levels shall have robust tripods. Levelling studs are to be provided for the purpose of precise levelling. Levelling studs shall be: -
 - 10.3.2.1. Manufactured from stainless steel.
 - 10.3.2.2. Fixed to the building lining in the same manner and standard.
 - 10.3.2.3. Designed such that their use in conjunction with the appropriate precise instruments allow precision levelling to an accuracy of +1.0mm. Designed such that the heads of the levelling studs on the walls can be easily levelled without the studs being vulnerable to damage.
 - 10.3.2.4. Designed such that the studs are safe from any hazards and to human life.

10.4. Rod Settlement Gauge

- 10.4.1. Rod settlement gauge is required to measure settlement beneath the embankment. The Contractor shall provide and install rod settlement gauge at location and level as shown on the Drawings or as specified by the S.O..

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- 10.4.2. The details of the rod settlement gauge shall be as shown on the Drawings and the Contractor shall be responsible for the installation of all the gauges as work proceeds. The base plate and first length of the rod shall be placed as early as possible during earthworks, preferably before any significant filling has been placed. Extension lengths shall be installed when the level of compacted embankment is 250mm below the top of the preceding lengths.
- 10.4.3. Should a rod settlement gauge be damaged, or should the Contractor fail to extend the gauge when required, the Contractor shall stop all filling activities in the vicinity of the gauge until the necessary remedial works have been carried out. The Contractor shall be liable for any delay in his programme, or any additional works that need to be done as result of such damage.
- 10.4.4. Should any rod settlement gauge be damaged in such a way as to make it useless for its purpose and unable for S.O. to assess the settlement, the Contractor shall engage a third-party specialist at his own cost to assess the settlement for measurement purposes and shall be agreeable and approved by S.O. as the final decision.
- 10.4.5. Rod settlement plates shall be monitored by standard precise levelling techniques, referencing and closing back to the survey reference station with instrument to a minimum of +1mm accuracy. Levels shall be taken at the top of rod itself and the fill adjacent to the gauge on each occasion. When rods are extended, levels shall be measured immediately before and immediately after adding the extension.

10.5. Inclinator

- 10.5.1. Inclinator provides a method of measuring a continuous profile of horizontal deflection both at the surface of and within a mass of soil. The Contractor shall install Inclinator at locations and depths as specified by the S.O.. The details of the Inclinator shall be as shown on the Drawings.
- 10.5.2. Inclinator access tube shall consist of broached polyvinyl chloride (PVC) tubing with four keyways set at right angles to each other and with couplings and end caps where necessary. The S.O. may instruct the Contractor to obtain spiral metric measurements of the keyways in the inclinometer tubing after installation. After that, assembly joints and rivets shall be wrapped in sealing tape. The tube shall be coated with thick grease over its upper part when it passes through compressible subsoils.
- 10.5.3. The assembled tube shall be lowered into borehole backfilled with a suitable bentonite: cement grout mix. Alternatively, the tube may be placed in an open borehole and grout placed afterwards. In granular material, the backfill may be sand or pea gravel. The keyways shall be orientated such that movements are measured parallel to and at right angles to the embankment axis.
- 10.5.4. Angular movements shall be measured by an inclinometer probe (torpedo) which shall be a biaxial type and the system shall be capable of measuring lateral deformation to an accuracy of $\pm 6\text{mm}$ over a depth of 25m.

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10.5.5. The inclinometer data logger unit shall display the readings from the inclinometer torpedo on an alphanumeric display. The following facilities are also, required within the readout unit:

10.5.5.1. Scan stored data.

10.5.5.2. Display of face errors as readings are being obtained.

10.5.5.3. Display of mean deviation and cumulative deviation of anyone set of readings.

10.5.5.4. Backlit LCD display.

10.5.6. The readings shall be read at every 0.5m and stored in the data logger.

10.5.7. The level of the top of the access tube shall be measured by standard precise levelling techniques as and when necessary.

10.6. Horizontal Inclinometer

10.6.1. The horizontal inclinometer provides a method of measuring vertical displacement beneath an embankment. Readings are taken at regular intervals across the entire width of the embankment. The Contractor shall install the horizontal inclinometer across the full width of the embankment at locations and with details as shown on the Drawings.

10.6.2. The horizontal inclinometer shall be installed before earthworks commence as shown on the Drawings and shall consist of 70mm or 85mm inclinometer casing installed in a trench. The trench shall be filled with sand or the excavated material provided it is suitable fill and stone free, and approval is given by the S.O.. Each end of the inclinometer casing shall have an end cap and shall have an eye for retention of the instrument draw cord. Each end of the inclinometer casing shall also pass freely through a plastic protective cover set into a concrete pad. The concrete pads shall have minimum dimensions of 1.5m x 1.5m x 0.3m. They shall be located beyond the influence of the area causing settlement. At each concrete pad, a survey pin shall be cast into the concrete.

10.6.3. Sufficient inclinometer casing shall be installed to accommodate large relative movement of the ground.

10.6.4. The horizontal inclinometer readout unit shall have a resolution of $\pm 0.02\text{mm}$ or better and a sensor accuracy of $\pm 0.1\text{mm}$ or better.

10.6.5. Immediately before taking a set of readings, levels shall be taken of the two survey pins set into the concrete pads.

10.7. Hydrostatic Profile Gauges

10.7.1. The hydrostatic profile gauge provides a method of measuring vertical displacement beneath an embankment. Readings are taken at regular intervals across the full width of the embankment and provide a continuous profile of settlement. The Contractor shall install hydrostatic profile gauges at locations and with details as shown on the Drawings.

- 10.7.2. The hydrostatic profile gauge shall be installed before earthwork commences as shown in the Drawings and shall consist of semi rigid or high-density polyethylene (HDPE) profile tube with minimum outer diameter of 50mm installed in a trench. The trench shall be filled with sand or the excavated material provided it is suitable fill and stone-free, and approval is given by the S.O.. Each end of the access tube shall pass freely through a protective cover fabricated in plastic complete with solid PVC taper-threaded plug. The plug shall have an eye for retention of the instrument drawcord.
- 10.7.3. Each protective cover shall be set into a concrete pad. If the expected settlement is large such that the protective cover may not be long enough to accommodate the relative movement of the access tube, then the protective cover shall be extended using a suitable piece of plastic pipe. The concrete pads shall have minimum dimensions of 1.5m x 1.5m x 0.3m at both ends of the HDPE tube. The concrete pads shall be located beyond the influence of the located area causing settlement. A survey pin shall be cast into each of the concrete pad. Both ends of the access tube shall be covered with a suitable end cap at all times.
- 10.7.4. The readout device system shall be capable of measuring elevation with reference to the survey pin to an accuracy of $\pm 1.0\text{mm}$. Immediately before taking a set of readings with the hydrostatic profile gauge, levels shall be measured of the two survey pins set into the concrete pads.

10.8. Magnetic Extensometer

- 10.8.1. Magnetic extensometer provides a method of measuring settlement at a point or a series of points below the ground surface. The Contractor shall install magnetic extensometer at locations and as specified by the S.O.. The details of the magnetic extensometer shall be as shown on the Drawings.
- 10.8.2. The magnetic extensometer shall consist of an access tube and a series of magnetic targets which are free to slide down the tube, together with a datum magnet which is fixed to the tube near its base. The access tube shall be a rigid PVC tube with minimum 33mm outer diameter and 24mm inner diameter. External coupling shall be used to connect the access tube and this compression/extension coupling shall allow axial movement of access tubes to minimize distortion due to vertical strain. A rigid PVC endcap shall be fixed to the lower end of the series of tubes.
- 10.8.3. A datum ring magnet shall be fixed approximately 1m above the lower end of the tube. Spider magnets shall be used within the subsoil and plate magnets within fill.
- 10.8.4. The tubes and spider magnets shall be assembled prior to installation in such a way that the magnets remain in the correct position in relation to the tube.
- 10.8.5. It shall then be lowered together with all magnets and necessary accessories fixed in position into a 100mm diameter borehole backfilled with a suitable bentonite: cement grout mix. Once in position the spider magnets shall be released.

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10.8.6. Where the access tube passes through fill which is being placed, the access tube and outer sleeve shall be extended as filling progresses. The top of the access tube, and the larger diameter sleeve where present, shall be protected with a suitable cover.

10.8.7. Magnetic extensometer shall be monitored by passing the probe down to the base of the access tube. The probe shall then be pulled upwards measuring the position of each magnet from the top of the tube. The position of each magnet shall be measured, once with the probe moving upwards from the base. Immediately before or after taking a series of readings, the level of the top of the access tube shall be measured by standard levelling techniques.

10.9. Combined Magnetic Extensometer and Inclinerometers

10.9.1. Combined magnetic extensometer and inclinometer provide a method of measuring both vertical settlement and horizontal displacement at a series of points below the ground surface. The Contractor shall install combined magnetic extensometer and inclinometer at locations, and with depths and details as specified by the S.O or as shown on the Drawings or as specified by the S.O..

10.9.2. The specification for magnetic extensometer shall be referred to sub-section 10.8. and the specification for Inclinerometer shall be referred to sub-section 10.5.

10.9.3. The magnets shall be positioned in relation to sleeved joints such that they can move downwards without obstruction sufficiently to monitor the expected settlement.

10.9.4. The borehole shall be 150mm diameter.

10.10. Standpipe

10.10.1. Standpipe provides a method of monitoring the water table or ground water level. The Contractor shall install standpipe at locations and with depths and details as specified in the Drawings or to the approval of the S.O..

10.10.2. The standpipe shall be slotted unplasticised polyvinyl chloride (uPVC) tubing of nominal size 50mm diameter. The perforated part shall be wrapped with filter fabric as indicated in the Drawings.

10.10.3. The uPVC tubing shall be installed in not less than 3m lengths, except for one shorter length as required to suit the total standpipe dimensions. The concrete upper end of the tube shall be set in concrete.

10.10.4. The standpipe shall be placed in a 100mm diameter borehole backfilled with a graded filter sand (600 to 1200microns) to the depth indicated. The top of the hole shall be sealed with bentonite pellets, and with a concrete plug. A protective cover shall be set into the concrete with caps and air vents.

10.10.5. Depth to water in the standpipe shall be measured using a dipmeter.

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10.11. Piezometers

10.11.1. Standpipe Piezometers

10.11.1.1. Standpipe piezometers give a measurement of piezometric level at a specific depth within a soil profile. They are generally used in soils of medium to high permeability. The Contractor shall install standpipe piezometer at locations, and with depth and details as shown on the Drawings or as directed by the S.O..

10.11.1.2. Standpipe piezometer shall be installed in boreholes at locations as shown on the Drawings or as instructed by the S.O.. The piezometer tip shall consist of a porous ceramic, plastic element or other suitable element not less than 150 mm long with minimum diameter of 25mm and shall be protected at each end by uPVC fittings. The filter element shall have a pore diameter of not more than 60 microns and a permeability of not higher than 3×10^{-4} m/s. The tubes shall be jointed together and to the porous element with threaded coupling or other approved coupling, tape and glue in such a manner that the joints remain leak proof under the anticipated head of water.

10.11.1.3. The standpipe piezometer shall be installed in a borehole of minimum 76mm diameter. The sand filter surrounding the porous element shall be clean and fall wholly between the limits of grading 600 and 1200 microns. The Contractor shall ensure that no sand adheres to the soil in the sides of the borehole. Where there is water in the borehole the Contractor shall allow sufficient time for all sand to settle. The final level of the top of this sand shall be recorded. The porous element shall be placed in the hole and the remaining sand filter shall then be added as described above.

10.11.1.4. Seals consisting of bentonite pellets shall be placed above, and if necessary, below a sand filter. The remainder of the hole shall be filled with a bentonite: cement grout, and the top part with concrete with caps and air vents as indicated in the Drawings. Before taking initial readings, the Contractor shall carry out simple falling head test by raising the water level 1.5m above the static level, using an extension pipe if necessary.

10.11.1.5. The depth to water in the standpipe piezometer shall be measured using a dip metre.

10.11.2. Pneumatic Piezometers

10.11.2.1. Pneumatic piezometer is used to measure pore water pressures at specific depths within a soil profile. They can be used in a wide variety of soil types. The Contractor shall install pneumatic piezometers at locations, and with depths and details as shown on the Drawings or as directed by the S.O..

- 10.11.2.2. Pneumatic piezometer tips shall be of high air entry ceramic type with an average pore diameter of 1 micron using stainless steel. The piezometer system shall be capable of measuring water pressures to an accuracy of 0.2m head of water in the range 0-35m head of water.
- 10.11.2.3. The piezometers shall be connected to twin tubing with suitable brass couplings. Joints in the tubing other than at the piezometer tip or at the terminal point shall not be permitted. The tubing shall be connected either to suitable quick release couplings or a terminal point which shall be protected at all times. Where tubing is laid in trenches the backfill shall either be sand or excavated material provided it is suitable fill and stone-free. The tubing shall be laid with sufficient slack to take up any lateral movements that are expected to occur due to settlement of embankments or structures.
- 10.11.2.4. Before installation and taking initial readings, the Contractor shall conduct a pressure test on the pneumatic piezometer tip in a container of water after connection to the tubing to check for leaks or poor connections. The ceramic element shall be workable under vacuum and precautions shall be taken to ensure that it remains saturated during installation. During installation, readings shall be taken when the piezometer tip is lowered down the borehole, when it is pushed in or placed in the sand pocket and at various times after installation to check the response of the piezometer and help find the static pressure value before the initial base readings are taken.
- 10.11.2.5. Readings shall be taken by and stored on the readout device. Care shall be taken to ensure that the flow and return leads are connected correctly.
- 10.11.3. Vibrating Wire Piezometer (VWP)
- 10.11.3.1. The Vibrating Wire Piezometer is used to measure water pressure at specific depths in variety of soil types. The Contractor shall install vibrating wire piezometer at location, and with depths and details as specified by the S.O.. Prior to the installation of the VWP, the Contractor shall submit all required technical specifications, including a calibration certificate for S.O.'s approval.
- 10.11.3.2. VWP is used to monitor pore water pressures in soils. The VWP converts water pressure signal via components of VWP, include a porous tip containing a pressure-sensitive diaphragm; a pre-tensioned steel wire; and an electro-magnetic coil, one end of which is connected to the diaphragm, and the other to the body of the piezometer.
- 10.11.3.3. The VWP tip shall be of high air entry ceramic type with an average pore diameter of 50 micron using a stainless-steel body. The piezometer system shall have a pressure range with an accuracy of 0.1% of full scale.

10.11.3.4. The cable shall be laid with sufficient slack to take up any lateral movements that are expected to occur due to settlement of embankments or structures.

10.11.3.5. During installation, readings shall be taken when the piezometer tip is lowered down the borehole, when it is pushed in or placed in the sand pocket and at various times after installation to check the response of the piezometer and help find the static pressure value before the initial base readings are taken.

10.11.3.6. Readings shall be taken by connecting the signal cable to the readout unit and the data shall be stored in the readout unit.

10.11.4. Installation of Piezometer (All Types)

10.11.4.1. The piezometer shall be installed in a borehole of not less than 76mm diameter. The drilling medium shall be water and extra care and attention shall be given during boring to ensure that the borehole is as vertical as possible to the required depth. Steel casing shall be used to prevent the collapse of the borehole. The borehole shall be flushed clean with water prior to installation.

10.11.4.2. Before installation the piezometer element shall be immersed in de-aired water for at least 24 hours to saturate the element. De-aired water shall be prepared by boiling and subsequently allowing the water to cool before use.

10.11.4.3. The piezometer tip shall be installed in a borehole backfilled with graded sand filter to the depth indicated. The sand filter surround to the porous element shall be clean and fall wholly between the limits of grading 600 and 1200 microns. The Contractor shall ensure that no sand adheres to the soil in the sides of the borehole. The Contractor shall allow sufficient time for all sand to settle. The final level of the top of the sand shall be recorded. The porous element shall be placed in the hole and the remaining sand filter shall then be added as described above.

10.11.4.4. Seals consisting of bentonite pellets shall be placed above, and if necessary, below the sand filter. The remainder of the hole shall be filled with a bentonite: cement grout, and the top part with a concrete plug. The bentonite: cement grout mix shall be designed to mimic the surrounding soil or as shown on the Drawings. A protective cover shall be set into the concrete with caps and air vents as indicated in the Drawings.

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10.12. Commissioning and Base Readings

- 10.12.1. After installation the functioning of each instrument shall be demonstrated to the S.O. including the recording of measured values using the appropriate readout device. As part of the commissioning three (3) sets of readings shall be taken and compared. These three (3) sets of readings shall be taken immediately after installation of the instruments. If there are significant differences or anomalies, further readings shall be taken. Once three (3) sets of comparable readings have been taken, these shall be averaged to form the base readings.
- 10.12.2. In cases where instruments are installed during earthworks, three (3) sets of readings shall be taken in quick succession and the results compared. These results shall be used to provide base readings in a manner to be agreed with the S.O..

10.13. Readings

- 10.13.1. The measured values shall be recorded on a record sheet. For readings that are recorded on data loggers, a record sheet shall be required giving references to the data stored. The format of plotted results shall be submitted to the S.O. for approval. Details of information and values to be stored on each record sheet in addition to the general information required but not limited to the details in **TABLE S10**.
- 10.13.2. The Contractor shall submit to the S.O. the specified number of copies of each record sheet with necessary raw data within one working day of taking the readings.
- 10.13.3. If any anomalous readings are detected and verified to be correct, the S.O. shall be informed immediately.
- 10.13.4. Frequency of Readings

Each instrument shall be read immediately before and after each change in loading (i.e. each layer of embankment or structural fill, etc.) unless otherwise shown on the Drawings or as directed by the S.O.. Any instruments found to be faulty shall be promptly brought to the S.O.'s attention so that remedial measures can be implemented.

10.13.5. Anomalous Readings

Whenever sets of data are measured, they shall be compared to previous sets of data. If anomalous readings are present which differ from the expected values or trends, then further readings shall be taken immediately and the S.O. shall be informed. If the anomalous values persist, then the S.O. shall be informed and an investigation shall be carried out to find the reason(s) for the anomalous readings.

10.14. Report

10.14.1. General Information on All Records

All records of instrumentation including installation, readings or monthly summaries, shall contain the following information:

- (i) Project name

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- (ii) Contract name and number
- (iii) Instrument reference number and type
- (iv) Dates and times of installation and completion,
- (v) Summary of reading
- (vi) Chainage and offset / coordinates in WGS 84
- (vii) Personnel names, roles and responsibilities
- (viii) Relevant comments or remarks

10.14.2. Installation Records and Reports

The Contractor shall prepare an installation record sheet for each instrument to be installed and submit to the S.O. for approval at least two (2) weeks before installation commences.

10.14.3. Monthly Monitoring Reports

10.14.3.1. A sample of the format of the report shall be submitted to the S.O. including all graphical presentations for approval at least 1 month before submission of the first monthly report unless specified by S.O.. Each monthly report shall include:

- (i) A description/scope of monitoring works
- (ii) Information on reading anomalies or corrections, if any, and factors which may influence measured data
- (iii) Observations or remarks
- (iv) A Drawing showing installed locations of instrumentation
- (v) Data tabulations or plots of instrument readings include but not limited to the details in **TABLE S11**.

10.14.3.2. The Contractor shall submit four (4) sets of report (hardcopy and softcopy) verified by geotechnical specialists and endorsed by PEPC within seven (7) days after the end of each calendar month of monitoring.

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TABLE S1: SAMPLING FREQUENCY AND TESTING REQUIREMENTS FOR GEOTEXTILE

Area of Geotextile (m ²)	Number of Rolls to be Sampled Representing the Area of Geotextile	Testing by the Contractor	
		Non-Woven Geotextile	High Strength Woven Geotextile
Initial 10,000 or part thereof	1	Tensile strength, Elongation, CBR puncture, Permeability, Effective Opening Size (O ₉₀) or Apparent Opening Size (O ₉₅)	Tensile strength, Elongation
Each subsequent 100,000 or part thereof	1		

TABLE S2: SAMPLING FREQUENCY AND TESTING REQUIREMENTS FOR GEOGRID

Area of Geogrid (m ²)	Number of Rolls to be Sampled Representing the Area of Geogrid	Testing by the Contractor
		Geogrid
Initial 10,000 or part thereof	1	Tensile strength, Elongation
Each subsequent 100,000 or part thereof	1	

TABLE S3: GUIDELINES FOR GEOTEXTILE OVERLAP REQUIREMENTS AS A FUNCTION OF (FOUNDATION SOIL) STRENGTH

Soil CBR	Minimum Overlaps
>3	0.3 – 0.45 metre
1 – 3	0.6 – 1 metre
0.5 – 1	1 metre or sewn
< 0.5	sewn

(Source: AASHTO M288-06,2007)

TABLE S4: PROPERTIES OF NON-WOVEN GEOTEXTILE

Item	Properties	Test Standard	Unit	Types of Non-Woven (NW) Geotextile					
				NW 9	NW 13	NW 15	NW 19	NW 21	NW 24
1.	Wide width tensile strength	ISO 10319 or ASTM D4595	kN/m	≥ 9	≥ 13	≥ 15	≥ 19	≥ 21	≥ 24
2.	Wide width elongation at break	ISO 10319 or ASTM D4595	%	≥ 35					
3.	CBR puncture resistance	ISO 12236 or ASTM D6241	N	≥ 1500	≥ 2100	≥2350	≥ 2850	≥3400	≥ 3850
4.	Cone drop	ISO 13433	mm	≤ 40	≤ 25	≤22	≤ 20	≤20	≤ 15
5.	Permeability at 50mm head	ISO 11058 or ASTM D4491	l/m ² /s	≥ 90	≥ 70	≥65	≥ 55	≥50	≥ 45
6.	Effective opening size, O ₉₀ ,	ISO 12956	μm	≤ 120	≤ 100	-	≤ 90	-	≤ 90
	or								
	Apparent Opening Size, O ₉₅	ASTM D4751	μm	≤ 270	≤ 240	≤210	≤ 190	≤180	≤ 180
7.	UV resistance	EN 12224	% retained after 430 hours	≥ 70					
		or							
		ASTM D4355	% retained after 500 hours						

Note:

ISO 10319: Geosynthetics — Wide-width tensile test

ASTM D4595: Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method

ASTM D4751: Standard Test Methods for Determining Apparent Opening Size of a Geotextile

ASTM D4491: Standard Test Methods for Water Permeability of Geotextiles by Permittivity

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TABLE S5: PROPERTIES OF HIGH STRENGTH WOVEN GEOTEXTILE

Item	Properties	Test Standard	Unit	Types of High Strength (HS) Woven Geotextile*						
				HS 100/50	HS 200/50	HS 300/50	HS 400/50	HS 600/50	HS 800/50	HS 1000/50
1.	Characteristics Short Term Strength – MD**	ISO 10319 or ASTM D4595	kN/m	≥ 100	≥ 200	≥ 300	≥ 400	≥ 600	≥ 800	≥ 1000
2.	Characteristics Short Term Strength at 5% elongation – MD**	ISO 10319 or ASTM D4595	kN/m	≥ 45	≥ 90	≥ 135	≥ 180	≥ 270	≥ 360	≥ 400
3.	Characteristics Short Term Strength – CD***	ISO 10319 or ASTM D4595	kN/m	≥ 50						
4.	Elongation at Characteristics Short Term Strength – MD**	ISO 10319 or ASTM D4595	%	≤ 10						
5.	Long Term Design Strength at 120 years design life****	BS 8006	kN/m	≥ 55	≥ 110	≥ 170	≥ 220	≥ 355	≥ 475	≥ 590

* For high strength woven geotextile with required strength more than 800 kN/m, special design and specification shall be discussed with the designer
 ** MD: Machine Direction
 *** CD: Cross Direction
 ****The long-term design strength assessment should take into consideration of reduction factors for creep, installation damage, environmental effects and extrapolation of data

Note:

ISO 10319: Geosynthetics — Wide-width tensile test

ASTM D4595: Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method

BS 8006: Code of practice for strengthened/reinforced soils

TABLE S6: PROPERTIES OF GEOGRID

Item	Properties	Test Standard	Unit	Types of Geogrid (GD)*							
				GD 40	GD 60	GD 80	GD 100	GD 130	GD 150	GD 160	GD 200
1.	Characteristics Short Term Strength – MD**	ISO 10319 or ASTM D4595	kN/m	≥ 40	≥ 60	≥ 80	≥ 100	≥ 130	≥ 150	≥ 160	≥ 200
2.	Characteristics Short Term Strength at 5% elongation – MD**	ISO 10319 or ASTM D4595	kN/m	≥ 20	≥ 30	≥ 40	≥ 50	≥ 65	≥ 75	≥ 80	≥ 100
3.	Characteristics Short Term Strength – CD***	ISO 10319 or ASTM D4595	kN/m	≥ 30							
4.	Elongation at Characteristics Short Term Strength – MD**	ISO 10319 or ASTM D4595	%	≤ 10							
5.	Long Term Design Strength at 120 years design life ****	BS 8006	kN/m	≥ 20	≥ 30	≥ 40	≥ 50	≥ 75	≥ 80	≥ 85	≥ 105

* For geogrid with required strength more than 800 kN/m, special design and specification shall be discussed with The designer
 ** MD: Machine Direction
 *** CD: Cross Direction
 ****The long-term design strength assessment should take into consideration of reduction factors for creep, installation damage, environmental effects and extrapolation of data

Note:

ISO 10319: Geosynthetics — Wide-width tensile test

ASTM D4595: Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method

BS 8006: Code of practice for strengthened/reinforced soils

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TABLE S7: PROPERTIES OF PREFABRICATED VERTICAL DRAIN

Item	Properties		Test Standard	Unit	Types of PVD	
					Type A*	Type B**
	Material	Core Filter			Continuous plastic drain core wrapped in non-woven geotextile material	
1.	Dimension of drain	Width		mm	100 ± 3	
		Thickness		mm	4 to 5	
2.	Coefficient of permeability of drain filter		ASTM D 4491	m/s	$\geq 1 \times 10^{-4}$	
3.	Discharge Capacity at Pressure, $P=240\text{kN/m}^2$ and Hydraulic Gradient, $i=1$		ASTM D 4716	m^3/s	$\geq 25 \times 10^{-6}$	$\geq 100 \times 10^{-6}$
4.	Apparent Opening Size, O_{95}		ASTM D 4751	μm	≤ 90	≤ 90
5.	Tensile strength of entire drain		ASTM D 4595	N	≥ 2500	≥ 2800
6.	Tensile strength of filter		ASTM D 4595	N/m	≥ 3000	≥ 6000
7.	Tensile elongation of entire drain at 1000N		ASTM D 4595	%	≤ 10	≤ 10

* PVD Type A: For common application where soft soil depth is generally <25m and less compressible soil [Vertical strain (Settlement) < 15%].

** PVD Type B: For more critical application such as when soft soil depth is generally $\geq 25\text{m}$, highly compressible soil like peat [Vertical strain (Settlement) $\geq 15\%$]. This type of PVD can be used associated with vacuum preloading method or other special considerations based on engineering judgement of the designer.

Note:

ASTM D4491: Standard Test Methods for Water Permeability of Geotextiles by Permittivity

ASTM D4716: Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head

ASTM D4751: Standard Test Methods for Determining Apparent Opening Size of a Geotextile

ASTM D4595: Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method

TABLE S8: TYPICAL GRADINGS USED WITH THE DIFFERENT PROCESSES FOR STONE COLUMN

Process	Grading in mm
Dry top-feed process	40 to 75
Wet process	25 to 75
Dry bottom-feed process	8 to 50

TABLE S9: CONSTRUCTION PARAMETERS TO BE MONITORED DURING DSM INSTALLATION

Dry Method	Wet Method
- Air tank pressure - Time vs depth (penetration and retrieval rate) - Rotation speed (revs/min during penetration and retrieval) - The quantity of binder per metre of depth during penetration and retrieval	- Slurry pressure; air pressure (if any) - Time vs depth (penetration and retrieval rate) - Rotation speed (revs/min during penetration and retrieval) - The quantity of slurry per metre of depth during penetration and retrieval

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TABLE S10: DATA REQUIRED FOR EACH INSTRUMENT

Instrument	Data Required
Displacement marker	- distance from fixed point (m) (details to be given) including base reading - change in distance from fixed point relative to base readings (mm)
Settlement marker	- reduced level of top of rod (mRL) including base reading - change in reduced level of top of rod relative to base readings and previous reading (mm)
Building Settlement Marker	- reduced level of stud (mRL) including base reading - change in reduced level of stud relative to base readings and previous reading (mm)
Survey reference station	- chainage, offset, coordinates (in WGS 84) and reduced level of top of rod (m)
Deep levelling datum	- reduced level of datum (mRL)
Rod settlement gauge	- reduced level of top of rod (mRL) including base reading - original ground level at gauge location (mRL) - reduced level of ground adjacent to gauge (mRL) - record of fill placed (m) - total thickness of fill (m) - record of extensions (m) - settlement of plate relative to base readings and previous reading (mm)
Hydrostatic profile gauge	- reduced levels of survey pins (mRL) - original ground level every 10.0m along line of gauge (mRL) - level of fill every 10.0m along line of gauge (mRL) - thickness of fill along the line of the gauge (m) - distance from end of access tube to point used as reference for longitudinal measurement (m) - listing of elevation of access tube relative to survey pin at 1.0m intervals (mRL) - graph of settlement of access tube relative to base readings and thickness of fill against distance along the tube - maximum settlement relative to base readings and previous reading and its location (mm)
Horizontal Inclinator	- reduced levels of survey pins (mRL) - original ground level every 10.0m along line of gauge (mRL) - level of fill every 10.0m along line of gauge (mRL) - thickness of fill along line of gauge (m) - distance from end of access tube to point used as reference for longitudinal measurement (m) - listing of elevation of access tube relative to survey pin at 0.5m intervals (mRL) - graph of settlement of access tube relative to base readings and thickness of fill against distance along the tube - maximum settlement relative to base readings and previous reading and its location (mm)

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Instrument	Data Required
Magnetic extensometer	- reduced level of top of access tube (mRL) - reduced level of ground adjacent to access tube (mRL) -distance of each magnet from top of tube (m) - reduced level of each magnet (mRL) - settlement of each magnet relative to base readings (mm)
Inclinometers	- reduced level of top of access tube (mRL) - reduced level of ground adjacent to access tube (mRL) - graph and listing of horizontal movement of access tube relative to base readings against depth
Combined magnetic extensometer and inclinometer	- reduced level of top of access tube (mRL) including base reading - reduced level of ground adjacent to access tube (mRL) -distance of each magnet from top of tube (m) - reduced level of each magnet (mRL) - settlement of each magnet relative to base readings (mm) - graph and listing of horizontal movement of access tube relative to base readings against depth depth to water from top of tube (m)
Standpipe piezometers	- depth to water from top of tube (mRL) including base reading - reduced level of top of tube (mRL) - reduced level of ground adjacent to standpipe (mRL) - water head (mRL) - change in water head relative to base readings (m)
Pneumatic piezometers	- water pressure reading (m water) including base reading - reduced level of piezometre tip as installed (mRL) - water head (mRL) - change in water head relative to base readings (m)
Vibrating wire piezometer	- water pressure reading (m water) including base reading - reduced level of piezometre tip as installed (mRL) - water head (mRL) - change in water head relative to base readings (m)

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TABLE S11: DATA REQUIRED FOR EACH INSTRUMENT

Instrument	Data Required Plots and Summaries Required
Displacement marker	- deflection vs. time indicating direction of movement (tabulation and plot)
Settlement marker	- settlement vs. time (tabulation and plot)
Building settlement marker	- settlement vs. time (tabulation and plot)
Survey reference station	- chainage, offset coordinates and reduced level (tabulation)
Deep levelling datum	- reduced level (tabulation)
Rod settlement gauge	- thickness of fill and settlement of plate vs. time (tabulation and plot)
Hydrostatic profile gauge	- latest graph of settlement of access tube relative to base readings and fill thickness against distance along the tube - maximum gauge settlement and corresponding fill thickness vs. time (tabulation and plot)
Horizontal inclinometer	- latest graph of settlement of access tube relative to base readings and fill thickness against distance along the tube maximum gauge settlement and corresponding fill thickness vs. time (tabulation and plot)
Magnetic extensometer	- settlement of each magnet vs. time (tabulation and plot) - settlement of each magnet vs. depth for latest set of readings (plot)
Inclinometer	- latest graph of horizontal movement of access tube relative to base readings against depth - Maximum horizontal movement relative to base readings vs. time (tabulation and plot)
Combined Magnetic Extensometer Inclinometer	- as per magnetic extensometer and inclinometer described above
Standpipe piezometer /Pneumatic piezometer/ Vibrating wire piezometer	- water head vs. time (tabulation and plot) - excess water head vs. time (tabulation and plot) - all instruments in a profile plotted on the same graph

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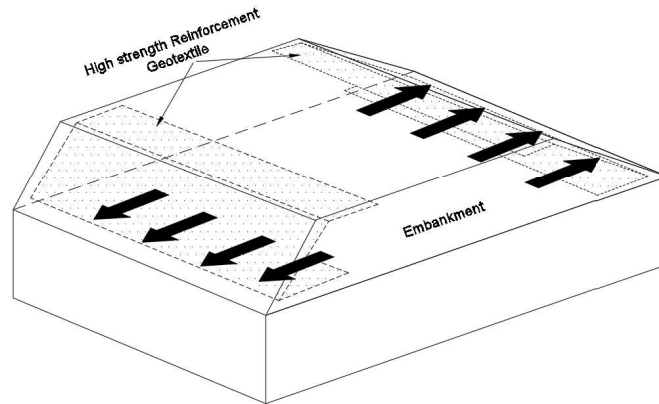


FIGURE S1: LAYING DIRECTION OF GEOTEXTILE

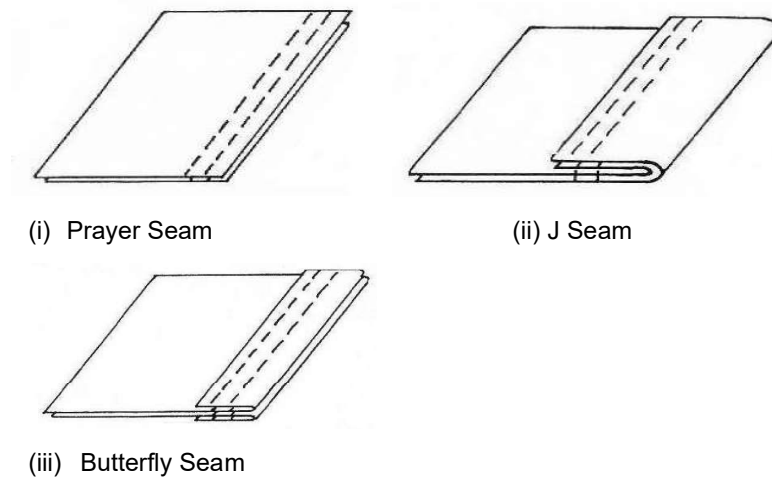


FIGURE S1: TYPES OF SEAM WITH DOUBLE THREAD LOCK STITCH

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1. General

- 1.1. The construction of roads and hardstanding shall generally be carried out only after completion of all drainage systems, services and ducts which may affect the Works, unless otherwise agreed by the S.O..

2. Flexible Pavement

2.1. Subgrade

- 2.1.1. Subgrade means that part of the embankment or existing ground in cutting which is immediately below the sub-base or lower sub-base of the road pavement and shoulders.
- 2.1.2. Material for the top 300mm of subgrade shall have a minimum soaked laboratory California Bearing Ratio (CBR) as shown on the Drawings when compacted to 95% of the maximum dry density determined in the MS 1056 Compaction Test (4.5kg Rammer Method). In the event CBR value not mentioned on the Drawings, a minimum CBR value of 10% shall be adopted.
- 2.1.3. Throughout the top 300mm of subgrade, the materials shall be compacted to not less than 95% of the maximum dry density determined in the MS 1056 Compaction Test (4.5kg Rammer Method).
- 2.1.4. In cut area, the top 300mm of the subgrade shall be scarified and recompacted to 95% of the maximum dry density determined in the MS 1056 Compaction Test (4.5kg Rammer Method). If the S.O. is fully satisfied that the subgrade in its natural state possesses a density exceeding the requirements, then the surface of the subgrade shall be trimmed and rolled to obtain a smooth finish.
- 2.1.5. Where the material in cut area is found to be unsuitable for use in the top 300mm of subgrade or to a suitable level to be determined by the S.O., it shall be removed and replaced with suitable material which shall be compacted as indicated above. Alternatively, stabilizing agent may be used subject to the S.O.'s approval.
- 2.1.6. The subgrade shall be finished in a neat and workmanlike manner, and the widths of embankments and cuts shall be everywhere at least of those specified or shown on the Drawings on both sides of the centre line. The top surface of the subgrade shall have the required shape, superelevation, levels and grades and shall be finished everywhere to within +10mm and -30mm of the required level.

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2.1.7. Where subgrade construction encounters rock surfaces:

2.1.7.1. Rock surfaces extend over the whole width of the formation:

The rock surface shall be trimmed to a free draining profile, at or below formation levels. No high spot shall protrude above the formation level. Any voids or cavities more than 0.5m below the formation level shall be filled up with approved crusher run, gravel or lean concrete having strength class of C12/15. The rock surface shall then be brought up to the formation levels with approved crushed rock or gravel, regulated and blinded.

2.1.7.2. Rock outcrop occurs over part of the formation only:

The rock outcrop shall be cut down to a level not less than 300mm below the formation level. The surface shall then be brought up to level with suitable subgrade material.

2.2. Drainage Layer

2.2.1. This work shall consist of furnishing, placing, compacting and shaping drainage layer on a prepared and accepted subgrade in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O..

2.2.2. Coarse aggregate shall be screened crushed hard rock and fine aggregate shall be screened quarry dust or sand. The aggregate shall be well graded and lie within the limits as shown in **TABLE T1**.

2.2.3. Notwithstanding any earlier approval of finished subgrade, the surface of the subgrade shall be, on completion of compaction and immediately before placing drainage layer, well closed and free from movement under the compaction plant and from ridges, cracks, loose material, potholes, ruts or other defects. Any damage to or deterioration of the subgrade shall be made good in accordance with sub-section 2.1.

2.2.4. The material shall be transported, laid and compacted at a moisture content within the range +1% to -2% of the optimum moisture content determined in compliance with BS 5835 and without drying out or segregation.

2.2.5. The drainage layer shall be placed and compacted to the required width and thickness as shown on the Drawings, in one single layer.

2.2.6. The material shall be spread and lightly compacted with tracked spreading plant or other approved equipment with consideration given to the protection of the subgrade.

2.3. Sub-base

2.3.1. This work shall consist of furnishing, placing, compacting and shaping sub-base material on a prepared and accepted subgrade in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O..

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- 2.3.2. Sub-base shall be a natural or artificial mixture of locally available materials such as sand, gravel, crushed aggregate, etc. free from organic matter, clay lumps and other deleterious materials. It shall be well graded and conform to **TABLE T2** and the following quality requirements:
- 2.3.2.1. The CBR of the sub-base shall not be less than 30% or as shown on the Drawings when compacted to 95% of the maximum dry density determined in the BS 1377 Compaction Test (4.5kg rammer method) and soaked for four (4) days under a surcharge of 4.5kg. This shall involve carrying out a series of CBR tests at various dry densities, using the field moisture content. The field density must then be measured at a number of points using the sand replacement method and the CBR deduced from the mean of the field density measurements.
 - 2.3.2.2. If more than 10% of the material is retained on the BS sieve size 20.0mm, the whole material can be assumed without test to have a CBR value of 30% or more.
 - 2.3.2.3. The plasticity index when tested in accordance with BS 1377 shall be not more than 12.
 - 2.3.2.4. The 10% fines value when tested in accordance with MS EN 933 shall be not less than 30kN.
 - 2.3.2.5. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.
- 2.3.3. Prior to placing any sub-base material, the underlying subgrade (particularly the top 300mm of the subgrade) shall have been shaped and compacted in accordance with the provisions of sub-section 2.1. or sub-section 2.2. as appropriate. Notwithstanding any earlier approval of finished subgrade, the surface of the subgrade shall be, on completion of compaction and immediately before placing sub-base layer, well closed and free from movement under the compaction plant and from ridges, cracks, loose material, potholes, ruts or other defects. Any damage to or deterioration of the subgrade shall be made good in accordance with sub-section 2.1.
- 2.3.4. Sub-base material shall be transported, laid and compacted at a moisture content within the range +1% to -2% of the optimum moisture content without drying out or segregation.
- 2.3.5. Sub-base material shall be placed over the full width of the formation to the required thickness as shown on the Drawings or directed by the S.O. in one (1) layer or more, each layer not exceeding 200mm compacted thickness. Where two (2) or more layers are required, they shall be of approximately equal thickness and none shall be less than 100mm compacted thickness.

- 2.3.6. Each layer of sub-base shall be processed as necessary to bring its moisture content to a uniform level throughout the material suitable for compaction and shall then be compacted using suitable compaction equipment approved by the S.O. to not less than 95% of the maximum dry density determined in the BS 1377 Compaction Test (4.5kg rammer method). Compaction shall be carried out in a longitudinal direction along the roadbed and shall generally begin at the outer edge and progress uniformly towards the crown on each side in such a manner that each section receives equal compaction effort, all to the satisfaction of the S.O..
- 2.3.7. All loose, segregated or other defective areas shall be removed to the full thickness of the layer, and new sub-base material laid and compacted.
- 2.3.8. The sub-base shall be finished in a neat and workmanlike manner and shall have an average thickness over any 100m length not less than the required thickness. The top surface of the sub-base shall have the required shape, superelevation, levels and grades, and shall be everywhere within the tolerances as specified in sub-section 3.2.

2.4. Crushed Aggregate Road Base

- 2.4.1. This work shall consist of furnishing, placing, compacting and shaping crushed aggregate road base material on a prepared and accepted subgrade or sub-base in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O..
- 2.4.2. Crushed aggregate road base material shall be crushed rock, crushed gravel or a mixture of crushed rock and gravel, which shall be hard, durable, clean and essentially free from clay and other deleterious materials. The material shall conform to the following physical and mechanical quality requirements:
- 2.4.2.1. The plasticity index when tested in accordance with BS 1377 shall be not more than 6.
- 2.4.2.2. The aggregate crushing value when tested in accordance with MS 30 shall be not more than 25%.
- 2.4.2.3. The flakiness index when tested in accordance with MS 30 shall be not more than 25%.
- 2.4.2.4. The weighted average loss of weight in the magnesium sulphate soundness test (5 cycles) when tested in accordance with AASHTO Test Method T 104 shall be not more than 18%.
- 2.4.2.5. The material shall have a CBR value of not less than 80% when compacted to 95% of the maximum dry density determined in the BS 1377 Compaction Test (4.5kg rammer method) and soaked for 4 days under a surcharge of 4.5kg.
- 2.4.2.6. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

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2.4.2.7. The gradation shall comply with the envelope as shown in **TABLE T3**.

- 2.4.3. Prior to placing any crushed aggregate road base material, the sub-base shall have been constructed in accordance with the provisions of sub-section 2.3.
- 2.4.4. Crushed aggregate road base shall be placed to the required width and thickness as shown on the Drawings or directed by the S.O. in one (1) layer or more, each layer not exceeding 200mm compacted thickness.
- 2.4.5. Where two (2) or more layers are required, each layer shall be of approximately equal thickness and none shall be less than 100mm compacted thickness.
- 2.4.6. The material shall be spread using a motor grader of sufficient capacity or other approved mechanical spreader, at the optimum moisture content $\pm 1\%$.
- 2.4.7. Compaction shall be carried out using suitable approved equipment, in a longitudinal direction, and begin at the lower edges and progress towards the crown, or in the case of superelevation towards the upper edge, in such a manner that each section receives equal compaction effort, sufficient to produce a density of not less than 95% of the maximum dry density as determined by BS 1377: Test 13.
- 2.4.8. Throughout the placing, adjustment of moisture content and compaction of crushed aggregate road base material, care shall be taken to maintain a uniform gradation of the material and prevent its separation into coarse and fine parts, all to the satisfaction of the S.O..
- 2.4.9. The crushed aggregate road base width shall be everywhere at least that specified or shown on the Drawings on both sides of the centreline; and its average thickness over any 100m length shall be not less than the required thickness.
- 2.4.10. The surface of the road base shall on completion of compaction and immediately before placing bituminous surfacing be well closed and free from movement under the compaction plant and from ridges, cracks, loose material, potholes, ruts other defects.
- 2.4.11. All loose, segregated or otherwise defective areas shall be removed to the full thickness of the layer, and new material laid and compacted. The addition of fine material will not be permitted.
- 2.4.12. The surface shall be to the required level and grade and comply with the tolerances as specified in sub-section 3.2.

2.5. Wet-Mix Road Base

- 2.5.1. This works shall consist of furnishing, placing, compacting wet-mix road base on a prepared and accepted sub-base in accordance with this Specification and the lines and levels as shown on the Drawings and/or as directed by the S.O..



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- 2.5.2. Aggregate for wet-mix road base shall be crushed rock, crushed gravel or a mixture of crushed rock and gravel, which shall be hard, durable, clean and essentially free from clay and other deleterious materials.
- 2.5.3. The aggregate shall conform to the following physical and mechanical quality requirements:
- 2.5.3.1. The flakiness index when tested in accordance with MS EN 933 shall be not more than 25%.
- 2.5.3.2. The aggregate crushing value when tested in accordance with MS 30 shall be not more than 25%.
- 2.5.3.3. The weighted average loss of weight in the magnesium sulphate soundness test (5 cycles) when tested in accordance with AASHTO Test Method T 104 shall be not more than 18%.
- 2.5.3.4. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.
- 2.5.3.5. The gradation shall comply with the limits shown in **TABLE T4**.
- 2.5.4. Notwithstanding any earlier approval of finished sub-base, prior to placing wet-mix road base material, any damage to or deterioration of the sub-base shall be made good in accordance with sub-section 2.3.
- 2.5.5. Wet-mix road base material shall be placed to the required width and thickness as shown on the Drawings or as directed by the S.O. in one (1) layer or more, each layer not exceeding 200mm compacted thickness. Where two (2) or more layers are required, they shall be of approximately equal thickness and none shall be less than 100mm compacted thickness.
- 2.5.6. The material shall be laid using a paving machine at moisture content +0.5% of the optimum which shall be maintained during the compaction operation.
- 2.5.7. Compaction shall be carried out using suitable approved equipment in a longitudinal direction, and begin at the lower edges and progress towards the crown, or in the case of superelevation towards the upper edge, in such a manner that each section receives equal compaction effort, sufficient to produce a density of not less than 95% of the maximum dry density as determined by BS 1377: Test 13.
- 2.5.8. Throughout the placing, and compaction of wet-mix road base material, care shall be taken to maintain a uniform gradation of the material and prevent its separation into coarse and fine parts.
- 2.5.9. All loose, segregated or otherwise defective areas shall be removed to the full thickness of the layer, and new wet-mix road base material laid and compacted, the addition of fine aggregate only shall not be permitted.

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- 2.5.10. The wet-mix road base width shall be everywhere at least that specified or shown on the Drawings on both sides of the centreline. The average thickness measured over any 100m length shall be not less than shown on the Drawings or specified and the minimum thickness measured at any one point shall be not less than the thickness shown on the Drawings or specified **TABLE T5**.
- 2.5.11. The surface of the wet-mix road base shall, on completion of compaction and immediately before placing bituminous surfacing, be well closed and free from movement under the compaction plant and from ridges, cracks, loose material, potholes, ruts or other defects.
- 2.5.12. The surface shall be to the required level and grade and comply with the tolerances specified in sub-section 3.2.
- 2.6. Bituminous Pavement Courses
- 2.6.1. Bituminous Prime Coat
- 2.6.1.1. This work shall consist of the careful and thorough cleaning of the surface of a prepared and accepted unbound road base and cement-treated base (CTB), and the furnishing and application to the cleaned road base and CTB surface of a bituminous prime coat, all in accordance with this Specification and the lines, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O..
- 2.6.1.2. The materials, equipment and construction methods shall be in accordance with Standard Specification for Roadworks Section 4: Flexible Pavement JKR Specification No. JKR/SPJ/2008-S4.
- 2.6.2. Bituminous Tack Coat
- 2.6.2.1. This work shall consist of the careful and thorough cleaning of the surface of a prepared and accepted bituminous or bitumen primed pavement course, and the furnishing and application to the cleaned surface of a bituminous tack coat prior to the construction of an overlying bituminous pavement course, all in accordance with this Specification and the lines, dimensions and cross-sections as shown on the Drawings and/or as required by the S.O..
- 2.6.2.2. The materials, equipment and construction methods shall be in accordance with Standard Specification for Roadworks Section 4: Flexible Pavement JKR Specification No. JKR/SPJ/2008-S4.

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2.6.3. Asphaltic Concrete

2.6.3.1. This work shall consist of furnishing, placing, shaping and compacting asphaltic concrete binder course and/or wearing course on a prepared and accepted bituminous or bitumen primed pavement course, and shall include the careful and thorough cleaning of surfaces which are to be covered prior to the application of bituminous prime coat and tack coat. The work shall be carried out all in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as required by the S.O..

2.6.3.2. The materials, mix design, equipment and construction methods shall be in accordance with JKR Specification No. JKR/SPJ/2008-S4.

3. Horizontal Alignment, Surface Levels and Surface Regularity of Pavement Courses

3.1. Horizontal Alignment

3.1.1. The horizontal alignment shall be determined from the of the pavement surface shown on the Drawings. The edges of the pavement as constructed and all other parallel construction lines shall be correct within a tolerance of +50mm and -0mm from the centreline, except for kerbs, channel blocks and edge lines which shall be laid with a smooth alignment within a tolerance of +25mm and -0mm from the centreline.

3.2. Surface Levels of Pavement Courses

3.2.1. The design levels of pavement courses shall be calculated from the vertical profile, crossfall and pavement course thicknesses shown on the Drawings. Crossfall for hardstanding shall be constructed at a minimum of 2.5% gradient from the highest point of the area or as approved by S.O.. The level of any point on the constructed surface of a pavement course shall be the design level subject to the appropriate tolerances given in **TABLE T5**.

3.2.2. The combination of permitted tolerances in the levels of different pavement courses shall not result in a pavement thickness less than that shown on the Drawings. Each pavement course shall have an average thickness not less than that shown on the Drawings.

4. Shoulders

4.1. This work shall consist of furnishing, compacting and shaping earth, gravel or paved shoulder material on a prepared and accepted sub-base or subgrade, all in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as required by the S.O..

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4.2. Materials

4.2.1. Paved Shoulders

The bituminous surfacing and underlying pavement courses shall be constructed as described in the appropriate sections of this Specification.

4.2.2. Gravel Shoulders

Gravel shoulder material shall conform to the requirements for gravel surfacing material set forth in Standard Specification for Roadworks Section 4: Flexible Pavement JKR Specification No. JKR/SPJ/2008-S4.

4.2.3. Earth Shoulders

Earth shoulder material shall be suitable material as described in Standard Specification for Roadworks Section 2: Earthworks JKR Specification No. JKR/SPJ/2020-S2.

4.2.4. Construction

4.2.4.1. Shoulders shall be constructed in stages or in one operation as directed or approved by the S.O., but in no instance shall a shoulder be built up to a level higher than that part of the abutting carriageway structure which has been completed and accepted.

4.2.4.2. Prior to placing any shoulder material, the underlying sub-base or subgrade shall have been shaped and compacted in accordance with the provisions of Standard Specification for Roadworks Section 2: Earthworks JKR Specification No. JKR/SPJ/2020-S2. respectively, and the abutting carriageway structure course or courses shall likewise have been shaped and compacted in accordance with the provisions of the appropriate sub-sections of this Specification. Notwithstanding any earlier approval of the underlying and abutting pavement courses, any damage to or deterioration of these underlying and abutting pavement courses shall be made good to the satisfaction of the S.O. before shoulder construction proceeds.

4.2.4.3. Shoulders shall be placed to the required width and thickness as shown on the Drawings or as directed by the S.O. in one (1) layer or more, each layer not exceeding 200mm compacted thickness at the point of maximum thickness. Where two (2) or more layers are required, they shall be of approximately equal shape and thickness, and none shall be less than 100mm compacted thickness at the point of maximum thickness.

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- 4.2.4.4. Each layer of shoulder material shall be processed as necessary to bring its moisture content to a uniform level throughout the material suitable for compaction and shall then be compacted using suitable compaction equipment approved by the S.O. to not less than 95% of the maximum dry density determined in the BS 1377 Compaction Test (4.5kg rammer method). Compaction shall be carried out in a longitudinal direction along the shoulder and shall generally begin at the outer edge and progress uniformly towards the carriageway, except on super-elevated curves where rolling shall begin at lower edge and progress uniformly towards the higher edge. In all cases, compaction shall be carried out in such a manner that each section receives compaction effort appropriate to its thickness, all to the satisfaction of the S.O..
- 4.2.4.5. Throughout the placing, adjustment of moisture content and compaction of shoulder material, care shall be taken to maintain a uniform gradation of the material and prevent its separation into coarse and separate parts, all to the satisfaction of the S.O..
- 4.2.4.6. Where shown on the Drawings or directed by the S.O., earth shoulders shall be turfed in accordance with Standard Specification for Roadworks Section 2: Earthworks JKR Specification No. JKR/SPJ/2013-S2.
- 4.2.4.7. Shoulders shall be finished in a neat and workmanlike manner. The total width of carriageway and shoulder shall throughout be at least as specified or shown on the Drawings on both sides of the centreline. The top surface of each shoulder shall throughout have the required shape, super-elevation, levels and grades, within 10mm of the required plane, and shall provide a flush joint with the carriageway surface and shall be uniformly free draining away from the carriageway, all to the satisfaction of the S.O..

5. Concrete Pavement

Concrete Pavement works shall be in accordance with Standard Specification for Road Works JKR Specification No. JKR/SPJ/2020 Section 5: Portland Cement Concrete Pavement.

6. Road Furniture

6.1. Corrugated Sheet Steel Beam Guardrail

The supply and method of installation of guardrails shall be in accordance with Standard Specification for Road Works Section 6: Road Furniture JKR Specification No. JKR/SPJ/2017-S6.

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6.2. Traffic Signs

The supply and method of installation of traffic signs shall be in accordance with Standard Specification for Road Works Section 6: Road Furniture JKR Specification No. JKR/SPJ/2017-S6.

6.3. Road Markings

The supply and application of road markings shall be in accordance with Standard Specification for Road Works Section 6: Road Furniture JKR Specification No. JKR/SPJ/2017-S6.

6.4. Concrete Kerb

The supply and installation of concrete kerb shall be in accordance with Standard Specification for Road Works Section 6: Road Furniture JKR Specification No. JKR/SPJ/2017-S6.

7. Street Lighting

The supply and installation of street lighting shall be in accordance with Standard Specification for Road Works Section 7: Street Lighting JKR Specification No. JKR/SPJ/2011-S7.

8. Traffic Signal System

The supply and installation of traffic signal system shall be in accordance with Standard Specification for Road Works Section 8: Traffic Signal System JKR Specification No. JKR/SPJ/2008-S8.

TABLE T1: GRADATION LIMITS FOR DRAINAGE LAYER

B.S. Sieve Size (mm)	Percentage Passing by Weight
75.0	100
37.5	75 - 100
20.0	60 - 90
10.0	25 - 75
5.0	10 - 45
2.00	0 - 20
1.18	0 - 10

TABLE T2: GRADATION LIMITS FOR SUB-BASE

BS Sieve Size (mm)	Percentage Passing by Weight
75.0	100
37.5	85 - 100
20.0	65 - 100
10.0	45 - 100
5.0	25 - 85
0.600	8 - 45
0.075	0 - 10
The particle size shall be determined by the washing and sieving method of <i>BS 1377</i> .	



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TABLE T3: GRADATION LIMITS FOR CRUSHED AGGREGATE ROAD BASE

B.S. Sieve Size (mm)	Percentage Passing by Weight
50.0	100
37.5	85 - 100
28.0	70 - 100
20.0	60 - 90
10.0	40 - 65
5.0	30 - 55
2.00	20 - 40
0.425	10 - 25
0.075	2 - 10

The particle size shall be determined by the washing and sieving method of *BS 1377*.

TABLE T4: GRADATION LIMIT FOR WET-MIX ROAD BASE

B.S. Sieve Size (mm)	Percentage by Weight Passing
50.0	100
37.5	95 - 100
20.0	60 - 80
10.0	40 - 60
5.0	25 - 40
2.36	15 - 30
0.060	8 - 22
0.075	0 - 8

The particle size shall be determined by the washing and sieving method of *BS 1377*.

TABLE T5: TOLERANCES IN SURFACE LEVELS OF PAVEMENT COURSES

Pavement Course	Tolerance
Wearing Course	±5mm
Binder Course	±5mm
Road base	+0mm to -20mm
Sub-base	+10mm to -20mm

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1. General

- 1.1. All drainage works shall conform to the latest requirements of the Urban Stormwater Management Manual for Malaysia (MSMA)/ MS 2526 and for Works in Sarawak shall comply with Sarawak Urban Stormwater Management (SUStoM).
- 1.2. The works shall include the construction of surface drains, sumps, culverts, subsoil drains, and other drainage structures in accordance with the above requirements or as directed by the S.O..
- 1.3. Drainage works shall be constructed to the lines, levels, grades and cross-sections shown on the Drawings or to suit the site as approved by the S.O..
- 1.4. The site drainage system shall be constructed to direct the runoff from the entire site to the storage area. There shall be no flooding, ponding, silting-up either during construction or after completion of the works. The quantity and quality of runoff from post development area shall be maintained to be the same or less than pre-development condition.
- 1.5. Final discharge point shall be identified and approved by the relevant local Authority. Where necessary, the existing drainage system shall be upgraded to ensure they are fully functional.

2. Excavation and Backfilling

- 2.1. All general excavation works shall be as specified in SECTION C: EARTHWORKS.
- 2.2. The Contractor shall notify the S.O. sufficiently in advance of the beginning of any excavation so that cross-section elevations and measurements shall be taken of undisturbed ground. The natural ground adjacent to the structure shall not be disturbed without permission of the S.O.. The excavation works shall be carried out so as not to cause any danger or obstruction to the traffic or public.
- 2.3. All excavation shall be inspected and approved by the S.O. prior to further work being carried out.
 - 2.3.1. Excavation of Hard Materials/Rock
 - 2.3.1.1. Hard materials/rock encountered in the trench excavation shall be removed to the approval of the S.O.. Layer of rock encountered along the bottom of the excavation shall be cut and trimmed to the required level.
 - 2.3.1.2. Voids formed at bottom of the trench due to the removal of rocks shall be backfilled to the required level with 20mm concrete strength class C16/20 or other suitable materials, well rammed and compacted all to the approval of the S.O..
 - 2.3.1.3. Jagged surfaces of rocks at the bottom of the excavation due to the trimming shall be levelled and smoothed with sand blinding to the approval of the S.O..

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2.3.2. Excavation of Soft Materials

When, in the opinion of the S.O., the foundation material is soft or otherwise unsuitable, the Contractor shall remove and insert foundation fill material or concrete as specified or shown on the Drawings or directed by the S.O.. It shall be placed and compacted in layers not more than 150mm thick or as directed by the S.O..

2.4. Excavation for Drain Trenches

- 2.4.1. The trench shall be excavated to a depth intended or shown on the Drawings. The blinding material shall be laid immediately after the excavation.
- 2.4.2. Should the bottom of the trench be inadvertently excavated below the specified level, it should be brought back at the Contractor's expense to the correct level with good selected earth or sand, carefully rammed into place.
- 2.4.3. The trench bottom shall be of sufficient width to allow adequate working space for the pipe workers. Trenches deeper than 1.5 m shall be provided with any trench support method, approved by the S.O.. The Contractor at all times shall ensure the excavated trench is in the safe working condition for the workers.
- 2.4.4. Unless otherwise specified, excavated material shall not be deposited at the edges of the trench.

2.5. Excavation for Culvert

- 2.5.1. The earthworks at the required location shall be constructed to a level at least 600mm above the top of culverts design levels or to the top of subgrade levels, whichever is lower. The culverts specified to be constructed in trench conditions shall be excavated in accordance with sub-section 2.6.
- 2.5.2. Where drainage conditions or other circumstances so require, the S.O. shall direct the Contractor to construct the culvert without first constructing the earthworks to the level specified above, in which case excavation, and foundation preparation shall be in accordance with sub-section 2.7.

2.6. Trench Method

- 2.6.1. The trench to receive culvert shall have sufficient width and depth to enable the placing of bedding material. The bottom of the trench shall be trimmed to suitably smooth plane surface which shall be kept free from water, all to the satisfaction of the S.O..
- 2.6.2. Rock or other hard material encountered shall be excavated to a depth as directed by S.O.. The excavated hard material shall be replaced with suitable material uniformly compacted in layers of not more than 150mm compacted thickness to provide satisfactory support for the culvert, all to the satisfaction of the S.O..



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2.7. Open Ground Method

2.7.1. Where existing ground levels are above top bedding material design levels and firm foundation materials are encountered, excavation and foundation preparation shall be similar to the described in trench method above. Otherwise, a firm foundation plane shall be prepared, which shall be essentially free draining along the line of the culvert by trimming the existing ground, or such fill as it is necessary to place and compact, over a width sufficient to permit satisfactory construction of the pipe bedding, all to the satisfaction of the S.O..

2.7.2. Where soft or unstable soil is encountered in the foundation, it shall be excavated over a width of at least 1.5 times the outside of each side of the culvert centre-line to the depth directed by the S.O. and replaced with suitable material uniformly compacted in layers of not more than 150mm compacted thickness to provide satisfactory support for the pipe, all to the satisfaction of the S.O..

2.8. Backfilling

2.8.1. Drainage trenches shall be backfilled immediately after completion of drain laying or installation of culverts and as soon as the S.O. has inspected and given his approval.

2.8.2. Backfilling with approved fill materials shall be placed evenly in layers not exceeding 150mm. To provide uniform support, loose thickness of fill materials on both sides of the drain shall be thoroughly compacted with mechanical rammers. This procedure shall be followed for the whole depth of drain section.

2.8.3. All spaces excavated under this Specification and not occupied by a permanent structure shall be backfilled with material free from large lumps, wood and extraneous material.

2.8.4. Backfill shall be in layers not more than 150mm compacted thickness. Each layer of backfill shall be wetted uniformly as necessary and compacted to the same requirements as the adjacent undisturbed material. Unless otherwise approved by the S.O., hand tamping shall not be permitted.

2.8.5. In placing the backfill, the material shall be to the same height on both sides of the structure. If conditions require backfilling appreciably higher on one side, the additional material on the higher side shall not be placed until the S.O. is satisfied that the structure has enough strength to withstand any pressure created.

3. Materials

3.1. Basic construction materials shall comprise the following;

3.1.1. Granular Bedding Material

The foundations shall be of granular bedding material suitably graded broken rubble, crushed stone, crushed gravel, sand or other material as shown on the Drawings or as directed by the S.O..

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3.1.2. Concrete Bedding

- 3.1.2.1. Concrete for blinding, bedding and cast-in-situ drains shall be as shown on the Drawings and as specified in SECTION E: CONCRETING.
- 3.1.2.2. Unless otherwise shown on the Drawings, concrete bedding shall be of concrete strength class C20/25 and blinding for the foundations of structure such as drains, sumps and culvert shall be of concrete strength class C12/15 or as directed by the S.O..

3.1.3. Cement Mortar

- 3.1.3.1. Cement mortar, unless otherwise specified, shall contain 1 part ordinary Portland cement to 3 parts fine aggregate by volume. Water shall be added to the mix to produce a suitable consistency for the intended use, all to the approval of the S.O..
- 3.1.3.2. The ingredients for mortar shall be measured in proper gauge boxes and mixed on a clean boarded platform or in an approved mechanical batch mixer.
- 3.1.3.3. All mortar shall be used within 45 minutes of mixing and no reworking of mortar shall be permitted thereafter.

3.1.4. Ordinary Backfill Material

- 3.1.4.1. Ordinary backfill material shall be of suitable material as defined in SECTION C: EARTHWORK.
- 3.1.4.2. Materials from swamps, peats or topsoil and other highly organic clay or silt, materials containing logs, stumps or boulders, which are susceptible to combustion, and any other materials which, by virtue of their physical or chemical composition or at their moisture content will not compact properly, shall not be used for filling.

3.1.5. Granular Backfill Material

- 3.1.5.1. Granular backfill material shall be sand, crushed stone, crushed gravel or a mixture of crushed and natural aggregates, shall be essentially free from vegetative and other organic matter and clay, and shall not contain lateritic or concretionary materials. The material shall conform to the following physical and mechanical quality requirements:
 - i) The fines shall be non-plastic;
 - ii) Sand shall have a gradation conforming to the envelope shown in **TABLE U1**;
 - iii) Material other than sand shall have a gradation conforming to one of the envelopes shown in **TABLE U2**.

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3.1.5.2. The granular backfill shall be placed in layers not to exceed 150mm in depth and each layer shall be thoroughly compacted by means of packers or mechanical tampers to a relative compaction of not less than 95% Standard Proctor Density for the backfill material at optimum moisture content.

4. Surface Drainage

- 4.1. Surface drains shall be constructed with regard to both operation and ease of maintenance and adequate gradient shall be provided to enable self-cleansing flow.
- 4.2. Where gradient designed is not practical or above the finished level, the Contractor shall submit their proposal for the approval of the S.O.
- 4.3. Reinforced concrete struts shall be provided for all drain side walls exceeding 0.9m height. Handrails shall be provided for open drains more than 1.2m width and / or maximum depth as specified in **TABLE U3**.

4.4. Types of Surface Drains

4.4.1. Surface drains of all types shown on the Drawings shall be constructed either unlined or lined using cast in situ concrete, precast or porous concrete drain sections or stone pitching.

4.4.2. Unlined (Earth) Drains

- 4.4.2.1. The Contractor shall refer to approved plans for location, extent and construction details as shown on the Drawings, or otherwise directed by the S.O.. Clearing shall be done only when is necessary to provide access for personnel and equipment installation. Roots, stumps and other debris shall be removed and disposed off properly and not be used to build the bank.
- 4.4.2.2. Excavation for unlined/ earth drains shall be trimmed to form a smooth, firm surface to the required lines, levels, grades and cross-sections as shown on the Drawings or as directed by the S.O..
- 4.4.2.3. Any areas of over excavation shall be made good to the satisfaction of the S.O., all at the contractor's expenses.
- 4.4.2.4. The sides of cut drain shall not be steeper than 1:1.5 (V:H), while fill slopes shall not be steeper than 1:2 (V:H). The surface water shall be discharged to a stable outlet such that soil erosion is prevented from occurring.

4.4.3. Lined Drain

- 4.4.3.1. Lined drains shall be constructed from material proven to be structurally sound and durable and have satisfactory jointing systems. Unless otherwise stated on the Drawings, the maximum steepness of the side slopes for lined open drains shall be as indicated in **TABLE U4**.
- 4.4.3.2. All concrete works shall conform to the requirement in SECTION D: CONCRETING of this Specification or unless otherwise specified.

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4.4.3.3. Lined drains shall be constructed by the following means;

- i) Cast In Situ Concrete Drains
 - a) Cast in-situ concrete drains shall be concrete strength class C20/25 unless otherwise stated. Weep holes shall be cast in-situ as shown on the Drawings or as directed by the S.O..
 - b) Where the concrete grade is found to be of the lower grade, the S.O. shall request the Contractor to do the rectification work according to the requested proper method.
- ii) Precast Concrete Drain
 - a) Precast concrete block inverts shall be of the shapes and dimensions as shown on the Drawings and shall be of concrete strength class C20/25 or unless otherwise specified.
 - b) The joint shall be grouted with cement mortar (1:3) and weep holes shall be provided as shown on the Drawings or as directed by the S.O..
 - c) The S.O. shall have access to the casting yards where the proprietary precast concrete product are being utilized. A copy of the manufacturer's test certificate shall be provided to the S.O..
 - d) All inspections shall be conducted in the presence of the S.O. and any rectification works shall be carried out in accordance to the method as approved by the S.O..
- iii) Cascade Drains
 - a) Cascade drains shall be constructed from precast concrete drain units and laid stepping on a 150mm thick bed of mass concrete of concrete strength class C20/25 or as shown on the Drawings or as approved by the S.O..

5. Subsoil Drain

- 5.1. This work shall include supply and installation of subsoil drains, constructed in accordance with these Specifications at locations and in accordance with the lines, levels and grades as shown on the Drawings and/or to suit the site as approved by the S.O..
- 5.2. Minimum gradient of 1:200 shall be provided for the drain to discharge into existing stormwater system, open drain, creek or pond in the area unless otherwise stated on the Drawings. The discharge shall not create an unwanted bog.
- 5.3. Unless otherwise shown on the Drawings, lateral drains shall have a minimum slope of 1: 200 to ensure water always flowing even though there are undulations and laid at minimum 2m spacing at 45° to the main pipes/ collector drain.

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5.4. The pipes for subsoil drains shall be made up preferably of the materials/ system as stated below or as approved by the S.O.:

- i) Perforated Corrugated Double Wall HDPE pipe
- ii) Porous concrete pipes comply to MS 525
- iii) Proprietary System

All proposed materials shall be approved by the S.O..

5.5. Filter Material

5.5.1. Filter material shall consist of hard, clean, sand conforming to the grading limits given in **TABLE U5**. The material passing the 425µm sieve shall be non-plastic when tested in accordance with BS 1377.

5.5.2. Geotextile shall be of non-woven type thermally bonded as approved by the S.O. Trenches shall be lined with geotextile filter fabric as shown on the Standard Drawings or otherwise approved by the S.O.. Where fabric requires jointing, it shall be stitched and overlapped with a minimum of 500mm at transverse joints and the full trench width at the top shall be provided. Subsoil drains shall be laid, bedded and jointed as detailed on the Drawings.

6. Sumps

6.1. Sumps shall be constructed as accordance to the Drawings or as directed by the S.O. to facilitate changes in level and flow within a drainage system. All sumps shall be covered either by concrete slab or galvanized steel grating hinged to the seating frame on the sumps for safety purposes.

6.2. Unless otherwise as shown on the Drawings, sumps of depth less than 1.5m (internal depth) shall be made up of brickwalls of minimum 225mm thickness. Sump of depth (internal depth) more than 1.5m shall use reinforced concrete strength class C20/25 or otherwise specified on the Drawings.

6.3. The invert levels of pipe/ drain to the sump inlet as shown on the Drawings.

7. Piling Works

7.1. Wherever applicable, all piling works shall comply with the requirements as specified in SECTION D: FOUNDATION WORKS AND WORKS BELOW LOWEST FLOOR LEVEL.

8. Culverts

8.1. The work shall comprise of supply and installation of either reinforced concrete pipe culverts or precast box culverts, including the end treatment components such as headwall, wingwalls, aprons and sumps and channel protection works, all in accordance with these Specifications and details as shown on the Drawings.

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8.2. Culvert Bedding

- 8.2.1. Type A bedding material shall consist of concrete strength class C20/25, complying with SECTION E: CONCRETING unless otherwise stated on the Drawings.
- 8.2.2. Type B bedding shall consist of clean, natural sand or gravelly sand of suitable gradation and quality with maximum particle size of not more than 20mm.

8.3. Culvert Components

- 8.3.1. Culvert shall be constructed with barrel and end treatments including headwalls, endwalls, wingwalls, outlet protection, inlet improvement and debris control structures.

8.4. In each culvert, the following markings shall be clearly shown:

- i) Size
- ii) Date of manufacture
- iii) Name and trademark of the manufacturer

8.5. Pipe Culverts

- 8.5.1. Reinforced concrete pipes shall conform to the requirement of MS EN 1916 and shall be approved by the S.O..
- 8.5.2. Minimum cover to concrete pipe culvert shall be 600mm to avoid undesirable load action. Where the minimum cover cannot be achieved, the concrete pipe shall be surrounded in concrete.
- 8.5.3. Installation of Pipe Culverts
 - 8.5.3.1. Culverts shall not be installed at any location until the type of pipe, the exact location, the lines, levels and grades, the length of pipe and details of inlet and outlet structures have been confirmed and approved by the S.O..
 - 8.5.3.2. Special requirements recommended by the manufacturer with respect to assembly and installation shall be complied. Where elliptically reinforced pipe sections are used, care shall be taken to ensure that the loading axes are positioned exactly vertically.

8.6. Precast Box Culverts

- 8.6.1. Precast box culverts shall conform to the requirement of MS 1293-1 and shall be approved by the S.O..
- 8.6.2. Unless otherwise shown on the Drawings, the precast box culvert shall be capable of withstanding a proof load test of 112.5kN applied over an area of 320mm x 320mm at any position on the cover slab.
- 8.6.3. Precast box culverts shall be laid on Type B bedding with layer of crushed aggregate of maximum particle size not exceeding 50mm as shown on the Drawings or directed by the S.O..

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- 8.6.4. The maximum gap between each culvert shall not be more than 13mm and the difference in level shall less than 3mm. The gap shall be filled with cement mortar (1:3) with smooth finished.
- 8.6.5. To ensure uniform bearing, a layer of cement grout shall be spread along the top of the walls of the invert where the lid shall sit.
- 8.7. The S.O. reserves the right to request for test certificates and further tests to be carried out on samples, all at the Contractor's expenses.
- 8.8. An individual section of culvert shall be rejected due to any of the following:
- i) Fractures or cracks passing through the wall, except for a single end crack that does not exceed the depth of the joint.
 - ii) Defects that indicate imperfect proportioning, mixing and moulding.
 - iii) Surface defects indicating honeycombed or open texture.
 - iv) Damaged ends where such damage would prevent making a satisfactory joint.
- 8.9. All culverts damaged during laying, handling, transporting, or any other time shall be replaced, all at the Contractor's expenses. Rejected culverts shall be marked and removed from the Site.
- 8.10. Extension of Existing Culverts
- 8.10.1. Existing structures
- The existing wing walls, aprons and concrete bedding shall be demolished wherever indicated on the Drawings to expose the existing culvert on the side(s) to be extended. The end of the existing culvert to be extended shall then be wire-brushed or some other means to give a clean end.
- 8.10.2. Extension joints
- Extension joints shall be formed as shown on the drawings and such material to be of a type approved by the S.O. and in accordance with the manufacturer's specification or otherwise specified on the Drawings.

9. On-Site Detention

- 9.1. On-site detention (OSD) facilities shall be constructed in accordance with the Drawings and conform to the relevant authorities requirements.
- 9.2. The construction of OSD facilities shall include the system components at the inlet, storage and outlet zone to cater outflow discharges without causing adverse effects on downstream properties. Fencing and warning signs shall be provided as shown on the Drawings.
- 9.3. Maintenance shall be done periodically or as and when the silt has accumulated to 0.3m thick. The desilted material shall be transported to disposal site approved by S.O..

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10. Stormwater Pumping

- 10.1. Wherever applicable, all works involving stormwater pumping shall comply with the requirements as specified in Mechanical and Electrical works specification.

11. Bio-Ecological Drainage System (BIOECODS)

- 11.1. All Bio-Ecological Drainage System (BIOECODS) works shall comply with the requirements as specified in BIOECODS Specification (JKR 20601-0266-21) or its latest revision.

- 11.1.1. The work shall include the supply and installation of the ecological drainage system in accordance with project specifications and Drawings, or as directed by the S.O..

- 11.1.2. Unless otherwise shown on the Drawings, drain reserves for ecological drainage system shall be at least five (5) metres from the side of the road pavement.

11.1.3. Materials

- 11.1.3.1. All Subsurface ecological drainage products used shall comply with the specifications and requirements of the manufacturer.

- i) The material shall be resistant to chemical and bacterial attack.
- ii) Unless otherwise shown on the Drawings, all soil and subsurface product interface shall have a layer of geotextile to prevent fine particles from entering the drainage system.
- iii) If damage occurs to one of the geotextile fabric during installation, repairs shall be carried out by placing new material over the damaged area by allowing 300mm excess on all sides and then fixing with silicon adhesive.

11.1.4. Filter Materials

- 11.1.4.1. Filter material shall be of hard and clean river sand normally used in construction of subsoil drains to give better infiltration rates.

- 11.1.4.2. The material passing the 0.425mm sieve shall be non-plastic when tested in accordance with BS 1377.

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12. Types of Lining

12.1. Stone Pitching

12.1.1. Construction

12.1.1.1. This work shall consist of the construction of all structures or part of structures to be composed of stone pitching either grouted or ungrouted as shown on the Drawings or as directed by the S.O. including erosion protection pavements and aprons, drain linings, culvert inlets and outlets, etc..

12.1.1.2. The work shall be carried out to the lines, levels, grades, dimensions and cross-sections shown on the Drawings and as approved by the S.O..

12.1.2. Stone

12.1.2.1. Stone shall be clean roughly quarry stone, or pit or river cobbles, or a mixture of any of these materials, and shall be essentially free from dust, clay, vegetative matter and other deleterious materials.

12.1.2.2. Unless otherwise specified, individual pieces of stone shall be approximately cubical or spherical and shall have a minimum dimension of 100mm and a maximum dimension of 250mm. The stone shall be hard, tough, durable and dense. They shall be resistant to the action of air and water, and suitable in all respects for the purpose intended.

12.1.3. Grouted Stone Pitching

12.1.3.1. Prior to construction grouted stone pitching, the surfaces against which it is to be placed shall have been finished to the satisfaction of the S.O.. Notwithstanding any earlier approval of these finished surfaces, any damage to or deterioration of them shall be made good to the satisfaction of the S.O. before grouted stone pitching is placed.

12.1.3.2. Construction of grouted stone pitching shall commence at the lowest part of each structure or section of a structure and continue progressively upward. Long structures such as drain linings and slope protection pavements shall be constructed in sections of practicable lengths, to the approval of the S.O..

12.1.3.3. Stones shall then be firmly set by hand into the mortar, densely packed against adjacent stones and built up to form a stone structure of more or less uniform thickness which shall nowhere be less than 150mm (measured perpendicularly to the surface covered).

12.1.3.4. All voids in the structure shall be packed solidly with mortar and stone spalls; however, the surfaces of stones in the exposed faces and edges shall not be covered with mortar.

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12.1.3.5. The exposed surfaces and edges of the structure shall be constructed such that they have as large a proportion as practicable composed of stone faces. Weep holes shall be provided as shown on the Drawings or as directed by the S.O..

12.1.3.6. Mortar which has been mixed for more than 45 minutes shall not be used in the works. The work shall be carried out and finished all to the approval of the S.O..

12.1.4. Ungrouted Stone Pitching

12.1.4.1. Where shown on the Drawings, ungrouted stone pitching shall be hand set to provide maximum interlocking effect. The stones, the largest of which shall be used at the bottom, shall be well bedded on a 75mm layer of gravel or aggregate rammed to an even surface. The whole work shall be finished to the approval of the S.O..

13. Brickwork

13.1. The bricks shall comply with the requirements of MS 76 and as specified in SECTION F: WALL SYSTEM of this specification. All bricks shall be clean, sound, hard, well burnt, proper size and shall give a clear ring when struck. Bricks shall be obtained from manufacturers approved by the S.O..

13.2. Brick Laying

13.2.1. Brickwork shall be executed with cement mortar and shall be of the thickness and bonds as shown on the Drawings. Bricks shall be kept damp until used and shall be laid on a full bed of mortar.

13.2.2. The brickwork shall be true to line and plumb, and courses shall be kept truly level. The thickness of mortar joints shall not exceed 10mm and shall be such that four (4) courses of brickwork form a height of 300mm.

13.2.3. Any brickwork that is damaged shall be taken down and rebuilt and the joints raked out and pointed as directed by the S.O.. Any such remedial work shall be at the Contractor's expenses.

13.3. Plastering Works

13.3.1. All exposed brickwork surfaces shall be plastered. The plaster shall be applied in two (2) coats generally to a total thickness of 20mm and shall be finished with a steel trowel for internal surfaces and with a wooden float for external surfaces.

13.3.2. Application of plain plaster shall comply with MS 794.

13.3.3. Weep holes shall be provided as shown on the Drawings or as approved by the S.O..



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TABLE U1: GRADING LIMITS FOR SAND BACKFILL

B.S. Sieve Size	% Passing by Weight
10.0mm	100
5.0mm	90 - 100
1.18mm	45 - 80
300 µm	10 - 30
150 µm	2 - 10

TABLE U2: GRADING LIMIT FOR GRANULAR BACKFILL OTHER THAN SAND

B.S Sieve Size	% Passing by Weight		
	A	B	C
37.5mm	100	-	-
28.0mm	70 - 100	100	-
20.0mm	60 - 90	70 - 100	100
10.0mm	45 - 75	45 - 75	-
5.0mm	30 - 60	35 - 65	45 - 75
2.0mm	20 - 50	25 - 50	30 - 60
425 µm	10 - 30	10 - 30	15 - 35
75 µm	0 - 2	0 - 2	0 - 2

TABLE U3: MAXIMUM DEPTHS OF OPEN DRAIN

Cover/Handrail Fence Condition	Maximum Depth (m)
Without protective covering	0.6
With solid or grated cover	1.2

TABLE U4: MAXIMUM STEEPNESS OF THE SIDE SLOPES

Drain lining	Maximum steepness of the maximum side slopes (V:H)
Concrete, brickwork and blockwork	Vertical
Stone Pitching	1:1.5
Grassed/Vegetated, rock riprap	1:2



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TABLE U5: FILTER MATERIAL

B.S. Sieve Size	% Passing By Weight
10.0mm	100
5.0mm	90 - 100
2.36mm	75 - 100
1.18mm	55 - 90
600µm	35 - 59
300µm	8 - 30
150µm	0 - 10

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1. General

- 1.1. This section shall comply with the latest Suruhanjaya Perkhidmatan Air Negara (SPAN) requirement, Malaysian Sewerage Industry Guideline (MSIG), MS 1228 or any other relevant standards approved by the Government.
- 1.2. This section of the Works shall be carried out strictly with the provisions of all legislation, regulations and by-laws currently in force with regard to and in connection with the works as specified in Section A.
- 1.3. The Works to be done under this section unless otherwise shall consist of the supply, delivery, construction, and testing of all sewerage works and ancillary works, and all necessary works up to the point of final discharge of the effluent. In the case of discharge into the public sewer or the package sewage treatment plant, the Works shall terminate up to and including the last manhole or intercepting trap of the system. This section of the Works shall be carried out strictly in accordance with the appropriate by-laws and to the approval of the S.O..
- 1.4. The Contractor is responsible to ensure that all works are carried out by a competent person and any submission for approval to the Certifying Agency appointed by SPAN.

2. Material

- 2.1. Cement, Sand, Aggregates and Bricks
 - 2.1.1. Cement, sand and aggregates shall be as specified in SECTION E: CONCRETING. All bricks used unless otherwise shown on the Drawings shall be clay bricks as specified in SECTION F: WALL SYSTEM.
- 2.2. Sewerage Pipe
 - 2.2.1. The Contractor shall use sewer pipes from suppliers approved by the relevant authorities' and the S.O. before being installed.
 - 2.2.2. The Contractor shall submit the certificate and test report of sewer pipe to the S.O. for approval.
 - 2.2.3. The Contractor shall make sure the sewer pipe is stored and/or stacked in such manner to prevent breakage.

3. Layout

The whole sewerage work shall be carried out according to the layout as shown on the Drawings unless otherwise instructed by the S.O..

4. Excavation

- 4.1. Generally, all excavation works in this section unless otherwise specified hereunder shall be as specified in SECTION C: EARTHWORKS.



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- 4.2. The Contractor shall carry out survey works and any other necessary preliminary work to determine the sewer pipe alignment, method of excavation and protection and all related works. Excavation works clearance from the building/ road shall be 1 metre. The pipe alignment shall be approved by the S.O. before the Contractor starts the excavation works.
- 4.3. The trench shall be excavated to the depths intended or as shown on the Drawings and shall be finished and trimmed to the correct level and grade. Unless indicated otherwise, the bottom of the trench shall be graded so that the pipe invert slopes evenly between the appropriate outlet invert of the preceding manhole and the inlet invert of the next manhole.
- 4.4. The trench shall be excavated to such width so as to ensure that a minimum working space of 300mm will be available on each side of the pipe when properly aligned. At all joints, the trench shall be excavated to give a minimum working space of not less than 300mm all-round the joint.
- 4.5. The sides of all excavation unless otherwise approved by the S.O. shall be cut vertical and where necessary shall be protected against caving in by timbering or other temporary shoring to the approval of the S.O.. If the trench is more than 1.5m, the Contractor shall provide support for the trench to avoid collapse, settlement or movement of the banks.
- 4.6. The trench excavation shall not advance more than 100m ahead of the completed backfilled pipeline. Pipe shall be laid in all trenches that have been excavated at the end of each day's work, unless the Contractor get approval from the S.O. to do otherwise.
- 4.7. It shall be the responsibility of the Contractor to identify, protect and support all existing service utilities within 3 metres of excavation or work to be performed and to arrange with the services owner or authority for the temporary closure, removal and subsequent replacement or relocation as approved by the S.O..
- 4.8. The trench should be excavated precisely to ensure the sewer pipe will be in the centre of the trench. The bottoms of the trenches for all sewers shall be carefully and truly graded, formed and lined according to the grades and dimensions as shown on the Drawings.
- 4.9. Should the ground be so wet or soft and does not form a firm base for the pipe, and if it is deemed necessary in the opinion of the S.O. then the trench shall be excavated 225mm below the intended level or shown on the Drawings and then brought to the correct level with good selected earth, quarry dust or sand well rammed into place. Such deepening of pipe trench and filling back shall be treated as a variation under the terms of the Contract. Should the bottom of the trench be inadvertently excavated below the specified level, it shall be brought back at the Contractor's expense to the correct level with good selected earth, quarry dust or sand carefully rammed into place.
- 4.10. The Contractor shall remove any water that collects in the trenches while sewer pipes are being laid. Water encountered shall be disposed of by the Contractor in a manner satisfactory to the S.O..
- 4.11. Excess material from the trench excavation shall be located 600mm (minimum) away from the trench.

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- 4.12. When excavating pipe trenches in roadway or other paved surfaces, the Contractor shall first remove all metal, slabs or bricks forming the existing pavement to the width of the trenches and reinstate to the approval of the S.O. after the trenches have been backfilled. The Contractor must make sure that not more than half of the width of a roadway shall be disrupted at any one time during the sewerage work.
- 4.13. Generally, where rock is encountered in the trench excavation, it shall be removed to the approval of the S.O.. Where layer of rock is encountered along the bottom of the excavation, it shall be cut and trimmed to the required level of the trench. All voids formed at the bottom of the trench by the removal of rocks shall be back filled to the required level with concrete strength class of C20/25 or other suitable materials well rammed and compacted to the approval of the S.O.. Uneven surfaces of rocks at the bottom of the excavation due to the trimming shall be levelled and smoothen with sand blinding to the approval of the S.O..
- 4.14. If the works required pipe jacking, the Contractor shall provide method statement for S.O.'s review and approval.
- 4.15. The Contractor shall ensure that the work performed is safe and in compliance with Occupational Safety and Health Act (OSHA).
- 4.16. The Contractor shall halt the excavation works once the medium of protection and signage of existing utilities area is visible. The Contractor shall use suitable tools and method as approved by the S.O. to further excavate the particular area.
- 4.17. Existing drains, gutters and channels shall not be obstructed. Existing drains affected by the works shall be realigned to ensure continual operation.

5. Pipes and Fittings

- 5.1. Generally, all sewer pipes and fittings shall comply with the relevant authorities' guidelines.
- 5.2. Sewer pipes used for gravity types of sewer shall be a minimum size of 150mm for service connection and 225mm for public sewer.
- 5.3. Sewer pipes for force mains (which require pump) shall comply with the relevant authorities' guidelines.

6. Joint for Sewer Pipes

- 6.1. Generally, all joints shall comply with the relevant authorities' guidelines.
- 6.2. Unless otherwise approved by the S.O., joints of flexible and watertight type shall be used on all sewer pipes. The spigot and socket of each pipe shall be cleaned and lubricated before the running of each joint.
- 6.3. Couplings shall be made either of the same materials as the pipe or other material to the approval of the S.O.. The pipes and coupling shall have accurately machined or moulded tapered ends, the internal taper of the couplings matching the external taper of the pipes.

7. Pipe Laying

- 7.1. All pipes shall be laid in compliance with the relevant authorities' guidelines and in accordance with the sizes, locations, dimensions, grades and other particulars as shown on the Drawings. Each pipe shall be carefully inspected upon arrival at Site. Sewer pipes shall be carefully stored. Defective pipes shall be marked and removed from the site forthwith.
- 7.2. Prior to fixing or laying all pipes and fittings shall again be carefully inspecting for damage and only those found to be sound in every aspect shall be fixed or laid. Any pipes, specials, et cetera found to be damaged in any way shall be clearly marked, set aside and removed from the Site.
- 7.3. No pipe shall be laid until the trench has been inspected and approved by the S.O..
- 7.4. The pipes shall be gently lowered into the trench by means approved by the S.O.. No pipes shall be rolled or dropped into the trench. The pipe shall be laid true to alignment as shown on the Drawings or as instructed by the S.O.. Interior and exterior of each pipe at the joint shall be thoroughly cleaned before the joint is made. Pipes shall be laid from the downstream end towards the upstream end.
- 7.5. To prevent the entry of earth and other materials into the pipes, the Contractor shall provide and fix suitable stops for efficiently closing all open ends of pipes in the trench while work is not actually being carried out at such open ends.
- 7.6. Socketed pipes shall be laid with the sockets laid against the direction of flow. At every position of pipe joint's, the bedding shall be recessed sufficiently.
- 7.7. Where sewer pipes are to be laid on concrete bed, hunched or encased in concrete surrounds, these shall be as shown on the Drawings.
- 7.8. The gravity sewer pipes shall be laid to the gradients as shown on the Drawings. Where the gradients are not shown on the Drawings, the pipe shall be laid to the following gradients as shown in the **TABLE F1**.
- 7.9. The invert level of each pipe laid shall be checked during laying and immediately after laying as shown on the Drawings.
- 7.10. Where sewer pipes are laid above ground, they shall be supported at intervals to the details as shown on the Drawings or to the approval of the S.O..
- 7.11. Minimum depth of cover from crown of pipe to the finish road or ground level shall be minimum of 450mm unless shown otherwise on the Drawings or instructed by the S.O..
- 7.12. Sewers pipes shall not be laid above the water pipes. A minimum vertical clearance of 1.0m shall be provided between the crown of a sewer pipe and the bottom of a water pipe. The horizontal clearance between sewer and water pipelines shall be 3.0m where applicable unless otherwise shown on the Drawings.
- 7.13. Sewer line shall not be constructed under buildings, permanent structures or private lots and stagnant water bodies unless otherwise approved by the S.O..

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7.14. Other requirements

For easy identification of underground forced sewer mains, the layout shall be planted with marker posts at every 200m length and at every change of pipe direction. Valve chambers provided shall have adequate access for operations and maintenance.

8. Bedding, Haunching and Surround

- 8.1. Concrete bed, haunching and surround shall be of concrete strength class of C20/25.
- 8.2. Typical bedding is to be used for all pipes under normal site condition unless directed by the S.O..
- 8.3. Only approved materials are allowed to be used for pipe embedment.
- 8.4. The bedding material shall be placed as soon as possible after the base of the trench is prepared and excess water has been removed.
- 8.5. Whenever the bedding is disturbed, the pipe shall be raised to allow for repair works to be done.
- 8.6. Any pegs or other temporary aids for levelling works shall be removed before any pipe being laid.
- 8.7. All bedding shall comply with the relevant authorities' guidelines and in accordance with the sizes, locations, dimensions, grades and other particular as shown on the Drawings.

9. Connections

- 9.1. The Contractor shall allow and provide for all bends, junctions, traps, gullies as shown on the Drawings or where necessary. If a gully is used, it shall be of the inlet type, and shall be set level on a concrete base, with a riser to finish 50mm above the surrounding surface level, complete with concrete surrounds rendered on all sides and galvanized iron grating. Bends turned up to receive various stacks shall be set on concrete bases to the approval of the S.O.. The bends at the foot of vertical stacks shall be of gentle radius type.
- 9.2. All underground fittings shall be completely surrounded in concrete and the Contractor shall allow for any additional excavation and jointing of pipes.

10. Manholes, Inspection Chambers and Valve Chambers

- 10.1. Manholes, inspection chambers and valve chambers shall be constructed with the sizes, locations, spacing between manholes, and details shown on the Drawings and the relevant authorities' guidelines. Unless otherwise shown or specified, all dimensions on the plan shall be the inside measurement.
- 10.2. Manholes and inspection chambers shall be protected by lining/ coating to prevent corrosion of the concrete due to sulphide attack. Internal walls shall be either rendered with minimum 20mm thick sulphate resistant cement mortar or lined with PVC, HDPE or epoxy coating.

10.3. Manholes

10.3.1. Manhole Covers and Frames

10.3.1.1. No manhole shall be constructed on the road and hard standing unless otherwise shown on the Drawings.

10.3.1.2. Manhole covers, and frames shall comply with the relevant authorities' guidelines and be equipped with safety features such as locking device, and hinge to prevent rocking due to traffic and to provide a theft proof design.

10.3.1.3. All surfaces of manhole's covers and frames supplied shall be coated as stated in the relevant authorities' guidelines with either:

- (i) Hot applied bituminous material complying with BS EN 10300 (Steel tubes and fittings for onshore and offshore pipelines. Bitumen hot applied materials for external coating).
- (ii) Cold applied bituminous material complying with BS 3416 (Specification for bitumen-based coatings for cold application, suitable for use in contact with potable water)

10.3.2. Manhole Testing (Before Backfilling)

10.3.2.1. Water-tightness test shall be conducted where no visible leakage shall occur between the manhole cover and its seating in the frame when tested in accordance with the relevant authorities' guidelines.

10.3.2.2. A visual inspection shall be conducted on all the external and internal section of each manhole in accordance with the relevant authorities' guidelines. Particular attention shall be given to:

- (i) The slope of benching.
- (ii) Joints to pipes.
- (iii) Transitions at entry and exits.
- (iv) Joints in the structure.
- (v) Quality of concrete finish.
- (vi) Water-tightness of manhole covers and surround.

10.4. Inspection Chambers

10.4.1. Unless otherwise shown on the Drawings, inspection chambers shall be constructed using clay bricks on concrete foundation with strength class of C20/25. The dimensions shall be as shown on the Drawings.

10.4.2. Each inspection chamber shall have channels and open channel junctions of sizes as shown on the Drawings.

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- 10.4.3. Concrete benching shall be to a gradient of 1:6 and shall be with strength class of C20/25 concrete finished with 19mm steel trowelled waterproofed cement and sand (1:3) rendering.
- 10.4.4. The internal sides of the inspection chambers shall be lined with 20mm thick high alumina cement mortar or minimum of two (2) layers coal tar epoxy as approved by the S.O..
- 10.4.5. Externally, the exposed concrete or brick surfaces shall be rendered with 12mm cement and sand mortar (1:3) and terminated 150mm below the finished ground level. All internal angles shall be rounded off.
- 10.4.6. Inspection chambers shall be provided with covers and unless specified or as shown on the Drawings, covers shall be of medium duty 450mm x 600mm cast iron covers with air tight frames.
- 10.4.7. The usage of inspection chamber shall be restricted for internal sanitary uses only and shall not be located on the carriageway/ vehicle routes.

11. **Septic Tank, Small Sewage Treatment System (SSTS) and Sewage Treatment Plant (STP)**

- 11.1. Septic tank, SSTS and STP shall be constructed as shown on the Drawings complying to the relevant authorities' guidelines and to the approval of the S.O..
- 11.2. All septic tank, SSTS and STP shall be approved only by SPAN. The material shall be supplied by the supplier listed by SPAN.
- 11.3. The quality limit for sewage effluent at the discharge point shall comply with Environmental Quality Act (EQA) 1974 or latest. The limit for sewage effluent at the discharge point shall comply with Standard A of EQA as in **APPENDIX F1**.
- 11.4. Prior to the installation of the sewage treatment system, the Contractor shall submit to the S.O. the approved drawings duly endorsed by the authority, system design, method statement including structural, foundation, external work and M & E work duly certified by a Competent Person.
- 11.5. The procedures for certification of sewerage services are given in the relevant authorities' guidelines. Sewage treatment system shall be approved by the Local Authority/ Certifying Agency before installation at site. The submission approval to the Local Authority/ Certifying Agency is as per **APPENDIX F1**.
- 11.6. The S.P. shall provide specification on construction and installation of the system and during these periods, the Local Authority/ Certifying Agency will carry out inspection to ensure the compliance of their requirements. The S.P. shall adhere to the certification procedures for planning, system and design approval until the approval of final inspection prior to handing over.
- 11.7. Upon the completion of the installation of the sewage treatment system and prior to the issuance of the CPC, the Contractor shall submit the following documents to the S.O. for information and record:

- 11.7.1. S.P.'s Guarantee against any defects or damages during a period of five (5) years from the date of CPC due to any defect, fault or insufficiency in design, material or workmanship or against any other failure which an experienced Contractor may reasonably contemplate but shall not include normal replacement and maintenance. The terms of the Guarantee shall be such as approved by the S.O..
- 11.7.2. As-built Drawings and Operation Manual and Maintenance (OMM) of the sewage treatment system certified by a Professional Engineer with Practising Certificate (PEPC) registered with the Board of Engineers Malaysia.

12. Connections to the Public Sewerage Line

- 12.1. Connections to the public sewerage line, if any, shall be strictly carried out in accordance with requirements of the relevant Authorities' guidelines and to the approval of the S.O..
- 12.2. Connection to public sewerage line can only be carried out by licensed Contractor upon approval by the Local Authorities/ Certifying Agency.
- 12.3. The type and location of connections shall be determined by the Local Authorities/ Certifying Agency. Examples of the type of connections are connection to a manhole or a connection to a sewer through junction or saddle fittings.
- 12.4. For direct connection to existing public sewer of diameter 375mm or less, the connection shall be made using a proper Y-junction fitting. The typical connection configuration of junction is shown on the Drawings.
- 12.5. Saddle connections may only be permitted where the existing sewer is at least two (2) pipe sizes greater than the proposed connection pipe. Only saddles specifically designed for the type and size of the sewer to be connected to shall be used.

13. Testing for Sewer Pipes Installation

- 13.1. The Contractor shall carry out tests to the sewer pipes installation in accordance with the method of statement and requirements as described hereinafter. The Contractor shall give reasonable notice in writing to the S.O. before such tests to be carried out.
- 13.2. Testing of pipework shall be carried out and wherever possible, such testing shall be carried out from manhole to manhole. Short branch pipes connected to a main sewer between manholes shall be tested as one system with the main sewer. Long branches and manholes shall be separately tested.
- 13.3. Subject to type of pipe and size, pipes shall be subjected to either low water pressure tests, CCTV test or any other test required by the relevant Authorities' guidelines and to the approval of the S.O..
- 13.4. Low water pressure test
 - 13.4.1. The low water pressure test is commonly used for checking the water-tightness of the joints and the integrity of the sewer pipes.

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- 13.4.2. For the water test, the pipe shall be subjected to an internal test pressure of 2m head of water above the crown of the pipe at the higher end but not more than 7m at the lower end. Steeply graded pipe shall be tested in such a manner that the above maximum heads are not exceeded.
- 13.4.3. The test shall be carried out by filling the sewer with water slowly to the required head and bleed air from behind the upstream plugs. Maintain the water head for 2 hours. Top up the water as required.
- 13.4.4. Check the leakage at the plugs and the test apparatus during the pressurizing period and the constant pressure holding period. Release the water pressure if leakage occurs. Make the necessary repairs and adjustments before pressurizing again.
- 13.4.5. Commence the test immediately after the last adjustment of water head in the preceding 2 hours period.
- 13.4.6. Add water to maintain the starting water head every 5 minutes during the test period of 30 minutes. Record the total amount of water required for readjustment.
- 13.4.7. The test is considered pass when:
 - 13.4.7.1. The loss of water does not exceed 1 litre per hour linear metre per metre internal diameter for VCP and reinforced concrete pipes.
 - 13.4.7.2. There shall be no loss of water for pipe other than VCP and reinforced concrete pipes.
 - 13.4.7.3. There is no visible leakage at the joints for all pipe types.
- 13.5. Closed-circuit Television (CCTV) Testing (if required)
 - 13.5.1. General

CCTV inspection where required shall be carried out in accordance with the relevant Authorities' guidelines to enable detection of sewer defects such as cracks, deformations, collapse, dislocation etc. which are not detected by normal means.
 - 13.5.2. Inspection Requirements
 - 13.5.2.1. A CCTV Inspection Contractor with Permit Holder Class D registered with the relevant Authorities shall be appointed to carry out the inspection works and the inspection work shall be witnessed by the S.O..
 - 13.5.2.2. General Inspection Coverage

Initial CCTV testing and inspection shall be conducted for a minimum 10% random selection of sewer pipes including all manholes and connections in accordance with the relevant Authorities' guidelines.
 - 13.5.2.3. High Risk Areas

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

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- a) Average depth of 6m or more
- b) Pipe diameter above 600mm.
- c) Areas that have restricted vehicular access for repair (e.g. central business district).
- d) Crossing under buildings, roads, railway, rivers and lakes including their reserve.
- e) Ground slopes greater than 30° inclination.
- f) All sewers installed using pipe jacking method and horizontal drilling method.
- g) All diversion or re-alignment of existing sewer networks.
- h) All single private developments (with PE > 30) connecting to existing main sewer.

13.5.3. Witness

Representative from Certifying Agency, S.O., Consultant representative and Contractor responsible for the construction of sewer shall be present at the onset for CCTV inspection at each project Site.

13.5.4. Documentation

13.5.4.1. Within seven (7) days after completion of the inspection, the Contractor shall submit to the Certifying Agency and S.O. the following:

- (i) Two (2) copies of digital records; and
- (i) One (1) copy of hardcopy report and recommendation

13.5.4.2. The format of the report and documentation shall be in accordance with the relevant Authorities' guidelines. All documents shall be certified and duly signed by the qualified person responsible for the CCTV inspection declaring the authenticity of the recording submitted and done in accordance with the procedure stated in the relevant Authorities' guidelines.

13.5.4.3. Documents shall be submitted to S.O. for the acceptance of completion of works.

- (i) Photographs showing sewer pipe laying during and after construction.
- (ii) Testing certificates.
- (iii) Supervision report.
- (iv) As-built Drawings.

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13.5.4.4. During Defects Liability Period

If any blockages, damages, seepages occur to the sewer networks during the Defects Liability Period, the S.O. may require the Contractor to carry out further CCTV inspection to determine the cause within 24 hours.

14. Backfilling

- 14.1. After the pipes have been tested and approved, the trench shall be backfilled with approved fill material, free from rock and other hard material, well compacted around the pipes up to a level of at least 300mm above the top of the pipes. After this has been approved, the remaining excavation shall be backfilled in 300mm layers, each layer being well compacted. The bedding details and the types of fill material shall in accordance with Drawings and the relevant Authorities' guidelines.
- 14.2. Trench support shall be progressively removed during the backfill work.
- 14.3. There shall be at least 300mm of cover over the sewer pipe before light mechanical compaction can commence.
- 14.4. There shall be at least 1000mm of cover (depth of backfill) over the sewer before heavy mechanical compaction can commence.

APPENDIX F1

TABLE F1: GRADIENT OF SEWER PIPES

Size diameter (mm)	Gradient
100	1 : 60
150	1 : 80
225	1 : 110
250	1 : 120
300	1 : 140
375	1 : 170
450	1 : 200

NOTE: Not applicable for force mains.

TABLE F2: PARAMETER LIMITS FOR SEWAGE AND INDUSTRIAL EFFLUENTS

Parameter	Effluent discharge to rivers/stream				Effluent discharge to stagnant water bodies*			
	Standard A		Standard B		Standard A		Standard B	
	Absolute	Design	Absolute	Design	Absolute	Design	Absolute	Design
BOD5	20	10	50	20	20	10	50	20
SS	50	20	100	40	50	20	100	40
COD	120	60	200	100	120	60	200	100
AMN	10	5	20	10	5	2	5	2
Nitrate Nitrogen	20	10	50	20	10	5	10	5
Total Phosphorus	N/A	N/A	N/A	N/A	5	2	10	5
O&G	5	2	10	5	5	2	10	5

- NOTES 1) N/A = not applicable.
 2) All values in mg/l unless otherwise stated.
 3) *Stagnant water bodies refer to enclosed water bodies such as lakes, ponds and slow-moving watercourses where dead zone occurs.
 4) A: Discharge upstream of water supply sources.
 5) B: Discharge downstream of water supply sources.

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TABLE F3: SEWERAGE WORK SUBMISSION

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

NOTE: 1) The submission procedure might change due to authority requirement.
2) Only for single manhole (outside property boundary) connected direct to existing manhole (public sewer)
– fall under low risk category (submit SWA and SWC)

TABLE F4: SEWERAGE WORK SUBMISSION FOR STP

No.	Item	Description	Submitting Person / Person in Charge
1.	PDC 1	Planning Approval	HODT
2.	PDC 2	(i) Sewer pipe reticulation (ii) SSTS/STP Detail Design	(i) HODT (ii) S.O./Contractor
3.	PDC 3	Detail for Structural Plans and Design Calculations	S.O./Contractor
4.	PDC 4	Detail for Electrical Design and Drawing	S.O./Contractor
5.	PDC 5	Details for Equipment and Material Data Sheets (EMDS)	S.O./Contractor
6.	PDC 6	Notice of Commencement Sewerage Works/Septic Tank Works	S.O./Contractor
7.	PDC 7	Notice of Intermediate Inspection of Sewerage Works	S.O./Contractor
8.	PDC 8	Notice of Final Inspection	S.O./Contractor
9.	PDC 9	Declaration by Competent Person Who Supervised the Septic Tank Works.	S.O./Contractor

NOTES 1) PDC – Planning, Design and Construction
2) The submission procedure might change due to authority requirement.

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1. General

- 1.1. The Works in this section shall comply with the latest regulations of SPAN, Uniform Technical Guideline (UTG) and any other relevant standards approved by the Government. The Works in Sabah and Sarawak shall comply with the relevant State Water Authority's (SWA) regulations and guidelines.
- 1.2. The water reticulation and internal cold water plumbing works shall be executed by personnel with valid permits issued by the relevant Authorities' as stipulated under Water Service Industry Act 2006. The Contractor shall be responsible for employing such personnel and all the works performed by them.

2. Local Authority's Approval, Fees and Deposit

The Contractor shall comply with the Local Authority's requirements to obtain the necessary approval for storage of materials along the road shoulders and work permit to cut across the metal road. All necessary fees and deposit for obtaining approvals from the Local Authority's to execute the works shall be borne by the Contractor. The Contractor shall liaise with the Local Authority before commencement of work, regarding trenching work crossing metaled road and along road shoulder.

3. Products and Materials

- 3.1. All products and materials to be incorporated in the work shall be new and unused. Materials to be used within the scope of work shall be those approved by the relevant Authorities. When the quality of a material or process is not specifically set forth in the approved products and materials list, the drawings, or the specifications, the best available quality of the material or process shall be provided, subject to the approval of the S.O.. The pipe material from the tapping point to the bulk meter that will be handed over shall be inspected by the Water Service Provider.
- 3.2. All products and materials shall be supplied by suppliers registered with the relevant Authorities. The Contractor shall provide proof to the S.O. in the form of a valid Confirmation Letter or Certificate of Registration issued by the relevant Authorities to the supplier. The products and materials shall also be subjected to other terms and conditions mentioned in these specifications.
- 3.3. All products and materials shall be of makes and models tested and approved for use. It is the Contractor's responsibility to verify that products and materials received for the Works conform to the current approved products and materials supplied by the relevant Authorities' registered suppliers.
- 3.4. All products and materials shall be transported, handled and stored in such a manner as to prevent damage or deterioration.
- 3.5. All products and materials furnished shall be subject to inspection for compliance with these specifications and all other appropriate specifications. The Contractor shall make an application to the S.O. for inspection at least five (5) days in advance of starting any work.

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4. Inspection

The S.O. shall at all times have access to the work wherever it is in preparation or progress and the Contractor shall provide proper facilities for such access and for inspection. The Contractor shall provide safe means to inspect the work. Failure or oversight of the S.O. or his representative to reject defective materials at the time of use, or to reject improper work at the time it is performed, shall not diminish the Contractor's obligations to comply with Drawings and Specifications. The Contractor shall remove and replace any faulty materials and work at no additional cost to the Government upon discovery of the defects or upon receipt of notice from the S.O. to do so.

5. Water Reticulation

5.1. Setting Out

All settings out for pipe laying works shall be performed by the Contractor's surveyor. Generally, stakes for alignment and grade shall be set at 10m intervals. The survey shall conform to the lines, grades, and dimensions shown on the Drawings. The Contractor shall preserve all monuments, benchmarks, survey markers and stakes. In case of their removal or destruction by the Contractor or his employees, agents or subcontractors, the Contractor shall be liable for the cost of their replacement. The pipeline from the tapping point to the bulk meter that will be handed over shall be inspected by the Water Service Provider.

5.2. Excavation

5.2.1. General

All general excavation works shall be as specified in SECTION C: EARTHWORKS.

5.2.2. Excavation for Pipe Trenches

5.2.2.1. Before commencing the excavation of pipe trenches, the routes of the pipelines shall be pegged out accurately. Strong sight rails shall be fixed and maintained at each change of gradient, and at as many intermediate points as may be necessary but not exceeding 100m apart. On these rails shall be marked the centre line and level to which the pipes are to be laid, and such rails shall be maintained in position and at the correct level from the time the excavation commences until backfilling is completed. The run of pipe trenches opened up ahead of pipe laying operations at any one time shall not be more than:

- (i) 100m if the pipe laying operations are in an urban area,
- (ii) 300m if the pipe laying operations are in the side tables of a trunk road, or
- (iii) 600m if the pipe laying operations are in unoccupied land schemes or housing estates under development or are in the side tables of minor rural roads.

5.2.2.2. The S.O. may, at his absolute discretion, vary the distances stated above if he considers that traffic, road, weather or physical conditions warrant the variation.

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- 5.2.2.3. Unless the S.O. permits otherwise, the trenches shall be excavated to the widths given in **TABLE W1**.
- 5.2.2.4. Where pipes are to be laid on a concrete bed, the width of the excavation at the bottom of the trench shall be the width of the underside of the concrete bed. At all joints, the trench shall be so excavated as to give a working space of not less than 300mm all around the joint. Where bends are made by deflecting pipes at joints the trench shall be widened to permit this operation. The sides of the trench shall be cut vertically, and where necessary, shall be protected against caving in by timbering to the approval of the S.O..
- 5.2.2.5. The trench shall be excavated to the intended depths or shown on the Drawings and shall be finished and trimmed accurately to level and grade.
- 5.2.2.6. Should the ground be so wet or soft that, in the opinion of the S.O., it does not form a firm base for the pipe, or should rock be encountered at the bottom of the trench, the trench shall be excavated 250mm below the level intended or shown on the Drawings and then brought back to the correct level with good selected earth or sand well rammed into place. Such deepening of the pipe trench and filling back shall be treated as a variation under the terms of the Contract. Should the bottom of the trench be inadvertently excavated below the specified level, it shall be brought back, at the Contractor's expense, to the correct level with good selected earth or sand carefully rammed into place.

5.2.3. Excavation of Road Crossings

- 5.2.3.1. No trench is to be excavated in the carriageway unless specific approval has been given by the relevant road authority. The whole operation of excavation and reinstatement of the trench shall be completed as quickly as possible. The Contractor shall ensure that minimum interference to traffic flow is maintained at all times.
- 5.2.3.2. A joint site inspection shall be arranged by the Contractor before the commencement of work if requested by the road authority. After pegging out, the Contractor shall inform the road authority and the police of the actual date of commencement at least one week in advance of and on the day of commencement.
- 5.2.3.3. If specific approval has been given to lay services across the road by open excavation, proper cutting of the metalled pavement shall be done and the Contractor shall ensure that the top edges of the excavation are neat and straight.
- 5.2.3.4. All materials from the excavation, if accepted for backfilling shall be neatly stacked outside the carriageway. Where there is no place to stack the excavated materials outside the carriageway, the excavated materials shall be removed from the work site immediately after excavation.

- 5.2.3.5. Where specific approval has been given by the road authority for half-width construction, the traffic lanes may be reduced to not less than 5.0m wide, and where necessary, the shoulder should be strengthened to accommodate traffic load to the satisfaction of the S.O. by the Contractor and at the Contractor's expenses.
- 5.2.3.6. Trenches shall be provided with adequate shuttering, walling and struts to prevent the adjoining road pavement from cracking and subsiding.
- 5.2.3.7. If a road diversion is required, the Contractor shall build it to the specifications of the road authority. It shall be maintained in good motorable condition until the reinstatement is completed.
- 5.2.3.8. Carriageway excavation across important and busy roads and junctions shall be carried out during off-peak hours. The S.O. shall specify the appropriate times based on the merits of each case and such conditions shall be strictly adhered to by the Contractor.

5.2.4. Excavation of Rock in Trench

Rock shall mean those geological strata of hard material which necessitates the use of blasting or approved pneumatic tools for their removal. Solid boulders found in trench excavations and foundation pits shall be considered as rock if such boulders are of size each exceeding 0.08m³. Shale and clay boulders shall not be classified as rock. The S.O.'s decision as to whether or not the material of the excavation is to be classified as rock shall be final. The Contractor shall be entitled to extra payment for rock excavation only if reasonable notice is given to the S.O. to examine and measure such material prior to breaking up. The volume of rock excavated shall be taken as its volume in-situ before it is broken up.

5.2.5. Pipe Bedding

The pipe bedding and foundation shall be prepared according to the Drawings. No pipes shall be laid until the S.O. has inspected and approved the pipe bedding and foundation. Any work that has been carried out without the approval of the S.O. shall, on the instructions of the S.O., be uncovered or removed by the Contractor and reinstated to the S.O.'s approval at the Contractor's own expense

5.2.6. Crossing Water Courses

Where the pipeline crosses underneath streams, culverts and other water courses, the Contractor shall be deemed to have allowed for all additional measures necessary for the proper construction of the pipeline especially maintaining the flow of water.

5.2.7. Backfilling of Pipe Trenches

- 5.2.7.1. After the pipe laying has been approved by the S.O. and before the pipelines are tested, sufficient backfilling of the trenches will be permitted to prevent "snaking" and to maintain the pipes in position, but all joints shall be left exposed. In any other locality where the trench may be filled with water and cause flotation of the pipes, or elsewhere as may be decided by the S.O. the backfilling shall follow the pipe alignment as closely as possible.

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5.2.7.2. In backfilling pipe trenches, only approved materials free from stones or rocks or other hard materials shall be carefully spread along the trench bottom between the pipes and the trench walls to a depth of about 150mm and shall be hand-rammed. Further layers each of about 150mm thick of the same materials shall then be spread and rammed in the same manner up to the top of the pipes. The remainder of the backfilling may consist of coarse materials free from boulders and large earth clods. It shall be placed in layers each of 150mm thickness and hand or mechanically rammed until the backfill is 300mm above the top of the pipes. The rest of the trench backfill shall be in layers each of 300mm thickness and compacted by a mechanical vibrating tamper to finish off slightly proud of the surrounding ground. The degree of compaction of each layer shall not be less than 95% of the dry density obtainable using the BS 1377 Compaction Test. The Contractor shall make good any settlement to avoid the formation of drains or gullies within the refilled trenches.

5.2.7.3. Approved fill material to be used as backfill to the top of the pipes shall be uniform low plasticity granular material. The material shall be free from all organic or other materials subject to decay. Highly plastic or expansive soils or clay shall not be used. The filling material shall be readily compactable to its maximum density and must not form mud, or otherwise breakdown when wet.

5.2.7.4. Should the material being placed as fill or backfill while acceptable at the time of selection, become unacceptable to the S.O. due to exposure to weather conditions or due to flooding or have become puddled, soft or segregated during the progress of the works, the Contractor shall, at his own expense, remove such damaged, softened or segregated material and replaced it with fresh approved material.

5.2.7.5. Where the pipeline crosses a road, approved sand shall be used as fill material up to the road formation level.

5.2.8. Backfilling of Excavations Other Than Pipe Trenches

5.2.8.1. Backfilling of all excavations shall not be carried out until the Works therein have been inspected and approved by the S.O.. In backfilling excavations other than pipe trench excavations, portions of the excavated materials may be used with the approval of the S.O.. Where required, approved materials shall be brought to the site for backfilling works. The materials shall be deposited and spread in layers not more than 300mm deep, and each layer shall be thoroughly rammed by a mechanical vibrating tamper or smooth wheel roller and watered if required.

5.2.8.2. If directed by the S.O, the backfilling shall be finished off slightly proud of the surrounding ground to allow for settlement, but the Contractor shall make good any settlement which may occur during the construction of the Works and during the Defects Liability Period of the Contract at his own expense.

5.2.9. Road Reinstatement

- 5.2.9.1. Road reinstatement works shall be carried out by the Contractor to a standard equivalent or superior to the road condition existing prior to excavation and to the requirements of the relevant road authority and approval of the S.O..
- 5.2.9.2. All backfilling shall be done by the Contractor with approved sand. No organic soil, broken premix or stones are to be used. The sand shall be compacted in 225mm layers. The degree of compaction of each layer below the pavement course shall not be less than 95% of the dry density obtainable using the BS 1377 Compaction Test. The Contractor shall bear the cost of such tests and shall make good any works which are found to be unsatisfactory.
- 5.2.9.3. Sand material shall be deposited in layers on both sides of the pipe simultaneously and thoroughly compacted and around the pipe working alternately on either side of the pipe until the trench has been filled up to the base course formation level.
- 5.2.9.4. The Contractor shall reinstate the road pavement by replacing, in the proper sequence, any block or metaling removed to the requirements of the relevant road authority and the approval of the S.O.. The road surface shall be reinstated with new materials of the type existing on site. Edges of the reinstated road pavement shall be straight and neatly finished to match the existing road to the satisfaction of the S.O..
- 5.2.9.5. In the absence of any written requirement, all reinstatement works shall be carried out within 24 hours after backfilling.
- 5.2.9.6. If the Contractor fails to carry out the reinstatement to the requirements of the relevant road Authority and the satisfaction of the S.O., the S.O. or the relevant Authority may proceed with such repairs and the cost of such reinstatement shall be recouped by the S.O. from the Contractor.

5.3. Pipeworks

5.3.1. Handling and Laying Pipelines

- 5.3.1.1. All handling, laying and testing of pipelines shall comply to the latest technical specifications from the relevant Authorities' or other relevant standards and also to the manufacturer's requirements:
 - (i) The minimum cover for main pipelines shall be 1m. Under roads and hard standing the cover shall be 1.2m. Otherwise the pipes shall be encased with concrete strength class C20/25 with minimum thickness of 150mm or as approved by the S.O..
 - (ii) The section of pipeline that runs across roads and culverts shall be made from Ductile Iron pipe (D.I) or mild steel pipe approved by the relevant Authorities.

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5.3.2. Testing of Pipelines

- 5.3.2.1. The Contractor shall provide all water required for filling, testing and retesting the pipelines, and any pumps, pipework fittings and pressure gauges required for the purpose. The testing of pipeline from the tapping point to the bulk meter shall be witnessed and handed over to the Water Service Provider.
- 5.3.2.2. Whenever a section (which shall not exceed 1000m long in or adjacent to roads or not exceeding 2000m long in open ground) of any pipeline has been laid, jointed and part backfilled as specified, it shall be prepared for testing by sealing the open ends temporarily with stop ends. The stop ends shall be of cast iron or steel. The stop end at the lower end of the section of the pipeline shall be fitted with a valved inlet pipe for use to fill the section of the pipeline with water and the stop end at the higher end of the section of the pipeline shall be fitted with a valved air release vent pipe. A pressure gauge shall be connected to the valved inlet pipe. The pressure gauge shall have a dial of not less than 150mm diameter and graduate to read up to 15 bars with 0.25 bar graduations. All pressure gauges shall be tested by the S.O. before use, and provisions shall be made for connecting the pressure gauge, if the S.O. so elects, to the valved inlet pipe.
- 5.3.2.3. The stop ends shall be braced to the satisfaction of the S.O. to withstand the end thrust which develops from water pressure. All weight, thrust and anchor blocks intended to prevent the vertical and lateral displacement of the pipes and specials shall have been properly completed and have attained an adequate strength before the tests are carried out. When gentle curves are affected by deflection pipes, these pipes shall be securely packed with backfill to prevent movement.
- 5.3.2.4. The section of the pipeline to be tested shall be filled with water of fair quality, free from sediment and from a source approved by the S.O.. The water shall be introduced into the section of the pipeline through the valved inlet in the stop end at the lower end of the section. During filling, provision shall be made for the air to escape from all high spots in the section by properly installing all air valves and from the air-released vent pipe in the stop end at the higher end of the section. The pressure/strength test shall be carried out first. Each section of the pipelines shall be tested to a minimum pressure of 16.0 bars head of water and shall comply with the technical specifications from the relevant Authorities or other relevant standards and to the manufacturer's requirements.
- 5.3.2.5. After the section of the pipeline has been filled with water for a period of not less than seven (7) days, more water shall be pumped into the section to raise the pressure slowly in increments of 10m head of water with a pause of one minute between each increment.
- 5.3.2.6. Should any appreciable drop in pressure be noted during one of these pauses the test shall be stopped until the cause of the pressure drop has been investigated and rectified. An engine-driven pump may be used until 55m head pressure is attained, and thereafter only a hand-operated pump shall be used.

- 5.3.2.7. The pressure/strength test shall be considered to have been passed when the pressure gauge shows no reduction in pressure during the specified one-minute pause and also during the period of 10 minutes after full test pressure has been attained. If these conditions are not satisfied a thorough inspection of the section of the pipeline shall be made. All defects shall be repaired and the test shall be repeated.
- 5.3.2.8. The leakage test shall then follow. The pressure shall be reduced to 10.5 bars head of water and shall be maintained as constant as possible for a period of 24 hours. Make-up water shall be pumped into the section of the pipeline from time to time to maintain this pressure. The leakage test shall be considered to have been passed if the make-up water pumped into the section of the pipeline does not exceed the allowable leakage calculated as: 0.05l/mm of internal diameter per kilometer of pipe per 24 hours. If this specified rate of leakage is exceeded a thorough inspection of the section of the pipeline shall be made. All leaks discovered shall be repaired and the section shall be tested again.
- 5.3.2.9. Every section pipeline shall be tested as described above in the presence of the S.O.. Testing may be carried out between sluice valves but not against the gates of the sluice valves.
- 5.3.2.10. All permanent thrust block provided at tees/bends shall be concreted and sufficiently cured prior to permission being given for testing. No temporary strutting or temporary bracing will be permitted in lieu of the permanent thrust blocks as the tests are also to subject these blocks to the transmitted pressures.

5.3.3. Flushing and Disinfecting Pipelines

When the final connections have been made and the pipeline has been tested to the satisfaction of the S.O. it shall be thoroughly cleaned, disinfected and flushed in sections by the Contractor. Water for this purpose shall be obtained from the Water Service Provider's sources and the Contractor shall pay all the charges incurred in connection therewith.

5.3.4. Non-Precast Valve chambers

- 5.3.4.1. Valve chambers shall be constructed to the size shown on the Drawings. Unless otherwise specified, all dimensions on plan shall be inside measurement. Manhole covers shall comply with BS EN 124.

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5.3.4.2. Unless otherwise shown on the Drawings all manholes and chambers shall be of brickwork in cement mortar (1:2). The brickwork foundation shall be constructed with concrete strength class C20/25 unless shown otherwise. The thicknesses and sizes shall be as shown on the Drawings. The inside of the chambers and manholes shall be lined with 12mm thick cement plaster (1:2). Externally, the exposed concrete or block brick surfaces shall be plastered with 12mm cement mortar (1:2) and terminated 150mm below the finished ground level. All internal angles shall be rounded off. Manholes and chambers shall provide with precast concrete cover unless otherwise specified on the Drawings. Approved typed wrought iron steps shall be built into the brick wall of all manholes and chambers of depth 2.0m or more and they shall be spaced not more than 300mm apart projecting 100mm over face of wall.

5.3.5. Precast Chambers

Precast valve chambers shall be as shown on the Drawings and in accordance with SECTION E: CONCRETING. Chamber covers shall comply with BS EN 124.

5.3.6. Washout (Scour Valves Location)

Washouts shall be constructed at locations specified in the Drawings or as may be directed by the S.O.. The washout branches shall be connected to the pipeline by special washout tees and sluice valves. From the washout sluice valves, HDPE or mild steel pipes shall be laid to the nearest drain or stream. The discharge point shall be downstream.

5.3.7. Indicator Post (Pipe and Valve Markers)

The Contractor shall provide and fix indicator posts close to the centre line of pipes, at valves, washout and other points as directed by the S.O.. The details of indicator posts are as shown on the Drawings

5.3.8. Hot Tapping

5.3.8.1. The Contractor shall submit a method statement as how to conduct the hot tap that has been approved by the State Water Authorities' to the S.O. prior to commencement of the works.

5.3.8.2. Hot tapping shall only be done in the presence of the Water Service Provider's representative. The tapping mechanism shall be of the self-purging type so that cutting chips are removed from the tapping machine and do not enter the pipeline.

5.3.8.3. All hot tap connections to existing pipelines, whether for mainline extension or service laterals, shall be performed by an authorized and qualified person.

5.3.8.4. The tapping machine shall be cleaned and disinfected prior to attachment to the tapping valve and saddle.

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5.3.9. Pipe Jacking

- 5.3.9.1. Placement of pipe by boring or jacking methods requires special S.O.'s approval for each instance. The methods and equipment used in boring and jacking operations shall be optional to the Contractor, provided that the S.O. reviews them prior to any work.
- 5.3.9.2. The Contractor shall submit to the S.O. the method statement on how to conduct the pipe jacking operation prior to commencement of the works.

5.4. External Water Storage Tanks (Factory Fabricated Tanks)

- 5.4.1. The Contractor shall supply a new tank reservoir and water tanks from suppliers with valid product listing and registration with the relevant Authorities'. All materials shall comply with the relevant Authorities' guidelines and approved by the S.O. before being installed. The type of tanks that may be supplied and installed shall be only as shown in **TABLE W2**.
- 5.4.2. The tank shown on the Drawings and specified herein shall be fabricated, supplied and installed by a manufacturer with valid registration with the relevant Authorities' guidelines.
- 5.4.3. Construction shall be governed by the Contract Drawings and specifications showing general dimensions.
- 5.4.4. The water tank inclusive of all associated pipe works shall be cleaned upon completion, tested for water-tightness and disinfected and approved by the S.O. before it is commissioned.
- 5.4.5. The test for the water-tightness, strength, etc. shall be in accordance with the requirement as set out by the relevant Authorities. The method of testing and test approval certificate shall be submitted to the S.O.. Water-tightness testing results for water tanks and components that will be handed over shall be witnessed by the Water Service Provider.

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TABLE W1: WIDTH OF PIPE TRENCHES

External Pipe Diameter (D)	Width of Trench
Not exceeding 460mm	D+300mm
460mm and above	D+600mm

TABLE W2: TYPE OF WATER STORAGE TANK

No	Product Name	Specified conditions/ Requirements
1.	Steel Tank with Lining or Coating (Non-Corrugated Type) (Glass Fused/Glass Coated/Epoxy Lining/HDPE) Lining	Maximum capacity allowed for elevated tanks is 2.3ML (500,000 UK gallons) and for ground storage tanks is 3.4ML (750,000 UK gallons). Maximum height allowed is 5m or 4 panels high whichever is lower. The minimum warranty period for the tank and sealant/lining shall be 10 years. The minimum thickness of PE/HDPE lining shall be 2.0mm.
2.	Cylindrical Steel Tank - Double Fold System	Maximum capacity allowed is 4.5ML (1,000,000 UK gallons). Maximum height allowed is 5m. The minimum warranty period for the tank and sealant/lining shall be ten (10) years.
3.	Polyethylene Storage Tanks (PE Storage Tanks)	Tanks shall have interlocking mechanisms. Tanks shall only be allowed up to 4,546L (1,000 UK gallons) capacity only. Multiple tanks on one tower structure shall be strictly not allowed.

Note: The use of other types of tanks are subjected to approval of SPAN and the S.O.

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1. General

- 1.1. Unless otherwise as shown on the Drawings, fencing shall be of chain link type as specified hereunder.
- 1.2. Unless otherwise as shown on the Drawings, the height of the fence shall be 1500mm from the ground up to the full height of the chain link.
- 1.3. The fence shall be erected to the extent and location as shown on the Site plan. Where fencing is to be located on the boundary of the Site, the Contractor shall ensure that its construction shall not infringe the adjoining properties.
- 1.4. All trees, bushes, or other obstacles which interfere with the construction of the fence shall be removed prior to commencing fence construction.

2. Post and Bracings

2.1. Mild Steel Post

- 2.1.1. Unless otherwise as shown on the Drawings, mild steel angle posts and bracings shall be of size 60mm x 60mm x 6mm. All steel members for fencing and gates shall be free from rust, scales and other defects and shall be to the approval of the S.O.. Previously used steel members shall not be used in the construction of new fencing and gates. Before delivery to the Site, the steel members for fencing and gates shall be pre-cut and assembled at the Contractor's workshop and painted with one (1) coat of approved metallic primer.
- 2.1.2. Where three strands of barbed wires are required, a mild steel angle arm 430mm long, of the same cross-sectional dimension as the post shall be welded at the top of the post at 45° inclinations. Where six (6) strands of barbed wires are required, two (2) pieces of mild steel angle arms as specified hereinbefore shall be welded to the top of each post forming the shape 'Y' with each arm having three strands of barbed wires. The welding used shall be of continuous fillet welds. Necessary holes shall be made in the posts, arms and bracings for insertions of fixing bolts and clips.

2.2. Concrete Post

- 2.2.1. Concrete post and struts for fencing shall be of size 150mm x 150mm precast using Prescribed Mixes Grade 25P and shall be erected at 3000mm centres commencing from the gate post and the posts shall be embedded plumb in Prescribed Mixes Grade 25P concrete footings of size 250mm x 250mm x 600mm deep. The finish to the formed surfaces shall be Class F2 and the finish to the unformed surfaces shall be Class U2. The tops of the posts and all arises shall be rounded or chamfered.
- 2.2.2. Reinforcement for concrete posts and struts shall be Grade 250 plain round steel bars.
- 2.2.3. Post should be holed to allow the fixing of line wires, etc. the hole for top line wire shall be approximately 75mm below the top of the post. Holes for bolts shall allow the bolt to be freely inserted. All holes shall be free from obstructions and accurately positioned within ± 5 mm.

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3. Chain Link Fencing

3.1. Chain Link Mesh, Straining

- 3.1.1. Chain link fences shall comply with *BS 1722: Part 1 Specification for Chain Link Fences*.
- 3.1.2. Chain link mesh, straining wires and barbed wires shall be made of galvanized steel and of approved quality. The mesh shall be of size 64mm made up of 3.25mm (10 gauges) diameter wire. Straining wires shall be of 4.06mm (8 gauges) diameters and barbed wires shall be of 2.64mm (12 gauges) diameters.

3.2. Fencing

- 3.2.1. Unless otherwise as shown on the Drawings, the mild steel angle posts shall be erected at 3000mm centres commencing from the gate post and the posts shall be embedded plumb in Prescribed Mixes Grade 25P concrete footings of size 250mm x 250mm x 600mm deep. Mild steel angle bracings of the same cross-sectional dimensions as the post shall be fixed at all corners, bends, junctions, gate posts and at every five bays of straight fencing.
- 3.2.2. The posts shall be set in holes to the required depth and stamped in a plumb and firm position to the line and spacing shown on the drawings or as directed by the S.O.. Post holes shall be large enough to allow for proper tamping. Backfill shall be placed in layers not exceeding 150mm, and compacted by hand tampers, machine tampers or other suitable equipment. Compacted backfill shall be crowned slightly to permit drainage away from the post.
- 3.2.3. The bracings shall be fixed at an inclination of 45° to the horizontal with top end bolted to the post, 300mm below the top of the post and the bottom end encased in concrete footing as described hereinbefore.
- 3.2.4. The chain link mesh shall be stretched or pulled tightly across the post with hand stretcher, or tensioning apparatus capable of adjustment and secured in place using approved fencing clips. The end of chain link fencing abutting mild steel gate posts shall be fixed by means of 19mm x 3mm mild steel flat straps drawn through the mesh and bolted using 10mm diameter mild steel bolts to 25mm x 25mm x 6mm mild steel plates welded to the posts at equal intervals of 300mm. Where gate posts are non-metal, the termination of the fencing at the gate shall be by means of another mild steel angle post fixed to one side of the gate post and strengthened by bracing as described hereinbefore. The chain link mesh shall then be strained by three strands of 4.06mm (8 gauges) diameter galvanized steel straining wires threaded through the mesh and fixed to the posts.
- 3.2.5. Each line wire and each line of barbed wire shall be secured to each intermediate post by one of the following methods;
 - 3.2.5.1. A hairpin staple shall be passed through a hole in the post and secured to the wire by three complete turns on each side of the post.
 - 3.2.5.2. The wire shall be threaded through a hole in the post.

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- 3.2.6. Where shown on the Drawings, the bottom of the chain link mesh shall be buried in continuous Prescribed Mixes Grade 25P concrete curbs. Unless otherwise detailed in the Drawings, the cross-sectional dimension of curbs shall be 125mm wide x 375mm high with 150mm protruding above the ground. The portion of the curb above the ground shall be rendered with 13mm thick 1:6 cement render to a wood float finish.
- 3.2.7. The ground surface around post shall be made good with the same material as the adjoining area.

4. Security Fencing

- 4.1. The security fencing shall be constructed and/or installed as shown on the Drawings and comply to requirement of relevant Authority.
- 4.2. All components shall be manufactured only by reputable licensed suppliers and approved by the S.O.. The supplier shall include special requirement such as mount CCTV Camera, lighting, barbed wire, razor wire etc. (if any) and responsible for the analysis, design, detailing, drawing, manufacture, material, handling and erection of the fence members and their ancillary fixing components.
- 4.3. All component shall be of hot dipped galvanised comply to BS EN ISO 1461.

5. Sports Fencing

- 5.1. The sports fencing shall be constructed and/or installed as shown on the Drawings and comply to requirement of Certified Body.
- 5.2. All components shall be manufactured only by reputable licensed suppliers and approved by the S.O.. The supplier shall include special requirement such as mount CCTV Camera, lighting, barbed wire, razor wire etc. (if any) and responsible for the analysis, design, detailing, drawing, manufacture, material, handling and erection of the fence members and their ancillary fixing components.

6. Gates

The gates shall be constructed and/or installed as shown on the Drawings.

7. Storage of Fencing

- 7.1. Gates, steel post and struts for fencing shall be stored off the ground on level supports and in manner which will not result in damage or deformation to the materials.
- 7.2. Fencing shall be protected from damage and damaged fencing shall not be used in the permanent works.

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8. Painting of Fence and Gates

The metallic primer previously applied to the steelwork at the workshop shall be touched up where necessary. Unless otherwise specified, the posts, bracings and gates shall be finished with two (2) coats of approved aluminium paint.

9. Re-erecting, salvage and dispose of existing fencing.

9.1. Taking Down and Re-Erecting of Existing Fencing

Where specified, existing fences shall be taken down, the materials carefully salvaged, and the fence re-erected, to the satisfaction of the S.O..

9.2. Remove and Salvage of Existing Fencing

Where removal and salvage of existing fences is specified, the Contractors shall carefully take down the fence, roll the wire, and place the material at locations as directed by the S.O.. Material that are not suitable for salvage shall be disposed of at locations as directed or acceptable to the S.O..

9.3. Remove and Dispose of Existing Fencing

Where removal and disposal of existing fences is specified, the Contractor shall completely remove the fence and dispose of all materials at locations acceptable to the S.O..

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1. General

- 1.1. All landscaping works shall be as shown on the Drawings. Turfing works and tree planting shall be carried out in such a manner as to minimize risks of damage to turfs and plants, and stunted growth. Turfing on all slopes shall be carried out immediately after slopes are formed. Tree planting shall be carried out as soon as practicable.
- 1.2. All landscaping works shall start as early as possible so that trees and plants are well-grown, and fully adapted to the new environment when the project concerned is handed over upon completion.
- 1.3. All landscaping works shall be furnished, installed and maintained by the Contractor as specified herein, or as shown on the Drawings, using the best horticultural management, giving special attention to planting practices, soil mixtures, and application of agricultural chemicals.
- 1.4. Existing water elements such as lakes, ponds and streams shall be incorporated into the landscape design. Unless otherwise specified, mature existing trees shall be retained and incorporated into the landscape design. Replantation and relocation of the trees removed shall be considered as part of the landscaping works.
- 1.5. Unless otherwise specified, all specifications shall refer to '*Garis Panduan Landskap Negara*' (latest edition).

2. Classifications and Characteristics of Plants

- 2.1. Plants shall mean trees, palms, shrubs, ground covers, and plants of other descriptions to be provided by the Contractor, as shown on the Drawings or listed in the plant schedules.
 - 2.1.1. Each tree shall possess characteristics of its variety and growth typical to such tree. All trees shall be well-branched, with straight trunks characteristic of the species, with well-shaped top and intact leader. The height shall be measured from the stem's earth line to the top of the tree.
 - 2.1.2. Palms shall have a vigorous root system, crown of new leaves, proper color of leaves of adult palms, and sufficient hardlines. The height of palms shall be measured from the stem's earth line to the base of the first frond.
 - 2.1.3. Shrubs and vines shall possess characteristics and growth habits typical of their species. All shrubs shall be well-shaped and bushy, with well-spaced branches and not skinny. The height of shrubs or vines shall be measured from the stem's earth line to the top branches.
 - 2.1.4. Ground cover is defined as any plant or groups of plants other than grasses, which shall satisfactorily cover the ground, forming a compact and attractive cover.
- 2.2. All plants shall be in healthy growth condition, free from pests and diseases and shall be representatives of their normal species or variety. All plants shall have well-branched heads and vigorous root systems and shall be injury-free. Unless otherwise shown or specified in the Drawings, only nursery-grown plants shall be used. Plants which are potted or plastic-bag-grown shall not be root-bound.

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3. Size of Plants

3.1. The size of plants refers to plant table size required for planting out on sites. All plants shall have the following sizes, unless otherwise stated:

3.1.1. Ground Covers

Ground covers shall have a stem length of not less than 150mm and have a minimum of nine cuttings per bag.

3.1.2. Shrubs

The overall height should be between 150mm and 1000mm. Minimum canopy size shall be 300mm in diameter.

3.1.3. Trees

a) Standard Trees

The trunk of the tree must measure between 80mm to 120mm in girth, measured 1.0 metre from ground level, and must have a clean trunk height of 1.5 metres. The tree must also have an overall height between 2.0 metres to 2.5 metres after being planted.

b) Fruit Trees

The trunk of the tree must measure between 50mm to 100mm in girth, measured 0.6 metres from ground level, and must have a clean trunk height of 1.0 metre. The tree must also have an overall height between 1.6 metres to 2.0 metres after being planted.

c) Semi Instant Trees

The trunk of the tree must measure between 150mm in girth or 2.5 inches to 3.5 inches in diameter, measured 1.0 metre from ground level, and must have a clean trunk height of 1.8 metres. The tree must also have an overall height of between 2.5 metres to 4.0 metres after being planted.

d) Instant Trees

The trunk of the tree must measure between 300mm in girth or 4 inches in diameter, measured 1.0 metre from ground level, and must have a clean trunk height of 2.0 metres. The tree must also have an overall height between 4.0 metres to 4.8 metres after being planted.

e) Instant Trees (Extra)

The trunk of the tree must measure between 450mm in circumference or 6.5 inches in diameter, measured 1.0 metre from ground level, and must have a clean trunk height of 2.5 metres. The tree must also have an overall height between 5.0 metres and 10.0 metres after being planted or pruned.

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3.1.4. Palms

a) Standard palms

For standard (ordinary) palms, the height is 2.0 metres measured from ground level to the top of the palm (overall height). For clumping type palms, there must be at least three clusters measuring 750mm to 1000mm from the earth line to the base of the first frond.

b) Semi Instant Palms

For single trunk palms, the clean trunk height ranges from 0.6 metres to 1.5 metres, except for *Bismarchia* spp, *Borassus flabellifer*, and *Neodypsis* spp, which have a clean trunk height between 0.6 metres and 1.0 metre. Clumping type palms have an overall height of 2.5 metres to 3.5 metres.

c) Instant Palms

For single trunk palms, the clean trunk height is 1.5 metres and above, except for *Bismarchia*, *Borassus flabellifer*, and *Neodypsis* spp., which have a clean trunk height of 1.0 metre and above. Clumping type palms have an overall height of more than 3.0 metres.

3.1.5. Climbers & Creepers

Climbers should be between one to five years old and have a length of not less than 600mm.

4. Site Cleaning

4.1 Site cleaning must be carried out before any landscaping work begins. Site cleaning includes the following tasks:

- i. Weeding (removal of all unwanted plants).
- ii. Removal of stones, wood, and other components found in the planting area, according to the instructions of the S.O..
- iii. Cleaning up any debris, such as trash, found at the project Site.

5. Handling and Planting

5.1. Handling

Plants shall be transported, handled and stored in such a manner as to prevent deterioration, damage or contamination. All plant materials shall be carefully protected and, if necessary, wrapped with hessian or gunny cloth during lifting, transportation, unloading and storage on Site.

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5.2. Planting

5.2.1. Pits/Holes

- 5.2.1.1. Generally, all pits for palms and trees shall not be less than 1000mm x 1000mm or 1/3 size bigger than the root ball, spaced at intervals as shown on the Drawings or approved by the S.O..
- 5.2.1.2. For shrubs, the pit size may be reduced to 500mm x 500mm deep (for big shrubs), or 300mm x 300mm x 300mm deep (for medium shrubs). Alternatively, continuous trench 500mm x 300mm deep respectively, shall be formed where required.
- 5.2.1.3. The bottom of all pits and trenches shall be forked loose to a depth of 300mm prior to backfilling with approved soil mixture before transplanting. All pits and trenches shall be soaked with water before planting.
- 5.2.1.4. Flower beds or trenches shall be made to the size as shown on the Drawings, and to a depth not exceeding 200mm.
- 5.2.1.5. The distance for planting trees and palms shall be between 3000mm to 5000mm unless otherwise specified. The minimum distance between main trees and buildings is 5 metres.
- 5.2.1.6. The distance for planting shrubs shall be between 150mm to 300mm unless otherwise specified.
- 5.2.1.7. For ground covers, planting works shall be carried out in zig-zag manner at a distance between 100mm to 150mm unless otherwise specified.
- 5.2.1.8. To install a minimum of 1000mm (H) x 750mm (L) x 750mm (W) of Polyethylene root barrier for trees planting at pavement/ hardscape area e.g. parking, walkway and sidewalks.

5.2.2. Transplanting

- 5.2.2.1. Transplanting shall not be carried out in very hot, dry weather conditions which may result in initial drying out of the root system and/or scorching of leaves.
- 5.2.2.2. Immediately before transplanting, the plants shall be carefully removed from the nursery bags or pots. The plants shall be placed into the pits and the surround filled with approved black earth making sure that the roots are not excessively disturbed. The earth around the base of the stems shall be recessed slightly to facilitate watering.

5.2.3. Plants Supports

All new plants shall be supported either by staking, tying or guying. Stakes shall be of wood, still or plastic of an approved type, driven into the ground before planting so as not to damage the root ball or aerial parts of plants. Stakes shall be long enough to support the plants, with one (1) tie per stake set 150mm from the bottom.

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6. Soil Mixture, Soil Conditioners and Chemical Fertilizers

6.1. Soil Mixture

The ratio of soil mixture shall be 3:2:1 which is three (3) parts topsoil, two (2) parts organic material and one (1) part sand.

6.2. Topsoil

Topsoil shall consist of fertile and friable topsoil obtained from a well-drained flood-free site excavated from not more than 300mm deep from ground level. It shall be of medium texture and without admixture of stones, lumps, plants or roots, and other extraneous matter. Topsoil material shall be obtained from excavated topsoil sourced or, if not available, from other sources as approved by the S.O..

6.3. Soil Conditioners (Manure and Compost)

Soil Conditioners shall be organic materials such as composed coconut, fibre, peat or other approved materials which shall be composed in a stable condition, free from toxic impurities and containing no substance injurious to plants. The organic matter with 45% - 55% moisture content and with Ph adjusted to 5.5 - 6.5 shall be used. All manure or compost used as additive to the soil mixture shall be procured from an approved source.

6.4. Chemicals Fertilizers

Chemicals fertilizers shall be granular slow-release compound fertilizers with a minimum four (4) months release period at 32°C. They shall be stored in waterproof sealed bags and kept under shelter. The Contractor shall submit manufacturer's technical data on the proposed fertilizer for the S.O.'s approval prior to the application of the fertilizer.

7. Turfing

7.1. Unless otherwise shown on the Drawings, turfing shall be provided to all exposed earth surfaces throughout the Site. All surfaces to be turfed shall be completely cleared of all incidental Contractor's debris, stone and other obstructions.

7.2. The ground to be turfed shall be graded to fall toward the surface water discharge line as shown on the Drawings or approved by the S.O..

7.3. On level ground, minimum gradient of 1:60 shall be provided to eliminate ponding hollows. Any undesirable vegetation, debris, stumps or roots shall be grubbed up and removed from the Site.

7.4. Topsoil shall be provided on a prepared surface and compacted to provide a suitable tilt for the growth of the turf. Before spreading the topsoil, the ground is to be trimmed and levelled and all roots of bushes and undesirable growth grubbed up and removed from the Site.

7.5. All turfs shall be of good, healthy, dense indigenous cow grass (*Axonopus Compressus*) from an approved source. The grass shall be of even density, vigorous growth and green in colour, forming a turf sufficiently fibrous to hold together when installed. They shall be free from mimosa, weeds or other foreign vegetation.

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- 7.6. Each turf shall be approximately 300mm x 300mm x 50mm thick with roots still attached to the soil. They shall be kept moist and in shade and shall be planted within 24 hours of lifting. Samples of turfs to be used shall be submitted to the S.O. for approval before any turfs are brought in for use. The sources of material shall be stated by the Contractor.
- 7.7. Unless otherwise shown on the Drawings, close turfing shall be provided to slopes and extending 2m of the platform at the top and bottom of the slope, 1m the sides of all drains, and 2m wide of road shoulders, so that they cover the whole area without any space/gap between them. The minimum size of each spread is 300mm x 600mm x 25mm.
- 7.8. Each sod shall be pegged in place with wooden/bamboo pegs 12mm diameter and 200mm long through the sod and into the soil base. These pegs shall be removed after the turf have firmly established. On steep slopes, netting in shall be laid onto the turfed areas for protection.
- 7.9. Unless otherwise shown on the Drawings, spot turfing shall be carried out on all level ground. Grass planting distance is 150mm x 150mm. The minimum size of each piece is 150mm x 150mm x 25mm. The space between the plants should be filled with a soil mixture.
- 7.10. Turf shall be fertilized with approved slow-release fertilizers high in Nitrogen content, one (1) month after planting at the rate of 60gm/m² and evenly spread over the whole area. Turfs shall be well watered after each fertilizer application which shall be done once in every three (3) months after grass cutting.
- 7.11. Grass cutting shall be done every three (3) weeks after one (1) month growth/establishment by grass cutter/mover as often as is required to give a well-trimmed sod not more than 25mm in height for flat surface and not less than 50mm on slope. All clippings shall be removed from the Site before watering is carried out.
- 7.12. Unless otherwise specified, all specifications shall refer to '*Buku Spesifikasi Turf, Jabatan Landskap Negara*' (latest edition).

8. Football and Playing Fields

8.1. General

- 8.1.1. Unless otherwise specified hereinafter, turfing for football and playing fields shall be as specified hereinbefore. Turfing works shall start as soon as possible and shall be completed and fully established not later than three (3) months before the date of completion of the works.
- 8.1.2. The Contractor shall supply and install sub-soil drains as specified hereinafter at the locations and in accordance with the lines, levels and grades shown on the Drawings and/or as directed by the S.O..

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8.2. Materials

8.2.1. Subsoil Drain Pipes

Subsoil drain pipes shall be of high-Density Polyethylene (HDPE) perforated corrugated drainage pipe to DIN 16961 PT 1 and 2:1989 or equivalent, or Polyvinyl Chloride (PVC) pipes for subsoil drains complying with as Specification 2439.1 or BS 3656 or equivalent, of diameter and lengths of pipe as shown on the Drawings.

8.2.2. Filter Materials

Filter Materials shall consist of an angular, clean, hard and durable crush rock with uniformly sized particles of 14mm, free from lumps of clay or organic matter.

8.2.3. Geotextile Fabric

Geotextile fabric shall be of non-woven type thermally bonded with minimum weight of 100g/m² or equivalent and shall be of approved manufacturer.

8.3. Site Preparation

The Site area shall be completely cleared of all debris, large stones, discarded gravel and other unacceptable materials. The Site shall then be graded to form a crown at the centre of the field with a minimum gradient of 1:300. The soil shall be of good texture and structure with majority of the crumbs of size 1mm to 2mm and not contaminated with seeds, stolons or rhizomes of noxious weeds.

8.4. Trenching for Subsoil Drain Pipes

Trenches shall be excavated and trimmed clean true to grade and alignment and the geotextile fabric shall be laid as shown on the Drawings. The fabric shall overlap the full width of the trench at the top. Where the fabric requires jointing along the trench, it shall overlap a minimum of 500mm at the joint.

8.5. Laying and Jointing Subsoil Drain Pipe

Subsoil pipe shall be laid and bedded as shown on the Drawings. Subsoil drain pipe shall be joined according to the manufacturer's recommendations.

8.6. Backfilling

The trench shall be backfilled with the filter material in layers not exceeding 150mm loose thickness and uniformly compacted by suitable method approved by the S.O. to the level as shown on the Drawings. Care shall be taken that the pipe is not damaged or displaced.

8.7. Outlets

Outlets shall be constructed as shown on the Drawings and to the S.O.'s approval.

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8.8. Laying of Sand and Turf Mixture

- 8.8.1. The prepared surface of the field shall be laid with a first layer of 100mm thick river sand or other suitable coarse grained granular materials and a second layer of 100mm thick turf mixture before receiving the turf.
- 8.8.2. The Contactor surface shall carry out final gradient check prior to the turfing works.
- 8.8.3. Before turfing works commence, the Contractor shall submit samples of the turf mixture for the approval of the S.O.. The turf mixture shall be laid to the required formation level and gradient.
- 8.8.4. The turf mixture shall have the following composition by weight of 4% - 5% organic matter, 12% - 15% clay and 81% - 85% river sand. The PH value for the root zone medium shall be 5 to 7.5.

8.9. Inspections

- 8.9.1. The Contractor shall give not less than 24 hour notice prior to the commencement and upon completion of the under mentioned works. The Contractor shall not proceed with the next succeeding operation until specific approval has been given for the following:
 - 8.9.1.1. Trench excavation.
 - 8.9.1.2. Trench lining with geotextile fabric and laying of subsoil drain pipe
 - 8.9.1.3. Filter material backfill
 - 8.9.1.4. Sand laying
 - 8.9.1.5. Turf mixture
 - 8.9.1.6. Turfing work

8.10. Levelling of Field

- 8.10.1. The Contractors shall water the turf at least twice a day or as instructed by the S.O.. The rate of application and frequency of watering shall be sufficient to maintain the turf mixture in a moist condition to ensure proper and healthy growth of the turf even during the dry weather.
- 8.10.2. Water shall be applied as fine spray by means of suitable pumps and hose or sprinkler or any other method approved by the S.O. as not to disturb the turf mixture.

8.11. Weed Control

Weeding shall be carried out on the newly turfed area about ten (10) days after planting to get rid of foreign species and maintain a pure culture of Axonopus Compressus (Cow Grass). Weeding on a Continuous basis shall be carried out to prevent weeds from growing.

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8.12. Fertilization

The first fertilization shall be carried out two (2) weeks after planting, using a mechanical spreader. Subsequently, the fertilizer shall be applied at three (3) weeks intervals.

8.13. Mowing

8.13.1. Mowing shall be carried out using properly sharpened and adjusted machine tools so that the turf is cut cleanly, and no tearing takes place.

8.13.2. The first cut shall be carried out when the turf reaches 50mm – 70mm in height. The turf shall be cut to 25mm – 30mm in height. Subsequently, mowing shall be done at least once in every two (2) weeks.

8.14. Top Dressing

The Contractor shall, from time to time or whenever directed by the S.O. to check the flatness of the field and if found uneven, rectify by top dressing with turf mixture and followed by proper compaction.

8.15. Maintenance during Defect Liability Period

8.15.1. The Contractor shall be responsible for carrying out full-time intensive maintenance of the turfing works for the entire duration of the Defect Liability Period of the Works.

8.15.2. The maintenance includes watering, weed control, fertilization, mowing and top dressing, all as specified hereinbefore.

8.16. Handing Over of the Works

On handing over of the works, the field shall be in good playable condition with all the full line markings to the dimensions as shown on the Drawings.

9. Relocation and Protection of Existing Trees

9.1. Relocation of Trees

9.1.1. Where specified shown on the Drawings or if directed by the S.O., all existing trees having girth of 300mm and below identified and marked for relocation, shall not be cut, but shall be dug up, prepared for, and relocated by the Contractor to other areas within, or in the vicinity of the Site. In the event of any such trees being accidentally cut or damaged, the same shall be replaced with trees of equivalent size and species by the Contractor.

9.1.2. The Contractor shall protect and maintain the relocated trees by fencing to a height of 1.2m, watering, manuring, pruning, and other necessary treatments throughout the contract period (including the Defects Liability Period) until satisfactory growth is established. Any relocated trees which damage are accidentally or fail to re-grow satisfactorily within the Defect Liability Period, shall be replaced accordingly at the Contractor own cost.

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9.2. Protection of Trees Retained on Site

- 9.2.1. All existing trees having girth of 800mm and above identified and marked by the S.O. or as shown on the Drawings to be retained on Site, shall be protected and maintained by fencing to a height of 1.2m, watering manuring, pruning and other necessary treatments throughout the contract (including the Defects Liability Period) so as not to jeopardize their growth.
- 9.2.2. The ground around the tree spread shall be protected to prevent contamination from materials and chemicals detrimental to plant growth. Method of protection shall be to the approval of the S.O. in the event of any such trees being accidentally or otherwise cut or damaged, the same shall be replaced by the Contractor with trees equivalent size and species at his own cost.

10. Maintenance of Plant and Turf

10.1. General

- 10.1.1. After planting and prior to the onset of the maintenance period, the Contractor shall be responsible for carrying out all necessary measures to ensure that all plant materials and turfing thrive and become established, and that the landscaped areas are kept in a clean and tidy condition.
- 10.1.2. The Contractor shall protect and maintain the plants and turfing from any damage and destruction, by way of watering, manuring and tilling, any by staking and fencing, where necessary, to support and protect the plants, until the end of the Defects Liability Period. All plants and turfs which are defective and/ or fail to grow within the Defect Liability Period or as instructed by the S.O. shall be replaced immediately and/ or replanted accordingly, at the Contractor's own cost.
- 10.1.3. Unless otherwise specified, all maintenance works shall be carried out complying to the minimum standard as detailed out in the '*Piawaian Produktiviti Penyelenggaraan Landskap*' (latest edition) by *Jabatan Landskap Negara, Kementerian Perumahan dan Kerajaan Tempatan*. During the Defects Liability Period, the Contractor is required to implement the maintenance works as follows:
 - 10.1.3.1. Water the plants twice per day.
 - 10.1.3.2. Feeding the plants with fertilizers (NPK Green) 15:15:15 once (1) every month for the first six (6) months and as needed after six (6) months onwards. Application of the fertilizer shall be as specified hereinafter, and as recommended by the fertilizer manufacturer.
 - 10.1.3.3. Weeding/Hoeing and Site Cleaning
 - 10.1.3.4. Disease and Pest Control
 - 10.1.3.5. Plants Replacement
 - 10.1.3.6. Mulching

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10.1.3.7. Trimming/Pruning

- 10.1.4. The Contractor shall provide persons who are competent and experienced for organizing and running the maintenance programs during the Defects Liability Period, at the Contractor's own cost.
- 10.1.5. The Contractor shall be responsible for the use of all materials, labour and equipment. Any injury to plants caused by such materials, labour and equipment shall be corrected and repaired at the Contractor's own cost.
- 10.1.6. The Contractor shall carry out all necessary measures to ensure that all plants thrive and become established within this period. All landscaped areas shall be inspected at monthly intervals and lists of remedial works shall be issued upon each inspection within seven (7) working days. All items on the remedial work list shall be executed before the next scheduled inspection.

10.2. Weeding and Hoeing

Weeding and hoeing shall be done frequently, depending on weed growth or whenever directed to do so by the S.O.. The Contractor shall be responsible for maintaining areas close to the base of trees or shrubs. Weeding shall be done manually either by hand, hoe or garden tools at least once (1) a month, with care taken not to wound plant stems.

10.3. Fertilizers and Application Rate

- 10.3.1. Feedings to plants shall be done with approved organic manure or slow-release fertilizers at regular intervals to maintain healthy growth. The S.O. reserves the right to request the Contractors to use any kind of fertilizer, let it be straight mixture, complex or slow release, at the Contractor's own cost.
- 10.3.2. Six (6) applications shall be required during the maintenance period. The first shall be carried out during the second (2nd) month after planting. The second and subsequent applications shall be worked into the soil above the roots and lightly watered in. fertilizer shall be applied, preferable, when the plants are in their active stage of growth.
- 10.3.3. Slow-release fertilizers shall be applied strictly in accordance with the manufacturer's directions and recommendations.
- 10.3.4. The Contractor shall take note that plant feeding shall be carried out only after all other maintenance works like weeding, hoeing and trimming or pruning have been carried out.

11. Final Handing Over

- 11.1. Two (2) weeks before the expiry of the Defects Liability Period a joint final inspection shall be held with the S.O. to review the requirements for any alteration or replacement in order to gain approval for Final Handing Over.

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- 11.2. At the time of Final Inspection, all areas under this Contract shall be free from weeds, neatly cultivated and raked, and all plant boxes in good order. Grass shall be neatly cut and all clippings removed. No bare patches of earth shall be visible in turf or planting areas unless otherwise specified.
- 11.3. If any portions of the works are found to be not acceptable, under the terms and intent of the Drawings and specifications, the Contractor shall carry out immediate remedial works to S.O.'s acceptance before the date of Final Handing Over. The cost of all remedial works shall be borne by the Contractor.



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