

 JKR MALAYSIA	SECTION O: INTERNAL COLD WATER AND SANITARY PLUMBING SYSTEM	No. Dokumen : JKR 20800-0257-25 No. Keluaran : 01 No. Pindaan : 00 Tarikh : 14 Februari 2025 Muka Surat : O/31
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- 5.10.2. All repairs on the complete internal cold water and sanitary plumbing system shall be guaranteed by the Contractor against defects in workmanship and materials for a period of 1 year to take effect from date of completion of the repairs. During the guarantee period, the Contractor shall rectify defects in repairs carried out by him with no additional charge to the Government.

5.11. Service and Maintenance Records

- 5.11.1. The Contractor shall provide a service and maintenance record book for the complete internal cold water and sanitary plumbing system being serviced and maintained by the Contractor. This record book shall be kept in the plant or maintenance room of internal cold water and sanitary plumbing system being serviced and maintained, and brief details of all services, maintenance and repairs carried out the address and telephone number of the Contractor's personnel and person in charge shall also be recorded into this record book to facilitate emergency service call.
- 5.11.2. The Contractor shall also keep an accurate detailed record in duplicate of all service, maintenance and repair work carried out by him on the complete internal cold water and sanitary plumbing system as well as ancillary equipment. This record shall be in the form of a Maintenance/Repair Sheet and shall be countersigned by the S.O. each time the internal cold water and sanitary plumbing system as well as ancillary equipment is attended to by the Contractor.

APPENDIX X1

Limit of Mechanical Scope of Design (Civil and Mechanical)

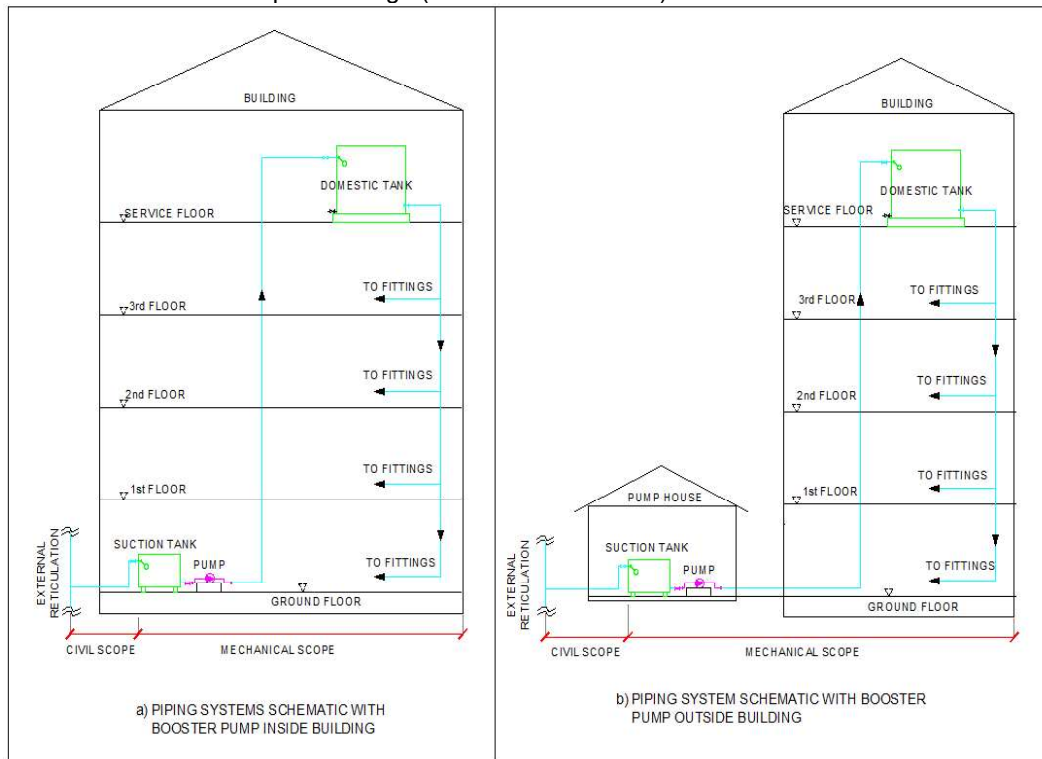


FIGURE O1: INDIRECT FEED SYSTEM

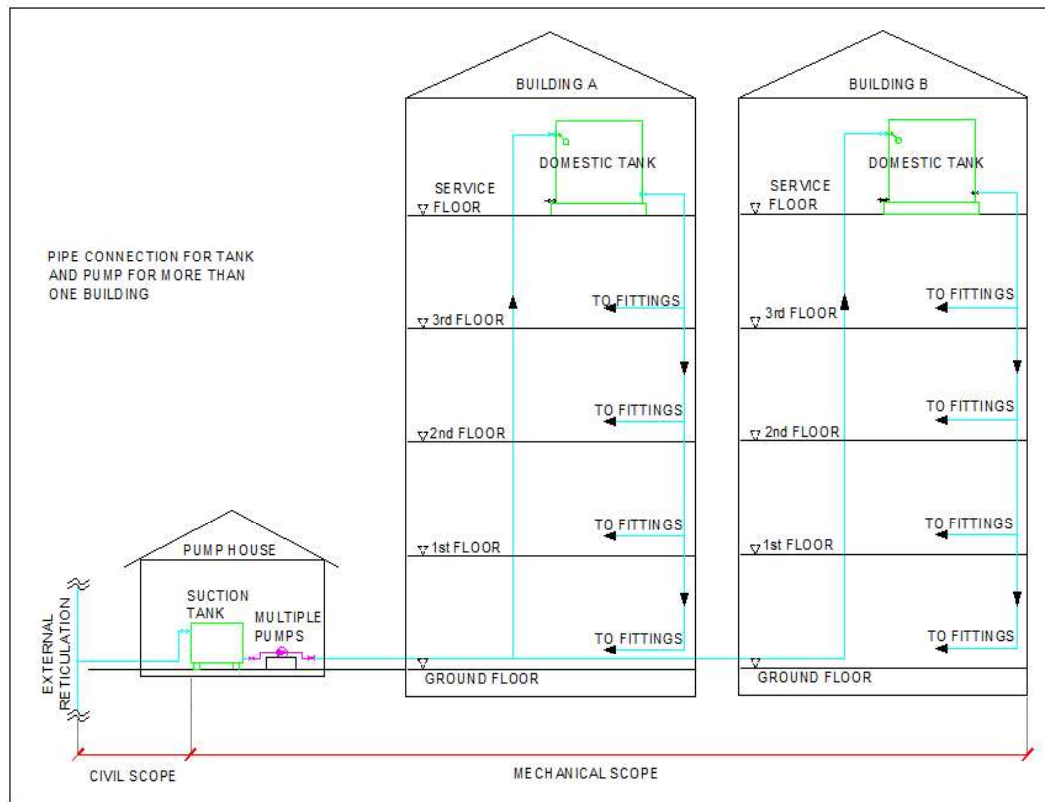


FIGURE O2: PUMPING TO MULTIPLE BUILDING BLOCKS

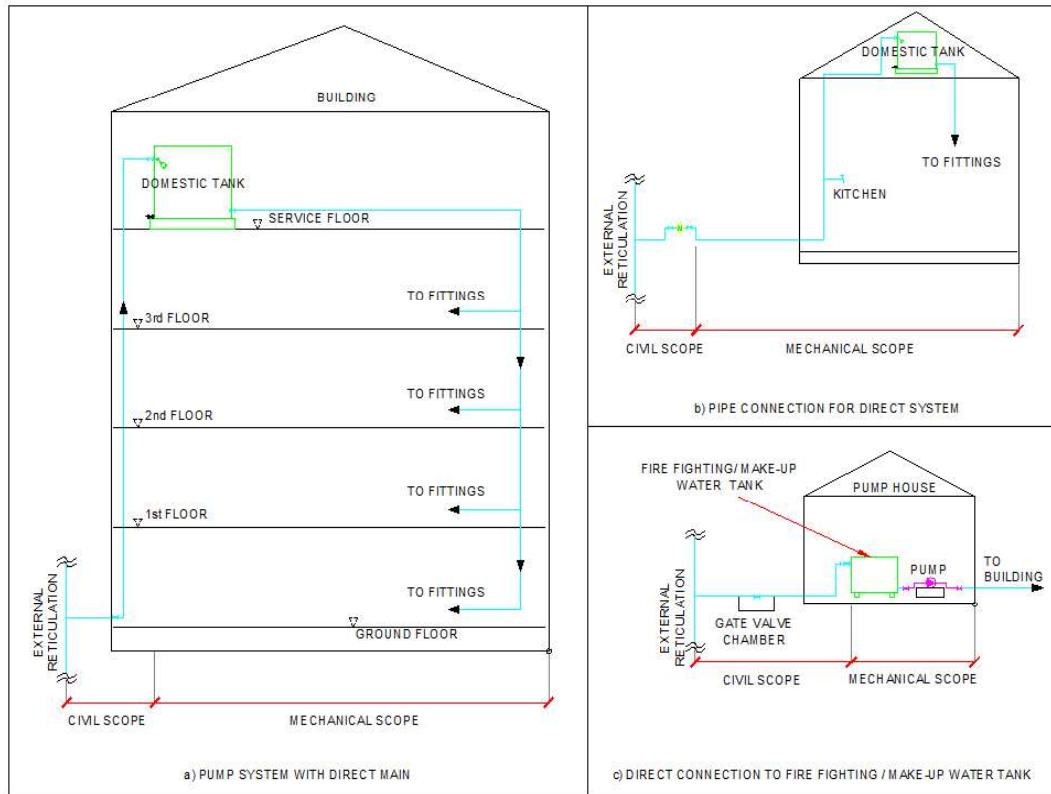


FIGURE O3: DIRECT FEED FROM MAIN WATER PIPE

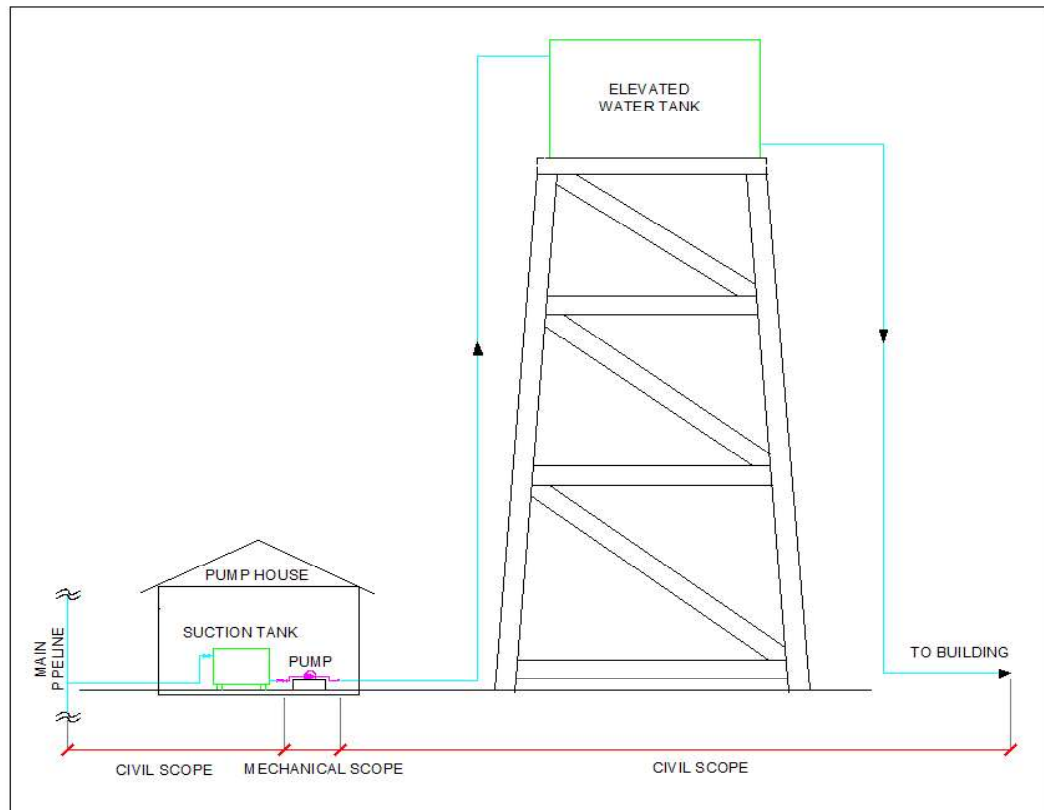


FIGURE O4: PUMPING TO ELEVATED WATER TANK

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1. General

- 1.1. The sanitary fitting works shall be executed by personnel with valid permits issued by SPAN as stipulated under *Water Service Industry Act 2006*. The Contractor shall be responsible for employing such personnel and all the work performed by them.
- 1.2. Design, dimension, requirement, specification and material for sanitary fittings shall comply with MS 1184: Universal Design and Accessibility in Built Environment-Code of Practice.

2. Products and Materials

- 2.1. 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 SPAN. 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..
- 2.2. All products and materials shall be supplied by suppliers registered with SPAN. The Contractor shall provide proof to the S.O.. in the form of a valid Confirmation Letter or Certificate of Registration issued by SPAN to the supplier. The products and materials shall also be subjected to other terms and conditions mentioned in these specifications.
- 2.3. All products and materials shall be of the makes and models tested and approved for use. It is the Contractor's responsibility to verify that products and materials received for the job conform to the current approved products and materials supplied by SPAN registered suppliers.
- 2.4. 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.

3. Sanitary Fittings

3.1. Fittings

- 3.1.1. All sanitary fittings shall be water-efficient with Water Efficient Product Labelling Scheme (WEPLS) certification and comply with the Water Services Industry Act 2006 and Water Services Industry (water reticulation and plumbing) Rules 2014.
- 3.1.2. Unless otherwise shown on the Drawings, all fittings including all necessary brackets and accessories shall be as scheduled in **TABLE P1** hereinafter. The Contractor shall be responsible for determining the type of trap required for each fitting. All necessary concrete backing shall be provided to fittings secured to floors.
- 3.1.3. Unless otherwise shown on the Drawings, the colour of sanitary ware shall be in white.

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3.2. Vanity tops

- 3.2.1. Unless otherwise shown on the Drawings, a minimum thickness of 12mm vanity tops of approved manufacture and colour shall be installed in accordance with the manufacturer's instructions. It shall be moulded as one solid piece with its top sloping gently towards the wash hand basin and having a slight upturn or kerb as its outer edges including backsplash to prevent water damage to wall and vanity back.
- 3.2.2. It shall be manufactured from non-porous composite product composed of polyester resin and calcium carbonate marble dust with the permanence of stone and an aesthetic appeal of natural marble or granite. The slab surface shall have a glossy finish and protected by suitable polymer to ensure durability and impermeability. It shall be stain-resistance and chemical-resistant, and UV stabilised.

3.3. Type of Sanitary Fittings and Description

- 3.3.1. Unless otherwise shown or/and specified on the Drawings, the sanitary fittings shall be of the following:
 - 3.3.1.1. All sanitary fittings shall be of white in colour, from an approved manufacturer, generally ensuite and complete with all necessary fittings.
 - 3.3.1.2. Waste and bath overflow, chains and stays, shall be chromium plated brass to BS EN 274 Part 1-3.
 - 3.3.1.3. Taps and combination tap assemblies shall be chromium plated brass to BS EN 200.
 - 3.3.1.4. All sanitary fittings shall comply with Water Services Industry Act 2006 and Water Services Industry (Water Reticulation and Plumbing) Rules 2014.

3.4. Wash Basin

- 3.4.1. Unless otherwise specified, wash basin for public buildings shall be 600mm x 410mm x 200mm earthenware plain edge sink in white fireclay complete with chromium plated tap, blank tap hole stopper, 30mm 'P' trap with 40mm seal, waste fittings, plug with chain and painted bracket supports to S.O. approval.
- 3.4.2. Where shown wash basins of MS 147 shall be of the following types as specified:
 - 3.4.2.1. Under counter basin with overflow.
 - 3.4.2.2. Wall hung basin with or without pedestal as specified.
 - 3.4.2.3. Semi-recessed basin with or without overflow as specified.
 - 3.4.2.4. Countertop basin with or without overflow as specified.
 - 3.4.2.5. Handicap basin.

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TABLE P1: SANITARY FITTINGS

No.	Item	Description
1.	Wash Basin	Wash basin for domestic purposes shall be 560mm x 410mm in approved colour vitreous china complete with chromium plated tap, blank tap hole stopper, 30mm 'P' trap with 40mm seal, waste fittings with chrome-plated brass pop up waste and painted bracket supports. All wash hand basins and countertops shall be fixed at a height between 750mm to 850mm measured from finished floor level to the top rim of the bowl with knee clearance for wheelchair access of 650mm to 700mm high and 200mm deep following MS 1184: Universal Design and Accessibility in Built Environment- Code of Practice Clinical wash hand basins shall be wall hung vitreous type and not less than 600mm in width complete with a wall mounted 175mm long elbow action lever mixer with premix function. Clinical wash hand basins shall not have any overflow outlet, soap recess nor basin plug.
2.	Vanity tops	Vanity top as specified, with integrated sink as shown on the Drawings, complete with chromium-plated tap, blank tap hole stopper, 30mm 'P' trap with 40mm seal, waste fittings with chrome-plated brass pop up waste. Vanity top as specified, but with holes pre-punched to receive an under-counter vanity basin and tap respectively, as shown in the Drawings, complete with 555mm x 415mm under-counter vanity basin in vitreous china, complete with chromium-plated tap, 30mm 'P' trap with 40mm seal, waste fittings with chrome-plated brass pop up waste and painted bracket supports.
3.	Sinks	915mm x 460mm, single bowl single drainer stainless steel sinks shall be to BS 1244, stainless steel grade 304 (0.8 to 0.9mm) minimum thick, with satin finish to the size and configuration shown on the Drawings with overflow and sound deadening pads under the sink and drainers. Metal sinks in stainless steel to size and shape as shown on the Drawings, complete with chromium plated tap as required, 40mm wastewater outlet, chrome-plated brass pop up waste and painted mild steel frames support.
4.	Water closet	Unless otherwise specified, water closet shall be pedestal closet in white vitreous china conforming to MS 1522 complete with pedestal pan, 'P' trap and ventilation outlet, plastic hinged seat and rubber buffers. Squatting closet in white vitreous china conforming to MS 1522 complete with pair of raised foot treads in white fire clay with 'P' trap and 40mm diameter uPVC flush pipe. The top of the toilet seat shall be optimized at 460mm from the finished floor level and comply with MS 1184: Universal Design and Accessibility in Built Environment- Code of Practice.

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No.	Item	Description
6.	Cistern for Water Closet	Dual-flush cistern with a nominal volume of a full and partial flush not exceeding 6 and 3 litres respectively in compliance with Water Services Industry Act 2006 and Water Services Industry (Water Reticulation and Plumbing) Rules 2014. WC Cistern shall conform to MS 795 with 40mm flush pipe, water inlet valve, 20mm diameter overflow for discharge externally and chrome flushing lever handle. WC shall be of vitreous china cistern conforming to MS 795 with 40mm flush pipe, water inlet valve, 20mm diameter overflow for discharge externally and chromed lever handle. Each flush cistern for WC shall be tested as stipulated in the requirements of MS 795.
7.	Cistern for urinal	Single flush 2.5 litre urinal flushing cistern in white vitreous china conforming to MS 795 complete with chromium plated flushing inlet pipe, 20mm diameter overflow for discharge externally and chrome lever handle in compliance with Water Services Industry Act 2006 and Water Services Industry (Water Reticulation and Plumbing) Rules 2014.
8.	Flush valve for Water Closet	Unless specified, WC flush valve shall be low pressure single flush 6 litres gravity flush water closet valve. It shall have a non-hold-open feature or an automatic shut-off system in compliance with Water Services Industry Act 2006 and Water Services Industry (Water Reticulation and Plumbing) Rules 2014. Vacuum Breaker is optional, only applicable to WC flush valves intended to be connected to direct potable water mains. Its performance requires proper match of valve and WC pan conforming to MS 1522. Each flush valve shall be made of metal (preferably copper alloy) and corrosion resistant. All exposed surfaces to the users shall be chromed plated or made of stainless steel. Where applicable flush valve for water closet used in the building shall be certified by WELPS, SPAN or other eco labelling.

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No.	Item	Description
10.	Shower fittings	Shower fittings shall be approved chromium plated brass easy clean valve, with 3" diameter shower face and Chromium plated stainless steel grade 304 arm.
11.	All types of taps	Unless otherwise specified, taps shall be approved chromium plated brass/ ABS chrome plated taps conforming to BS EN 200 - testing method and have SIRIM certification with minimum 5 years warranty. All taps shall be fitted with aerator in compliance with Water Services Industry Act 2006 and Water Services Industry (Water Reticulation and Plumbing) Rules 2014. Where applicable the water taps used in the building shall be certified by WELPS, SPAN or other eco labelling.
12.	Hand Bidet	Unless otherwise specified, bidet shall be chromium plated copper alloy nozzle, 1.2m heavy duty double interlock stainless steel grade 304 flexible hose, chromium plated ABS plastic wall hanger and quarter turn angle valve. OR Bidet shall be chromium plated ABS nozzle with 1.2m heavy duty ABS flexible hose, chromium plated ABS plastic wall hanger and quarter turn angle valve.
13.	Sanitary appliances	Unless otherwise specified or shown on the Drawings, the sanitary appliances shall be: Floor trap, Robe Hook, Towel Rail, Safety Grab Bar and Handicap Safety Grab Bar shall be in stainless steel grade 304 chrome plated. Soap Dispenser shall be in uPVC (LEAD-FREE). Soap holder and toilet roll holder shall be in white earthenware (ceramic).

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1. General

- 1.1. All interior architectural signage shall be of acrylic plastic as approved by the S.O. unless otherwise specified in the Drawings. All panel signage surfaces shall be flat and smooth, constructed to remain flat under installed conditions within tolerance of plus or minus 1mm measured diagonally.
- 1.2. All external architectural signage shall be aluminium panel fabricate as approved by the S.O. unless otherwise specified in the Drawings. All panel signage shall be of corrosion free material.
- 1.3. All road signage shall be well coordinated and in accordance with *Arahan Teknik (Cawangan Jalan JKR)* latest edition.
- 1.4. All fire signages shall comply with the requirements of JBPM.
- 1.5. All signage works shall comply with the regulatory requirements currently enforced and shall comply with MS 1184: Universal Design and Accessibility in The Built Environment - CP Government Immoveable Asset Code System (*Sistem Kod Aset Tak Alih - SKATA*) as referred to sub-section 10 and Architectural Need Statement.
- 1.6. Unless otherwise stated in the Drawings, the panel and lettering size, profiles and dimensional requirements of the interior panel signage shall be as follows:
 - 1.6.1 The standard thickness of cast-acrylic matt clear sheets shall not be less than 4mm.
 - 1.6.2 Raised lettering and graphic symbols shall be of 0.8mm thickness obtained by using acrylic applique and chemically welded to sign panels.
 - 1.6.3 The type of panel material and size of letterings shall be as indicated in the Schedule of Signage prepared by the manufacturer to the S.O. approval.
- 1.7. Graphic content and style of signage shall be in accordance with the Schedule of Signage, shop drawings and comply with the requirements indicated below:
 - 1.7.1 Panel material shall be acrylic with machine-routed raised copy applied to the surface of panel, along with "raster-method" Grade 2 braille beads, or pictograms and other artwork to be reverse applied vinyl or silk-screened process in colours as indicated.
 - 1.7.2 For background colours, provide Pantone Matching System (PMS) coloured coatings, including inks and paints, that are recommended by acrylic manufacturer for optimum adherence to surface, and that are non-fading for application intended.
 - 1.7.3 Raised copy shall be machine routed copy, providing manufacturer's full range of solid to applique colours to the S.O.'s approval.
- 1.8. Pictogram/Symbol shall be provided where required with the S.O.'s approval.
- 1.9. Visual scale shall apply to the signages based on the distance, colour used and font types. Consideration shall be given to legibility and vividness to aid the visually impaired visitors.

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- 1.10. Location, accessories and mounting positions of signages shall comply with MS 1184, manufacturer's recommendations and as approved by the S.O..
- 1.11. Wall mounted panel signages shall be mounted to wall surfaces using the methods indicated below:
 - 1.11.1 Vinyl-tape mounting: use double-sided very high bond (VHB) tape to adhere signages to smooth, non-porous surfaces.
 - 1.11.2 Silicone-adhesive mounting: Use liquid-silicone adhesive recommended by manufacturer to attach signs to porous, irregular, or vinyl-coated surfaces. Use double-sided foam tape to hold the sign in position until silicone adhesive has fully cured.
 - 1.11.3 Mechanical fasteners: Use non-removable mechanical fasteners placed through pre-drilled holes in sign face, or through shim plate. Use proper anchors at masonry walls as recommended by the manufacturer. Attach panel signage to shim plate using vinyl-tape method as described above.
 - 1.11.4 Where signages are scheduled or indicated to be mounted on glass, to provide matching acrylic back plate at reverse-side of glass to conceal mounting materials.
 - 1.11.5 After installation, soiled signage surfaces shall be cleaned and protected from damage.
- 1.12. All suspended signages shall be 2-sided with a metal frame of 5mm clear acrylic and spray-painted with silkscreen finish or equivalent. The size of the panel signage shall be not less than 120mm (height) x 600mm (width) unless otherwise specified in the Drawings. Suspended panel signs shall be hung to soffit of slab or others approved structure using stainless steel rod or cable.
- 1.13. During the Contractor's drawings preparation phase, the Contractor shall provide full size mock-up samples of each type as required for inspection and subsequent approval by the S.O..

2. Copper Plating

- 2.1. Surface preparation of the copper plate is to be done before the plating process. Cleaning process should include, degreasing, spray washing, immersion washing, stripping and or coating removal. The copper plate is to be pre-treated to receive plating treatment. Thickness of copper plating is to be of minimum 3-5µm. All copper plating should be a thick film coating with excellent levelling to cover all surface irregularities to improve the general aesthetics.
- 2.2. Where grainy texture is required, the copper plate should be allowed to run in copper sulphate bath or copper cyanide-based solution bath for a longer period.

3. Aluminium

- 3.1. Aluminium signage panels shall be preferably supported by extruded aluminium extrusions for both internal and external signs complying with the requirements of MS 2289: Aluminium and Aluminium Alloy - Extruded Shapes.

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- 3.2. Aluminium sheets where otherwise stated for construction shall be of minimum 3mm thick with welded angles for support. There shall be no tin-canning or deflection effect on the sign-face. Where tin-canning effect appears on the sign face, the sign panel shall be removed and replaced.
- 3.3. Aluminium sheets used shall comply with the requirements of MS 2040: Aluminium and Aluminium Alloys - Sheets and Coiled Sheets - Specification. The alloy selected will be of a temper suitable for cutting.
- 3.4. Where signage required more than one standard size aluminium panel, the jointing shall be performed in accordance with BS 1473 by using rivets or screws with welded angles to the main panels. The joint shall then be fine sand, smoothen to be flushed to be seen as one and no butt-line joint, division or separation is to be seen.
- 3.5. All aluminium sections shall be fabricated from aluminium alloy B6063-T5 complying with the requirements of MS 2289: Aluminium and Aluminium Alloy-Extruded Shapes.
- 3.6. The aluminium shall be electronically anodized in matte finish for etched aluminium required for the fire door sign.

4. Paint Finish

Unless otherwise specified, all painting works shall be carried out as specified in SECTION N: PAINTING.

5. Screen Printing Works

- 5.1. Applications of screen-printing works shall be in accordance with the Drawings. There shall be high accuracy in printing registration and workmanship.
- 5.2. Silkscreen ink shall be of two (2) pack sericol polyscreen with Ultraviolet protective agents against colour fading. All finished screen-printed text or graphics shall be coated with a layer of two (2) pack polyurethane clear coat matte finish.

6. Vinyl Graphic Stickers

- 6.1. Unless otherwise specified in the Drawings, vinyl graphic stickers shall be used as recommended by the manufacturer and approved by the S.O..
- 6.2. Unless otherwise specified in the Drawings, all illuminated graphics shall be of translucent graphic films and non-illuminated signs shall be translucent opaque graphic films as approved by the S.O..
- 6.3. All vinyl graphics shall be precision cut by computers with no jagged edge. Minimum performance of vinyl stickers shall be to the approval of the S.O..

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7. Stainless Steel

- 7.1. Stainless steel shall be austenitic, non-magnetic, using Grade 304 or 316 to BS EN 10088 and BS 1449 Part 2 for plate, sheet and strip and BS 970 where relevant. Stainless steel plate and component with hairline finish for all internal signages shall be of Grade 304 4B.
- 7.2. Stainless steel plate and component for all external signages shall be of marine Grade 316 with alloy addition of molybdenum to prevent specific forms of corrosion.
- 7.3. Stainless steel fasteners, bolts, screws, bolts, washers and other fixing components shall be of Grade A2 or Grade A4 to BS EN ISO 3506.

8. Acrylic

- 8.1. Acrylic used for the external signage shall be of high impact acrylic. Extruded acrylic shall not be acceptable. The Contractor shall comply with the required thickness of the acrylic as shown on the Drawings.

9. Installation and Fixing Works

- 9.1. A works programme and method statements for the installation of all internal and external signages shall be submitted. The method statement shall include safety processes, measures to be taken and procedures while erecting the external signages.
- 9.2. Unless otherwise shown on the Drawings, all base plates for external signages shall be galvanized steel plates with Drawings and calculation certified by a Professional Engineer.

10. Labelling For Registration of Immoveable Asset Components

- 10.1. The code and format for labelling of components shall be as stipulated in the Government's:
 - 10.1.1 Asset Code System (*Sistem Kod Aset Tak Alih – SKATA*) and
 - 10.1.2 Asset Data Collection Guidelines (*Garis Panduan Pengumpulan Data Aset Tak Alih – PeDATA*).
- 10.2. All labels for the registration of the asset components shall comply with the regulatory requirements currently enforced and shall comply with the relevant International and/or Malaysian Standards.
- 10.3. Labels for the assets must be durable and withstand exposure to extreme conditions such as chemicals, temperature, weather, oils and detergents. The labels must also be able to withstand the rigour of cleaning schedule, maintenance and repairs.
- 10.4. Unless otherwise, stated in the Drawings, minimum requirements for asset component labels shall be as follows:
 - 10.4.1 Normal Condition – vinyl stickers.

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10.4.2 Extreme Condition - steel / aluminium plate.

- 10.5. Asset component labels shall be affixed to the asset in a position that is easily accessible for readability while the asset is in normal operating position (Refer to PeDATA).
- 10.6. Labels shall be located on clean, smooth, flat surfaces where possible, and on surfaces that provide direct visual access to a label scanner and its operator.

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1. Horizontal Drains Installation

1.1. General

This work consists of furnishing and installing horizontal drain pipe. This includes drilling of holes, furnishing, and construction of jointed and end sections, as needed, to grades shown on the Drawings or established on the ground. The Contractor shall furnish all necessary labour, equipment, and materials and perform all operations necessary for the installation of the horizontal drains in accordance with the details shown on the plans and with the requirements of these specifications. The drains shall consist of a Polyvinyl Chloride (PVC) pipe wrapped in a suitable filter cloth and shall be spaced and arranged as shown on the plans or as otherwise directed by the S.O..

1.2. Materials

1.2.1. Polyvinyl Chloride (PVC) Pipes

- 1.2.1.1. The horizontal drains shall be a prefabricated type made up of Polyvinyl Chloride (PVC) pipe of high-impact strength, Schedule 80, Type II and Grade 1, in accordance with the specification of ASTM D 1785 and shall be wrapped in a filter cloth.
- 1.2.1.2. The Contractor shall submit drain samples and indicate the source of the proposed materials prior to delivery to the site and shall allow sufficient time for the S.O. to evaluate the material.
- 1.2.1.3. At least two (2) weeks prior to the installation of drains, the contractor shall submit to the S.O. for his review and approval, details of the sequence and method of installation. Approval by the S.O. will not relieve the Contractor of his responsibility to install drains in accordance with these specifications.

1.2.2. Filter Cloth

The synthetic filter cloth shall be a non-woven type of approved manufacture having the following properties:

1.2.2.1. Chemical Composition Requirements

Fibres used in the manufacture of the engineering fabric shall consist of a long chain synthetic polymer, composed of at least 85% by weight of polypropylene, and shall contain stabilisers and/or inhibitors added to the base plastic (as necessary) to make the fabric resistant to deterioration from ultraviolet and heat exposure.

1.2.2.2. Physical Property Requirements

The physical properties of the filter cloth shall comply with **TABLE R1**.

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TABLE R1: PHYSICAL PROPERTY REQUIREMENTS FOR FILTER CLOTH

Physical Properties	Strength
Grab Strength (ASTM D1682)	0.9kN
Puncture Strength (ASTM D3787 - 80a)	0.4kN
Burst Strength (ASTM D3786 - 80a)	2100kN/m ²

1.2.2.3. Filtration Requirement

Equivalent opening size of the filter cloth determined by sieving as described in ASTM D422 is less than the 85% size of the adjacent soil.

1.2.3. Perforations

1.2.3.1. Perforations consist of two (2) rows of slots on 120-degree centres cut around the circumference of the pipe. A special type of cutter or disc cutter shall be used to cut slots in the PVC pipes. Unless otherwise shown on the Drawings or directed by the S.O., each slot shall be between 3 to 5mm wide with a minimum of 1600 square mm of slot opening per linear m of the slotted pipe.

1.2.3.2. The slotted perimeter of the pipe shall be positioned at the top to allow inflow of underground water into the pipe and the uncut section of the pipe shall be laid at the bottom to drain the water out from the hole.

1.3. Construction

1.3.1. Requirements

1.3.1.1. The location, number and length of horizontal drains shall be decided by the designer. Unless otherwise stated, the distance between horizontal drains shall be between 1 to 3m.

1.3.1.2. The location of the drains shall not vary by more than 150mm from the locations indicated on the Drawings or as directed by the S.O..

1.3.1.3. Drains that are out of their proper location by more than 150mm or drains that are damaged in construction or drains that are improperly completed shall be rejected by the S.O., and no compensation will be allowed for any materials furnished or for any work performed on such drains.

1.3.1.4. The Contractor shall provide the S.O. with suitable means of making a linear determination of the quantity of drain material used.

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1.3.2. Drilling

The Contractor shall deploy suitable drilling equipment plus skilled operator and supervisor that have adequate capacity and experience to produce the drill hole according to the size, length and accuracy as shown on the Drawings and as specified in this specification

- 1.3.2.1. The position of each horizontal drain shall be marked and pegged clearly on the ground/slope before the commencement of drilling works. If necessary, survey equipment shall be used to locate the position of horizontal drains.
- 1.3.2.2. The temporary drilling platform shall be erected firmly on the ground/slope, such that no excessive movements or sway occurs during drilling.
- 1.3.2.3. The drain holes shall be drilled at an inclined angle into the ground/slope. The minimum angle of inclination shall be at least 2.5° upwards from the horizontal.
- 1.3.2.4. Dry rotary drill, auger or down-the-hole hammer shall be used. Suitable drill bit slightly larger than PVC pipe shall also be used. In ground likely to collapse, the drilled shaft shall be protected by suitable temporary casing. Drill holes shall be flushed clean on completion of drilling and the opening protected or sealed to prevent the entry of any foreign matter. A drilling record for each horizontal drain shall be carried out as specified in sub-section 1.3.5.
- 1.3.2.5. Drilling for the whole design length of horizontal drain shall be carried out uninterrupted and completed with necessary hole cleansing within one hour. To ensure reliable and effective cleansing of the drill holes, an additional drilled length of about 0.3m to the design length shall be provided so that cleansing of cuttings and debris towards the bottom of the drill holes by the compressed air through the drill rods can be effectively and eventually carried out. All drill rods shall be properly jointed without leakage. Alignment of drill holes shall not deviate more than 25mm in 3m in any direction.

1.3.3. Pipe Installation

- 1.3.3.1. Splices or connections in the drainage material shall be done in a workmanlike manner and so as to ensure continuity of drain material. Where joints are required between the pipes, the smaller end of one (1) pipe shall be slotted into the bigger end of the other and securely bonded with a bonding material recommended by the pipe manufacturer. Slotted PVC pipe shall then be tightly wrapped in filter cloth such that the entire length of the pipe is covered by the cloth, inclusive the inner end of the pipe. All joints of the cloth shall have an overlap of at least 100mm. The entrance end of the pipe shall be securely plugged with wood, plastic, or other nonporous material. The perforated plastic pipe shall be installed in the drilled hole with the perforations on top, unless otherwise directed by the S.O..

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1.3.3.2. Non-perforated plastic pipe shall be installed at the mouth or outlet end of all horizontal drains. The non-perforated plastic pipe shall be such inside diameter that it can be slipped over the perforated plastic pipe.

1.3.4. Control of Water

Water for drilling and water encountered during the drilling operation shall be controlled to ensure that siltation or damage will not occur to adjacent roads and streams.

1.3.5. Submittals

1.3.5.1. The Contractor shall keep records for each horizontal drain installation and shall submit one signed copy to the S.O. not later than noon of the next working day after the horizontal drains have been installed. The record for each horizontal drain shall include horizontal drain reference number, date/time of commencement and completion of drilling and inserting of pipe, names of supervisor and operators, plus the necessary drilling details, etc..

1.3.5.2. Drilling records shall include:

- (i) Description of drilling debris returns
- (ii) Observed exceptions & peculiarities
- (iii) Size, length and Class of PVC pipe
- (iv) Type of filter cloth
- (v) Drill hole diameter and total drilled length
- (vi) Time of start & completion of drilling

1.3.6. Installation of Horizontal Drain Near Soil Nail/Ground Anchor/Rock Bolt

In case the horizontal drains are to be installed together with soil nails/ground anchors/rock bolts on the same slope, the installation of soil nails/ground anchors/rock bolts shall be completed first before the commencement of horizontal drains.

1.3.7. Concrete Lined Chutes

Where necessary, Grade 20 concrete lined chute with minimum thickness of 75mm shall be constructed to drain the water from the mouth of the horizontal drain to nearby drain.

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2. Geocell

2.1. General

2.1.1. Scope

This specification covers the general and technical requirements for the supply and installation of geocell as described herein. All materials used and the works shall meet the requirements of this specification and details shown on the Drawings.

2.1.2. Contractor's Responsibilities

2.1.2.1. The Contractor shall provide all the necessary resources including materials, skilled workers, and plants/equipment to execute and complete the works related to supply and laying of geocell as shown on the Drawings.

2.1.2.2. The Contractor shall be responsible for the true and proper setting-out of the areas to which the geocell is to be placed and for the correctness of the lines, widths, levels and slopes as shown on the Drawings.

2.2. Material Properties

2.2.1. Product and Applications

2.2.1.1. The geocell is a flexible three-dimensional mattress and shall be made from high-density polyethylene (HDPE) strips, which are ultrasonically bonded to form multiple cellular openings.

2.2.1.2. The structure provides lateral confinement of the infill materials. The enhanced system works on the principle of friction between the infill materials and the cell walls as well as the lateral confinement forces generated by the applied load thus minimising deformation and subsequently improving the stability of the overall structure. The newly filled structure acts to redistribute the load, sustain the erosive forces to protect the underlying soil layers and reinforce the fill materials. When the geocell is applied with suitable infill materials, it offers cost-effective solutions to the following applications:

- (i) Load Support
 - By improving the bearing capacity of the sub-grade.
- (ii) Slope Protection
 - By providing a cost-effective slope protection solution where vegetation growth is difficult or impossible such as in the case of acidic soils or rocky edges, etc..
- (iii) Earth Retention
 - By providing confined stiffness with its cellular structure.

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- (iv) Channel and Pond Bank Protection
- By enhancing vegetation growth, providing confined support and preventing the downward migration of soil particles.

2.2.2. Technical Properties

The properties of the geocell shall meet or exceed the minimum values corresponding to the respectively test methods as shown in **TABLE R2** and **TABLE R3**.

TABLE R2: PROPERTIES OF GEOCELL (GENERAL)

Physical Properties	Test Method	Test Value/Data
Base Polymer	ASTM D 1505	HDPE
Polymer Density		0.938-0.960 g/cc
Colour	-	Black
Carbon Black Content	ASTM D 1603	1.3% - 2%
Env. Stress Crack Resistance	ASTM D 1693	> 2000hr
Wall Thickness	ASTM D 5199	> 1.30mm

TABLE R3: PROPERTIES OF GEOCELL

Property	Units	Type		
		CRS4	CRS6	CRS8
Cell Height, H	mm	100	150	200
Minimum Cell Seam Peel Strength	N	1450	2140	2850
Dimension: Expanded Piece				
Width	m	2.2	2.4	2.8
Length	m	3.05, 6.1 or as specified		
Dimension: Expanded Cell				
Width	mm	203	203	203
Length	mm	244	244	244
Area	mm	248	248	248

2.2.3. Locally Produced Products

The geocell to be used in this contract shall be fully of Malaysian origin unless otherwise approved by the designer. The geocell shall be produced by factory with ISO certification and equipped with testing laboratory, where sampling and testing can be readily carried out.

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2.2.4. Product Quality Assurance

The contractor must provide a Certificate of Approval from the Manufacturer to confirm that their Local Manufacturing Factory's production and management system are certified to be operating at least under Quality Management System (QMS) ISO 9001: 2008 or equivalent.

2.3. Testing

2.3.1. General

2.3.1.1. 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 geocell to all the above-specified property values corresponding to their respective test methods, for the approval of the S.O.. The S.O. reserves the right to carry out sampling at the factory to verify the test results.

2.3.1.2. 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..

2.3.1.3. Routine sample testing, when required and specified, shall be carried out at factory or at reputable institutions or 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.

2.3.2. Consignment Certificate

2.3.2.1. For the purpose of ascertaining that each consignment of geocell supplied to site is of the approved type and quality and are fully from the same Manufacturer and batch as indicated, the contractor must furnish with every consignment, an original Consignment Certificate from the Manufacturer giving the following information:

- (i) Name and Address of the Manufacturer
- (ii) Contact telephone/fax/email address of the manufacturer
- (iii) Consignment Certificate Reference Number and Date
- (iv) Title of the Contract and Name of Project Owner
- (v) Name and Address of the Purchaser
- (vi) Product Types and Quantities, Corresponding to each consignment

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2.4. Packaging and Storage

2.4.1. Product Labelling

The geocell shall be supplied with the Manufacturer's Label/Logo on each roll showing the following identifications:

2.4.1.1. Product Brand Name

2.4.1.2. Product Type

2.4.1.3. Panel Width and Length

2.4.1.4. Batch Serial Number

2.4.2. Product Packaging

The geocell shall be supplied in panels, labelled and wrapped in packaging materials to protect against water and photo-degradation by ultraviolet light.

2.4.3. Storage at Site

2.4.3.1. The Contractor shall ensure that the geocell is properly stored in a covered area at the worksite. If no covered area is available, the geocell may be stored on raised platform and covered with waterproof canvas.

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

2.5. Installation

2.5.1. General

Installation of geocell shall be carried out by qualified and experienced workers under the supervision of a qualified engineer.

2.5.2. Installation of Geocell

The geocell shall be installed in accordance with the Manufacturer's instructions. This also includes the earthworks preparation before the installation of geocell. All jointing and anchorage dowels on slopes shall be constructed according to Manufacturer's instructions.

2.5.3. Infill Material Placement

2.5.3.1. Suitable infill materials shall be as specified in Drawings or shall consist of one of the following:

- (i) Well graded aggregates with maximum size not exceeding 50mm

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(ii) Fertilised soil

(iii) Concrete Grade 25

2.5.3.2. The infill materials shall be well compacted within the cells, in accordance with the requirements of the Works Specifications and the Manufacturer's instructions as shown on the Drawings.

3. Soil Nailing

3.1. General

3.1.1. This works specification for soil nailing shall cover all the necessary resources and materials for the supply, installation, testing and completion of soil nails in accordance with this Specification and the details shown on the Drawings or as directed by the S.O..

3.1.2. The Contractor shall inspect the site, study soil investigation results and design details before preparation and submission of the method statement to the S.O. for prior approval (at least 14 days) before the commencement of works. The method statement shall describe how to execute the works to comply with the specifications and contain among other things the details of sequence of works, specific type of machines plus necessary staging to be deployed for drilling and grouting, estimated daily works output rate, necessary quality control tests/measurements/observations plus their respective frequency and acceptance criteria. Remedy or rectification shall also be proposed for cases where the acceptance criteria is not met or achieved. Specific operators/ supervisors (name, IC and CV, etc.), full details of specific type of rebars plus their protection system, centralisers, spacers, grout mix details and admixtures and any other materials to be used, etc., including catalogues, test certificates and photos of the equipment and materials to be used plus the proposed machines layout for drilling, grouting and pull-out test shall be shown on Drawings (A3 size) and shall also be included in the method statement. The proposals in the method statement shall meet the requirements shown on the Engineer's drawings and this specification hereafter.

3.1.3. The Contractor shall be fully responsible to provide all necessary and suitable resources and materials to complete all the soil nails strictly according to this Specification. The Contractor shall install the trial or preliminary soil nails and carry out the verification pull-out test as per sub-section 3.8 at locations selected by the S.O..

3.2. General Requirements

3.2.1. Setting Out

Setting out shall be as shown on the Drawings or as directed by the S.O.. Immediately before drilling or installation of soil nail, the nail head position shall be marked with suitable identifiable pegs or markers on the slope/wall for necessary inspection by the S.O..

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3.2.2. Position

The maximum allowable deviation for drill hole entry point shall not exceed 75mm in any direction.

3.2.3. Alignment of Nail

The drilling machine shall be attached with suitable alignment control device set to attain the finished nail direction or inclination shown on the Drawings and the maximum permitted deviation of alignment shall not exceed 1 in 20. Deviation from straight shall not exceed 20mm in any 3m length of drill hole.

3.2.4. Nail Out of Position or Alignment

The Contractor shall demonstrate to the S.O. that the position and alignment of soil nails is within the tolerance limits specified. Any nail found out of the tolerable position or alignment shall be rejected and the S.O. shall order to add additional nails at the Contractor's own costs.

3.2.5. Submittals

3.2.5.1. The contractor shall keep records for each soil nail installation and shall submit one signed copy to the S.O. not later than noon of the next working day after the soil nails have been installed. The record for each soil nail shall include soil nail reference number, date/time of commencement and completion of drilling and grouting, names of supervisor and operators, plus the necessary drilling and grouting details, etc..

3.2.5.2. Drilling records shall include:

- (i) Type & model of drilling machine
- (ii) Type & size of drill rods
- (iii) Description of drill rate
- (iv) Description of drilling debris returns
- (v) Observed exceptions & peculiarities
- (vi) Checking on straightness, cleaning & alignment
- (vii) Total drilled length
- (viii) Time of start & completion of drilling

3.2.5.3. Grouting records shall include:

- (i) Type & model of colloidal mixer & paddle mixer
- (ii) Type & model of pump
- (iii) Grout mix design details (WC ratio, admixture, etc.)

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- (iv) Results of bleeding, flow cone efflux time and strength tests
- (v) Conditions of pull-out check on centralisers (photos and description as per sub-section 3.5)
- (vi) Time of start & completion of grouting
- (vii) Volume of grout consumed
- (viii) Observed exceptions (loss of grout, etc)

3.2.5.4. Format and details of record and layout of nail shall be approved by the S.O.. Other important submittals are method statement [sub-section 3.1.2], test certificates [sub-section 3.3.1.3], pull-out test reports (sub-section 3.8), quality control tests as specified, As-built Drawings (showing nail layout plan, nail reference number, length, date completed, etc.) and project completion report, which shall include the following chapters:

- (i) Table of contents
- (ii) Introduction
- (iii) Design drawings and finalized BQ
- (iv) Method Statement
- (v) Works programme
- (vi) Drilling & Grouting records
- (vii) Quality control tests results for drilling, grouting, guniting, etc.
- (viii) Catalogues test certificates for rebar, centralisers, coupler HDPE sheath, etc
- (ix) Pull-out test results, including test layout, drawings, photos, calibration records & certificates
- (x) As-built Drawings
- (xi) Photos showing drilling layout, drill rod, head, drilling operation, etc.
- (xii) Photos showing grouting layout, colloidal mixer, paddle mixer, pump, etc.
- (xiii) Photos showing how the rebar is fixed with centralisers etc.

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3.3. Materials

3.3.1. Reinforcement

- 3.3.1.1. Reinforcement for soil nails shall be high yield steel reinforcing bars complying with M.S. 146, threaded and hot-dip galvanized to BS EN ISO 1461. The nail bars shall be threaded at the ends for a sufficient length (minimum 150mm long) to facilitate fixing of galvanized washer, overlap locking washer and nut at the exposed end and fixing of galvanized coupler at the other end, if required.
- 3.3.1.2. The tensile strength and galvanized rebar quality of the coupled nail bar shall be not less than 410N/mm² or specified in Drawings.
- 3.3.1.3. Only soil nails of more than 12m long shall have rebars spliced or coupled. The tensile strength of the coupler shall be capable to develop at least 95% of the tensile strength of the rebar as tested and certified by the manufacturer. 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.

3.3.2. Cement Grout

- 3.3.2.1. Cement for grouting shall be Ordinary Portland Cement complying with MS 522.
- 3.3.2.2. Grout shall consist of cement and water. Water cement ratio shall be 0.45 to 0.50 and minimum cube strength of 7-day strength and 28-day strength shall be 20MPa and 30MPa respectively (BS 1881). Sand shall not be used unless approved by the S.O.. Water shall be from approved public water supply and shall comply with the quality specified in MS 28. Suitable admixtures shall be used to improve flowability and bleeding or shrinkage problem. Admixtures shall comply with the requirements of BS 5075: Part 1 and Part 3 and shall only be used with the prior approval of the S.O.. Grout shall be thoroughly mixed by suitable high speed colloidal mixer (> 1000rpm) until a homogeneous grout free from undispersed cement, lumps and bleeding is obtained. The grout after mixing for a few minutes shall be transferred through a 5mm sieve into a storage tank attached with paddle agitator.
- 3.3.2.3. The following important quality control tests shall be carried out:
 - (i) Crushing strength of 100mm cubes at 7-days and 28-days (BS1881) shall be minimum 20 and 30MPa respectively.

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- (ii) Bleeding test (<0.5 % by volume 3 hours after mixing or 2 % (maximum) when measured at 20°C in a covered glass cylinder of 100mm diameter and with a grout depth of 100mm). In addition, the water shall be re-absorbed within 24 hours. Free expansion shall not exceed 10 %.

- (iii) Flow cone efflux time test (<15 seconds, ASTM C939-87).

3.3.2.4. If any of the above results falls below the acceptable limits, at least one or 1% of grouted working nails shall be subject to pull-out test (sub-section 3.8) at the Contractor's own cost.

3.3.3. Centralisers

3.3.3.1. Centralisers shall be tightly fixed to the rebar at the spacing as shown on the Drawings. The centralisers shall be firm and as small as possible (not more than 50 % of the nail section) so that the blockage of grout flow is minimum. Centralisers shall be fixed inside and outside of the protective sheath, if applicable, and shall be spaced at not more than 2m. Centralisers shall be sized to position the rebar within 25mm of the centre of the drill holes; and to allow tremie pipe (about 30mm diameter) insertion to the bottom of the drill hole. The centralisers shall be produced by reputable manufacturer or specialist using galvanized steel strips or PP (polypropylene) or PVC (polyvinyl chloride) and comply with following properties:

- (i) Tensile strength (BS 2782: Part 3, Method 320°C) > 30Mpa
- (ii) Hardness (BS 2782: Part 3, Method 365B) > 65
- (iii) Brittleness temperature (ASTM D746-79) < 5°C
- (iv) Environmental Stress Cracking Resistance (ASTM D1693-70): 200 hours (no cracking)

3.3.3.2. 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.

3.3.4. Corrugated HDPE Sheath

3.3.4.1. The size, shape and length of the sheath to protect the rebar shall be as shown on the Drawings or as directed by the S.O.. The sheath shall consist of HDPE (high density polyethylene) tube with wall thickness not less than 1.0mm and shall be at least 5mm of grout cover over the nail rebar within the sheath. The thickness of grout between the HDPE sheath and the sides of drill hole shall be not less than 25mm. Other important properties that shall be complied are as follows:

- (i) Tensile strength (BS 2782: part 3, method 320C) > 25Mpa

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- (ii) Softening point (BS 2781: Part 3, method 120A) >110°C
- (iii) Environmental stress cracking resistance (ASTM D1693-70): 200 hours (no cracking)
- (iv) Hydrostatic pressure resistance (BS 6437): no localized swelling, leaking or weeping

3.3.4.2. 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.

3.3.5. Materials Handling and Storage

3.3.5.1. Cement shall be stored properly to prevent moisture degradation and partial hydration. Cement that has been caked and lumpy shall be rejected and discard. Rebars shall be stored on firm supports to prevent the steel from contacting the ground. Damage to the rebar as a result of abrasion, cuts, nicks, welds and weld splatter shall be cause for rejection. Rebars shall be protected from dirt, rust and other deleterious substances prior to installation. Heavy corrosion or pitting of rebars shall be cause for rejection. Anchorage end of rebars to which bearing plate and nuts will be attached shall be protected by some protective wrap during handling, installation, grouting and guniting.

3.3.5.2. PregROUTED rebars in HDPE sheaths shall not be moved or transported until the grout has reached sufficient strength to resist damage during handling. The pregROUTED rebars shall be handled with care and with sufficient supports to prevent large deflections, distortions or damage. Conditions of the pregROUTED rebars shall be checked first before inserting into the drill holes. Damaged pregROUTED rebars shall be rejected.

3.4. Drilling

3.4.1. The Contractor shall deploy suitable drilling machine and tools plus skilled operator and supervisor that have adequate capacity and experience to produce the drill hole according to the size, length and accuracy as shown on the Drawings and as specified in this Specification.

3.4.2. Unless otherwise directed or approved by the S.O, only dry rotary percussion method by top hammer or down-the-hole hammer shall be used. Suitable drill bit of not less than 100mm diameter shall be used. In ground likely to collapse, the drilled shaft shall be protected by suitable casing. Drill holes shall be flushed clean on completion of drilling and the opening protected or sealed to prevent the entry of water or any foreign matter. A drilling record for each soil nail shall be carried out as specified in sub-section 3.2.5.

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3.4.3. Drilling for the whole design nail length shall be carried out uninterrupted and completed with necessary hole cleansing within one hour. To ensure reliable and effective cleansing of the drill holes, an additional drilled length of about 0.6m to the design length shall be provided so that cleansing of cuttings and debris towards the bottom of the drill holes by the compressed air through the drill rods can be effectively and eventually carried out. All drill rods shall be at least N size and can be properly jointed without leakage. Alignment of drill hole shall not deviate more than 20mm in 3m in any direction. At least 1% of the drilled holes shall be selected for straightness test by inserting 100mm diameter tube to the designed length. Drilled holes that cannot pass the test shall be redrilled and the suitability of the drilling machine be reassessed.

3.4.4. Adequate temporary or permanent site drainage or temporary tarpaulin shall be provided to prevent infiltration from surface run-off into the slope where soil nailing is carried out.

3.5. Insertion of Reinforcement

3.5.1. The galvanized rebar fixed with centralisers as shown on the Drawings shall be checked before inserting into the drill hole. The rebar shall be carried by experienced workers at spacing not greater than 3m.

3.5.2. After inserting about 75% of the total design length, the rebar shall be withdrawn to check the conditions of the centralisers and contamination of rebar. Such pull-out check shall be carried out on at least 1% of the nails especially for those drill holes that have been left for more than 2 hours after completion of drilling. If collapse of drill hole is suspected, redrilling and flushing have to be carried out as directed by S.O.. Damaged centralisers shall be replaced immediately and rechecked.

3.6. Grouting

Grout mix shall be prepared and tested according to sub-section 3.3.2. Layout of machine plus the capacity, etc., shall be as shown in method statement and approved by the S.O before mobilization. Grout shall be pumped into its final position in drill hole through a grouting tube of about 25mm diameter by tremie method under gravity or low pressure (< 5 bars) as soon as possible/immediately after the completion of hole drilling and is not more than 30 minutes after mixing. Grouting shall be carried out within 2 hours after drilling and cleansing of drill hole are completed. Grouting shall be carried out promptly and continuously in one operation without interruption to avoid any disturbance caused by sedimentation within the grout and to reduce air bubble entrapment. Full operation shall continue until injected grout of the same composition and consistency as that mixed emerges from the drill hole outlet for at least one minute. Failure to comply with these requirements may result in either the works being rejected or recleansing plus proof pull-out test at the contractor's own costs.

3.7. Nail Head Construction

3.7.1. All the disturbed, loose or soft soil around nail head shall be removed and replaced by non-shrink mortar of Grade 30 strength or approved equivalent by the S.O..

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- 3.7.2. Nail head with steel plate shall be in a plane normal to the nail axis clamped down with galvanized nut and washers to the clamping down forces of 5kN (min) or as shown on the Drawings, using a calibrated torque wrench. Clamping shall be carried out with a thin layer (< 25mm) of fresh non shrink mortar (Grade 30) behind the steel plate to ensure proper seating. Nail head construction shall only be carried out after the grout and the mortar have reached at least 7-days strength (>20MPa).

3.8. Pull-Out Tests

- 3.8.1. The Contractor shall provide all necessary resources including all torque wrenches, jacks, gauges, reaction frame, pump, load cell, bearing plates, and other equipment required to carry out the pull-out test of the soil nails specified. Measurement of nail head movement shall be made using at least 2 dial gauges capable of measuring to 0.025mm accuracy.
- 3.8.2. The contractor shall also present up-to-date test (not more than 1 year ago) and calibration certificates to the S.O for the equipment that are proposed for testing for approval before the test commences. Method statement and layout of pull-out test as specified in sub-section 3.1 shall also be submitted. The location of soil nail to be tested shall be selected by the S.O..
- 3.8.3. Purpose of pull-out test up to 2.0 times the design pull-out resistance/load or as specified in Drawings is to verify the designed pull-out resistance or designed bond strength between the grout and the soil/rock and also to verify the adequacy and suitability of drilling, installation and grouting techniques. The design/allowable pull-out resistance, Q_d (kN/m) shall be as shown on the Drawings or determined by the S.O at Site.
- 3.8.4. Pull-out test shall be carried out at least 72 hours after grouting or when the grout has achieved at least the specified 7-days strength (> 20MPa). Testing equipment including dial gauges, gauge supports, jack and pressure gauge, load cell, etc., shall be sufficiently rigid and shall be protected from sunlight and rain by some canvas. The complete jacking system including hydraulic jack, pump, and pressure gauge should be calibrated as a single unit before use to an accuracy of not less than 5% of the applied load. The centre and bearing plates of the jack system shall be properly arranged so that the test nail will not carry the weight of the testing equipment. The gauge used to measure the nail head movement shall be aligned parallel with the axis of the nail and the support of the gauges shall be independent from the jack and the reaction frame. Load cell is important to maintain constant load hold during the creep test load hold increment. The jack and pressure gauges shall have a pressure range not exceeding twice the anticipated maximum test pressure. Jack ram travel shall be sufficient to allow the test to be done without resetting the equipment.
- 3.8.5. At least 2 preliminary pull-out tests or verification or sacrificial tests up to 2.0 times the design pull-out resistance, Q_d or as specified in Drawings shall be carried out for different soil/rock unit or for different drilling/grouting method for each nailed slope/hill or as specified and directed by the S.O..

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3.8.6. For the soil nails selected for pull-out test, the temporary unbonded length (L_u) of the test nail shall be at least 1m, i.e. the bonded length (L_b) of the soil nail selected for pull-out test shall be $L_b = L - L_u$, where L = total soil nail length. To prevent collapse of the unbonded drill hole during the test, a temporary GI pipe of about 1m long near the slope surface shall be installed. In case the drill hole is fully grouted, a GI pipe of about at least 600mm long and slightly larger than the grouted hole shall be driven to ensure the reaction force is not transmitting to the grouted hole near the slope surface. L_b shall be at least 3m.

3.8.7. The loading schedule for verification test is as shown in **TABLE R4**.

TABLE R4: VERIFICATION TEST LOADING SCHEDULE

Load	Holding Time (Minimum)
(5% DTL), alignment load	1 minutes
0.25 DTL	10 minutes
0.50 DTL	10 minutes
0.75 DTL	10 minutes
1.00 DTL	10 minutes
1.25 DTL	10 minutes
1.50 DTL (Creep Test)	60 minutes
1.75 DTL	10 minutes
2.00 DTL (Max test Load)	10 minutes

DTL = Design Test Load (kN) = $L_b \times Q_d$

L_b = Pull-out test bonded length

L_b = Design nail length - unbonded length

L_b shall not exceed $0.9f_y A_s / 2.0 Q_d$, where f_y and A_s are yield stress and area of rebar respectively.

Q_d = $f_a \times \pi d$
= Design allowable pull-out resistance (kN/m)
specified in the Drawing or by the Designer.
 f_a =design allowable bond stress (kN/m²),
 d =diameter of nail in m.

3.8.8. The alignment load shall be the minimum load required to align the testing apparatus. Dial gauges shall be set to zero after DTL is applied. At least 2 calibrated dial gauges of 0.025mm accuracy shall be used to measure nail head movement. Each load increment shall be held for at least 10 minutes. Nail movement at creep test (1.50 DTL) shall be taken at 1, 2, 3, 5, 6, 10, 20, 30, 50 and 60 minutes. The load during the creep test shall be maintained within 2% of the intended load by use of a calibrated load cell.

3.8.9. For working pull-out tests or proof tests, the testing procedure including creep test is similar to verification test except that the max test load (MTL) = 1.5 x DTL.

3.8.10. A pull-out test is deemed satisfactory and acceptable when all the following criteria are met:

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3.8.10.1. For verification tests, the total creep movement is less than 2mm between the 6 and 60 minute readings measured during the creep test and the creep rate is linear or decreasing throughout the creep test load hold period.

3.8.10.2. For proof tests, the total creep movement is less than 1mm measured between the 1 and 10 minute readings or the creep movement is less than 2mm during the 60 minute readings and the creep rate is linear or decreasing throughout the creep test load hold period.

3.8.10.3. The total measured movement at the maximum test load (MTL) exceed 80% of the theoretical elastic elongation (l_e) of the test nail unbonded length ($l_e = 0.8P (L_u) (10^6) / A_s E$, where P = max applied load (kN), L_u = length from the back of nail to jack connection to the top of the bond (m), A_s = rebar cross-sectional area (mm²) and E = rebar's modulus = 200,000 MPa).

3.8.11. A pull-out failure does not occur at the maximum test load. Pull-out failure is defined as the load at which attempts to further increase the test load simply result in continued pull-out movement of the test nail.

3.8.12. The Contractor shall submit the results of pull-out tests to the S.O for final interpretation and necessary design review immediately after the test. Full formal report of pull-out test including all plotting, method statement, test length, photos, test certificates, etc. shall be submitted to the S.O. within 1 week after the test.

3.8.13. For verification test nails, the S.O. shall evaluated the results and make necessary design review after consultation with the designer. Installation methods that do not satisfy the nail testing requirements shall be rejected and replacement test nails shall be installed and tested at no additional cost.

3.9. Calibration

Calibration of gauges for pull-out test shall be submitted together with calibration record and testing certificate and the validity must be not more than 1 year.

4. Guniting

4.1. General

4.1.1. This works specification for guniting covers the technical requirements for gunite mix, machine and plant, surface preparation, method of operation, quality control and works acceptance criteria.

4.1.2. The Contractor shall apply gunite to the excavated slope surfaces at locations shown on the Drawings or at locations directed by the S.O..

4.1.3. "GUNITED" is a mixture of cement, sand or aggregate and water projected at high velocity from a suitable nozzle onto slope to produce a dense homogeneous protective layer. The maximum aggregate size shall be less than 10mm.

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4.1.4. “Dry Process” is a mixture of cement, aggregate and sand weighted or volume batched, thoroughly mixed ‘dry’ and fed into a purpose-made machine where the mixture is suitably pressurized, metered into a dry air stream and conveyed through hoses or pipes to a nozzle before which water is introduced to hydrate the mix and is projected without interruption onto slope surfaces.

4.1.5. “Rebound” is a term used for all material having passed through the nozzle which does not conform to the definition of gunite as defined above.

4.2. Materials

4.2.1. Cement

Cement shall be Ordinary Portland Cement and comply with the requirements of MS 522.

4.2.2. Sand / Aggregate

Sand or aggregate shall be clean and durable, and free from clay or organic matters and other impurities. The sand and aggregate shall be not more than 10mm and shall comply with the requirements of MS 29 and MS 30. The grading limits for the sand and aggregate mixture shall be as shown in **TABLE R5**:

TABLE R5: GRADING LIMITS FOR SAND / AGGREGATE

Sieve Size	Percentage Passing (%)
10.0mm	100
5.0mm	90-100
2.36mm	75-100
1.18mm	55-90
600µm	35-59
300µm	8-30
150µm	0-10

4.2.3. Water

Water for mixing shall be clean and free from harmful matter. Where tests are required, they shall be in accordance with the requirements of MS 28.

4.2.4. Reinforcement

Unless otherwise stated in the Drawings steel fabric reinforcement shall be hard-drawn steel wire reinforcing fabric with minimum wire diameter of 6mm pitch of 200mm in each direction (wire mesh A6) and comply with the requirements of MS 145.

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4.2.5. Mix

- 4.2.5.1. The gunite shall have a minimum cement content of 350kg per cubic meter and with water/cement ratio of not exceeding 0.5 by mass. Mix proportions shall be designed by the Contractor to achieve minimum Grade 30 or the specified grade of strength as shown on the Drawing and shall be approved by the S.O. before commencement of works.
- 4.2.5.2. Mixed dry aggregate and cement, which are not applied on slope surfaces within 30 minutes after mixing, shall be discarded.
- 4.2.5.3. Admixtures shall be added at 3 – 5% by weight of cement to speed the setting rate of cement, when directed by the S.O..
- 4.2.5.4. All constituents shall be uniformly dispersed throughout the mix. Mixing by hand is **NOT** allowed.

4.3. Plant and Equipment

Before commencement of work, the Contractor shall submit to the S.O. for approval, the type, make and number of plant and equipment to be used. A drawing showing the proposed plant and works arrangement with brief description about the equipment, the method of operation and mix proportion, etc., shall be included in the method statement as specified in subsection 4.10.1.

4.4. Preconstruction Test Panels

- 4.4.1. The purpose of preconstruction tests panels is to assess the quality of guniting with respect to density, uniformity, thickness, strength, and works output rate to ensure the resources for guniting works are satisfactory with respect to skill and quality.
- 4.4.2. Preconstruction testing shall be carried out using plant identical to that proposed for the works and shall be undertaken in such time before the commencement of the works as to allow approval by the S.O..
- 4.4.3. Trial mixes of each mix design proposed shall be carried out by the Contractor. For each mix design, 3 number of test panels of minimum size 750mm x 750mm x 100mm thick shall be sprayed from each position required in the works, such as down-hand, vertical and overhead positions, with layer thickness appropriate to that position. Panel moulds shall be formed from 20mm thick plywood adequately braced and held rigidly in position.
- 4.4.4. Where required by the S.O., test panels of minimum size 750mm x 750mm x 100mm thick shall be sprayed from each position required in the works.

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4.5. Interface Preparations

- 4.5.1. Earth or natural surfaces other than rock shall be compacted, trimmed and graded according to the design grade before guniting. The newly excavated or trimmed slope shall be immediately and adequately protected against infiltration by immediate guniting or protected by tarpaulin sheet or other method approved by the S.O.. The earth surface shall be maintained at equilibrium moisture, as directed by the S.O. (not too wet or too dry before guniting). Gunite shall **NOT** be applied on surfaces with loose or soft or wet materials.
- 4.5.2. Rock surfaces shall be cleaned and free from loose materials, mud or foreign matters. After washing down with water, the rock surfaces shall be damp but exhibiting no free water prior to guniting.
- 4.5.3. Where flow of water interferes with the application of gunite or cause leaching of cement, the flowing water shall be directed by appropriate drainage channels to convenient locations where plugging can be carried out.
- 4.5.4. The reinforcement shall be cleaned and free from loose mill scale, loose rust, oil or other coating prior to the application of gunite. All reinforcement shall be stored under cover and clear of the ground. Any reinforcement that is pitted with rust shall be rejected. The reinforcement fabric shall be securely and firmly fastened with the dowels shown on the Drawing and supported with approved spacers at about 1.6m spacing to provide 50mm clearance cover between the fabric and the slope surface.

4.6. Normal Guniting Procedure

- 4.6.1. Before starting work, the Contractor shall submit to the S.O. for approval a detailed schedule of the entire guniting operation and method statement of works. Approval of such schedule and method statement shall not relieve the Contractor of its responsibility to provide a fully satisfactory installation. The Contractor shall include with his submission evidence that he has successfully completed a gunite installation using the procedures similar to those proposed.
- 4.6.2. All reinforcement shall be firmly fixed with the dowels, weep holes and spaces to give the required cover, clearance, or laps as described or specified. Guniting shall commence from the top or upslope downwards to ensure no ingress of runoff below the gunite. Guniting shall be carried out by directing the nozzle perpendicularly to the surface to be gunited.
- 4.6.3. Guides shall be set-up to establish good finish surfaces. Gunite shall only be applied in the presence of the S.O. or his representative and shall be built up in successive layers, each layer generally not exceeding 50mm in thickness, such that sagging, and bleeding do not occur. Gunite shall be applied evenly without any sags or slumps. All reinforcement shall be completely surrounded by gunite.
- 4.6.4. Whenever the spraying operation becomes irregular, the nozzle shall be directed away from the works area and all spraying shall stop.

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4.6.5. The Contractor shall be required to monitor closely the progress of the guniting works. Daily site records of all materials delivered to the concrete mixer shall be properly maintained and made available to the S.O. when required.

4.6.6. All gunite shall be cured continuously for 7 days or by approved curing compound or equivalent.

4.7. Rebound

4.7.1. All rebound and loose materials shall be removed by air jets or other means from the surface of each layer as work proceeds. Rebound shall not be worked into the sprayed area or re-used in the works.

4.7.2. All surfaces which are not to receive gunite shall be protected by approved methods.

4.8. Construction Joints

The type and positions of all construction joints shall be approved by the S.O.. Construction joints shall be formed by placing or trimming the sprayed gunite layer to an angle of approximately 30°.

4.9. Weep Holes

Before starting works, the Contractor shall submit to the S.O. for approval a detailed proposal for the construction of weep holes. The location and spacing of weep holes shall be as shown on Drawings.

4.10. Quality Control

4.10.1. Method Statement

The Contractor shall submit method statement of works to the S.O. for prior approval by at least 7 days before commencement of works. The method statement shall contain details of material of specified quality, machines of specific model and capacity, operator and technician and his CV plus the estimated daily output to ensure the works can be completed within the scheduled work programme required. Quality control tests with respect to type and frequency plus the respective acceptance criteria shall also be included in the method statement. Remedial measures shall also be described in the method statement in cases where the acceptance criteria cannot be complied. In brief, method statement shall clearly describe how the guniting work will be carried out with particular reference to sequence of works, realistic work output, quality control and resources requirements, etc., to ensure the guniting work can be completed within the stipulated or agreed time frame according to the specification and approved programme. Method statement shall be prepared by experienced engineer who has extensive and intensive working experience and also is knowledgeable about the characteristics, capacity and efficiency of the resources available to his disposal. In addition, the engineer shall have inspected the site and surrounding conditions thoroughly and assesses how the specific conditions will affect the output of his resources.

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- 4.10.2. Rebound hammer test has to be carried out on pre-construction test panels at locations selected by the S.O. (at least 30 points). The Contractor has to redesign the mix and change equipment or nozzle man if the results of any cube or any rebound hammer test are below the specified strength shown on the Drawings.
- 4.10.3. For every 300m² of completed gunite works, a series of rebound hammer test (30 test point per series) has to be carried out to verify the strength (28 days strength). The S.O. reserves the right to reject the gunite work if the average test result is below the specified strength.
- 4.10.4. All the weep holes shall be marked by red paint to show the required effective thickness of gunite specified on the drawings.
- 4.10.5. Prior to spraying of gunite, the Contractor shall request inspection by the S.O. and a photo (minimum one photo for every 300m²) shall be taken to show the thickness markings. In addition to the markings, coring to check the thickness of gunite shall be subsequently carried out. Coring (100mm diameter) shall be at a rate of one core per 500m² at locations selected by the S.O. for checking the thickness and quality of gunite (void/honeycomb). The drilled holes shall be backfilled with dry-packed compressive (1:3) mortar. Documental evidence by photo for each core shall be carried out. The S.O. reserves the right to reject the gunite works if the thickness of gunite is found inadequate or the gunite is found porous or low strength (less than the specified value). Further coring (1 core per 200m²) shall be carried out at Contractor's own costs if defective works are detected.
- 4.10.6. The Contractor shall engage a specialist geotechnical engineer accredited by BEM or ACEM/IEM, to study and propose rectification works, when defective works are identified and directed by the S.O.. The Contractor shall be fully responsible for the costs, time delay in works and other incidental consequences for the defective works. The proposed rectification works, if accepted by the S.O., shall be carried out at the Contractor's own costs.

5. Rock Bolts and Rock Dowel

5.1. Description

This works consists of furnishing and installing rock reinforcing bolts and rock reinforcing dowels, complete with component parts, at locations shown or designated.

5.2. Work Plan

The Contractor shall submit a detailed work plan to the S.O at the preconstruction conference. Details to be included are as follows:

- 5.2.1. Proposed construction schedule and sequence.
- 5.2.2. Proposed drilling methods and equipment.

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- 5.2.3. Proposed components for rock reinforcing bolts and rock reinforcing dowels, couplers, bearing plates, rock reinforcing bolt mechanical anchorage system, flat washers, and beveled washer specifications including the manufacturer's data sheets.
- 5.2.4. Proposed drill hole diameter.
- 5.2.5. Proposed grout mix design, with polyester, resin, or epoxy specifications including manufacturer's data sheets. Include the procedures for placing the grout.
- 5.2.6. Proposed corrosion protection for the rock reinforcing bolt and rock reinforcing dowel systems.
- 5.2.7. Proposed installation, stressing procedures, torque wrench, test jack, and pressure gauge to be used.
- 5.2.8. Calibration data for each torque wrench, test jack, and pressure gauge to be used. An independent testing laboratory shall have performed the calibration tests within 60 calendar days of the date submitted. The torque wrenches shall have a capacity at least 20% greater than the rock reinforcing bolt manufacturer's recommended torque to achieve the design and test loads. The torque wrench shall have an accuracy of at least $\pm 2\%$ of the full-scale reading, and a resolution of at least 1% of the full-scale reading.

The S.O will respond within 21 days after receipt of the submittal. The Contractor shall not proceed with the work until the S.O has approved the submittal in writing.

5.3. Material

- 5.3.1. The Contractor shall provide rock reinforcing bolts, corresponding hardware, and grout from the manufacturer approved by the S.O.. Provide rock reinforcing dowels, corresponding hardware, and polyester or epoxy resin from a manufacturer regularly engaged in the manufacturer of rock reinforcing dowels. Additionally, all portions of rock reinforcing bolts and rock reinforcing dowels, accessories, and hardware shall have an approved corrosion protection coating. All non-exposed portions of rock reinforcing bolts and rock reinforcing dowels, accessories, and hardware shall be coated prior to installation. The use of cement grout for rock reinforcing bolts and polyester or epoxy resin for rock reinforcing dowels will not substitute for the required protective coatings.
- 5.3.2. The Contractor shall use proven non-shrink epoxy and polyester resin for rock reinforcing dowels capable of permanently developing the bond and internal strength between the rock reinforcing dowel and rock. Use a single speed cartridge system to anchor the dowel in rock. Select the cartridge diameter according to the recommendations of the manufacturer to ensure complete encapsulation of the rock reinforcing dowel and satisfactory in-hole mixing. An epoxy or polyester resin shall be selected with a gel time which is consistent with rapid installation. Epoxy or polyester resin to be incorporated into the rock reinforcing dowel installation shall be within the shelf-life period stated by the manufacturer. Provide samples of the epoxy or polyester resins for testing upon request of the Engineer. Store polyester or epoxy resins according to the manufacturer's recommendations.

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5.4. Equipment

The Contractor shall provide all equipment necessary for drilling and placement of rock reinforcing bolts and rock reinforcing dowels at the locations and depths designated by the S.O.. For rock reinforcing dowels, provide equipment to spin the dowel into place and properly mix the epoxy or polyester resin according to the manufacturer's recommendations.

5.5. Labour

5.5.1. The Contractor shall furnish personnel skilled in the installation of rock reinforcing bolts and rock reinforcing dowels. Experience shall be relevant to anticipated rock conditions and size of rock reinforcing bolts and rock reinforcing dowels being installed. The foreman and drill operator shall have no less than 2 years of demonstrated experience in rock reinforcing bolt and rock reinforcing dowel installation. The Contractor shall submit documentations relating its experience on similar jobs to the S.O. at the preconstruction conference. Details of the documentation shall include reference names and phone numbers, project names, locations, the year actually constructed.

5.5.2. The S.O will respond within 21 days after receipt of the submittal. If, after checking references submitted by the Contractor, it is in the judgment of the S.O that the proposed employees are not qualified; they will not be permitted to work on the Project. The Contractor shall not proceed with the work until the S.O has approved the submittal in writing.

5.6. Construction

5.6.1. Protection of Material

The Contractor shall protect rock reinforcing bolts and rock reinforcing dowels at all times from damage and corrosion. Corrosion, pitting or damage to the rock reinforcing bolt or rock reinforcing dowel may be cause for rejection. Damage includes, but is not limited to, abrasions, cuts, nicks, welds, and weld splatter. Prior to installation, remove all mill scale, flaking rust, and grease.

5.6.2. Installation

The Contractor shall drill holes to the diameter and depth recommended by the manufacturer. Unless otherwise directed, align drill holes normal to the rock face or as specified. The drill holes shall be cleaned of all drill cuttings and debris prior to installing the rock reinforcing bolt or rock reinforcing dowel.

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5.6.2.1. Rock Reinforcing Bolt

The Contractor shall install and tension each rock reinforcing bolt to the design load before grouting. The Contractor shall conduct proof testing of each bolt as described in sub-section 5.7.1. Grout shall be placed in the drill hole to ensure the filling of the entire space between the bolt and sides of the drill hole, and the full encapsulation of the bolt. The grout shall be pumped to the far end of the drill hole and continue pumping until grout is forced out of the de-airing tube at the face of the hole. After testing and grouting, cut the bolt off, if necessary, so that no more than 75mm extends beyond the nut.

5.6.2.2. Rock Reinforcing Dowel

The Contractor shall place the resin cartridges in the drill hole at a sufficient spacing to cause excess resin to be forced out the face of the hole when the rock reinforcing dowel is spun into place. Failure of resin to be extruded from the face of the hole may be cause for rejection of the bolt installation. After installation of the plate and nut, torque the nut to a nominal 73.8 Joules to ensure proper seating against the rock surface. The Contractor shall conduct proof testing of rock reinforcing dowels as described in sub-section 5.7.2. After testing, cut the bolt off, if necessary, so that no more than 75mm extends beyond the nut.

5.7. Proof Testing

Perform proof testing according to the following:

5.7.1. Rock Reinforcing Bolts

The Contractor shall tension each production rock reinforcing bolt installed to 120% of the design load using a calibrated hollow ram hydraulic jack and hold that tension for a minimum of 10 minutes. The S.O. will analyse the rock reinforcing bolt test results and determine whether the rock reinforcing bolt is acceptable. If no loss of load occurs in this time period, the rock reinforcing bolt is accepted. If a rock reinforcing bolt fails this test, the rock reinforcing bolt will be rejected, and a replacement bolt installed in a separate hole adjacent to the failed bolt. The Contractor shall test the new rock reinforcing bolt. The S.O. may require additional proof testing if any rock reinforcing bolts fail. No additional payment will be made for failed rock reinforcing bolts or for additional proof testing. After tensioning and testing, the Contractor shall lock off at 100% of the design load and grout the bolt. Grouting shall be carried out within 3 days of tensioning the rock bolt to provide corrosion protection and lock the tension stress permanently into the system.

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5.7.2. Rock Reinforcing Dowels

The Contractor shall proof test up to 5%, but not less than 3 of installed rock reinforcing dowels. The proof test shall be conducted by the Contractor and the Engineer will interpret the results. The Contractor shall tension the rock reinforcing dowel to 44.5kN with a calibrated hollow ram hydraulic jack and hold the load for 10 minutes with no loss of load. A rock reinforcing dowel will be considered to have failed if any movement of the dowel occurs. The S.O. may require additional proof testing beyond the 5% if any rock reinforcing dowels fail. Failed rock reinforcing dowels shall be replaced with a separate rock reinforcing dowel installed in a separate hole. No additional payment will be made for failed rock reinforcing dowels or for additional proof testing.

6. Ground Anchor

6.1. General

- 6.1.1. This specification deals with ground anchors and shall be read in conjunction with the conditions of contract and the Specification for Earthwork. The Contractor shall comply fully with the requirements of this specification in the design, erection and installation of ground anchors.
- 6.1.2. Where works are ordered to be performed by the Contractor but are not specified in this specification, the Contractor must carry them out with full diligence and expedience as are expected for works of this nature and shall comply with the relevant clauses of the British Standard Code of Practice for Ground Anchorages, BS 8081:1989.

6.2. Scope of Works

The contract comprises the provision of all labour, tools, plants, materials, transportation and all necessary equipment for the following works:

- 6.2.1. Design, supply, construct, install and test ground anchors as part of a permanent ground retaining system to support with safety the sides of open excavations.
- 6.2.2. Any other incidental works necessary to ensure the safety and satisfactory performance of the permanent earth retaining system.

6.3. Responsibility of the Contractor

- 6.3.1. The Contractor shall be experienced in ground anchor design (compression anchorage) and construction and shall have equipment and manpower suitable for the work and available for the entire operation of the work. The Contractor shall be wholly responsible at all times for the safety of works. He shall instruct his workers and all other personnel about the danger zones during the stressing of the anchors.
- 6.3.2. The Contractor is expected to study and place his own interpretation on the geotechnical data provided as well as obtain further data if he feels necessary. The Contractor shall give due consideration to existing underground utilities and limit of boundary in the design and installation of anchors.

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6.3.3. The Contractor shall engage a licensed surveyor to set out benchmarks and reference points from which to layout his work. It is the responsibility of the Contractor to acquire necessary permits and documents from the relevant authorities to carry out the work.

6.4. Designed by Specialist Contractor

6.4.1. The Contractor shall include in the submission of the tender, for the S.O.'s review, his proposed design of ground anchors in connection with the permanent earth retaining system. Unit rates of ground anchors shall be based on the allowable anchor forces required for the safe and adequate performance of the permanent retaining system. The Contractor's submission of calculations and shop drawings shall include the following information:

- 6.4.1.1. Anchor layout
- 6.4.1.2. Anchor design details
- 6.4.1.3. Anchor structural and geotechnical design capacity
- 6.4.1.4. Grade and properties of the tendon material
- 6.4.1.5. Percentage of tendon ultimate load at working load
- 6.4.1.6. Method and details of anchor fabrication
- 6.4.1.7. Details of double corrosion protection for permanent applications
- 6.4.1.8. Method and details of proposed grouting procedure
- 6.4.1.9. Grout/concrete - cement type, strength, additives
- 6.4.1.10. Anchor load, length, and bond diameter
- 6.4.1.11. Anchor free stressing length and de-bonding details
- 6.4.1.12. Initial pre-stress of anchor
- 6.4.1.13. Anchor bond design details
- 6.4.1.14. Endorsement by the Contractor's Professional Engineer
- 6.4.1.15. Any other information required by the S.O. in his review of the Contractor's design
- 6.4.1.16. Anchor head protection
- 6.4.1.17. Waller Beam design and details (if required)

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6.4.2. The Contractor's design calculations and specifications shall comply fully with the relevant recommendations of BS 8081: 1989: British Standard Code of Practice for Ground Anchorages, the requirements of the S.O.'s specifications, the Contractor's design shall be in accordance with accepted principles of good engineering practice. It shall be the Contractor's responsibility to clearly itemised those matters.

6.4.3. The review of the Contractor's design by the Engineer does not in any way absolve or reduce the duties and responsibilities of the Contractor to ensure the safety and adequacy of his works.

6.5. Method Statements for Construction Operations

6.5.1. Prior to commencement of works, the Contractor shall submit to the S.O. detailed method statements for the installation of ground anchors. For the purpose of this sub-section, a method statement shall be a document containing:

6.5.1.1. A detailed construction sequence

6.5.1.2. Proposed drilling method

6.5.1.3. Proposed installation method

6.5.1.4. Proposed stressing method and equipment

6.5.1.5. Proposed provisions for stressing or distressing

6.5.1.6. Material, plant and labour requirements at each construction stage

6.5.1.7. Rate of production output based on resources allocated, such as the average output in lineal metres of installed anchors per drilling frame per normal working day of 8 working hours per day

6.5.1.8. Shop drawings showing, among other things, details of all special requirements for the construction activities

6.5.1.9. Methods of testing: The S.O. shall during the execution of the works require the Contractor to submit detailed method statements of other construction operations. If requested by the S.O., the Contractor shall submit, within such times and in such detail as the S.O. may reasonably require, such information pertaining to the methods of construction (including the use of construction plant) which the Contractor proposes to use, and such calculations of the stresses and deflections that will arise in the permanent works or any part thereof during construction from the use of such methods, as will enable the S.O. to decide whether the permanent works can be executed with safety and in accordance with the contract if the methods are adhered to, and without detriment to the permanent works when completed.

6.5.2. The S.O. shall inform the Contractor in writing **within 14 days** after receiving the Contractor's method statement either:

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- 6.5.2.1. The Contractor's proposed methods have the consent of the S.O.; or
- 6.5.2.2. In what respect, in the opinion of the S.O., the proposed methods fail to meet the requirements of the contract.
- 6.5.3. In latter event, the Contractor shall take such steps or make such changes in the proposed methods as may be necessary to meet the S.O.'s requirements and to obtain his consent. The Contractor shall not change the methods that have received the S.O.'s consent without further consent in writing of the S.O., which shall not be unreasonably withheld. Works shall commence at such times when and not before the S.O. has given his consent to the method of construction.
- 6.5.4. Consent by the S.O. of the Contractor's proposed methods of construction in accordance with this sub-section shall not in any way relieve the Contractor of any of his duties or responsibilities under the contract.
- 6.6. Equipment and Labour
- 6.6.1. The Contractor shall provide all frames, equipment, lifting devices and labour necessary for the installation and grouting of anchors.
- 6.6.2. The Contractor shall satisfy the S.O. regarding the suitability, efficiency and operational capability of the anchor installation equipment. The Contractor shall be required to provide adequate numbers of operational drilling frames to ensure that the works are completed within the time period stipulated in the approved construction programme. The Contractor is deemed to have made provision for the availability of standby plant at all times to allow for the contingency of equipment failure.
- 6.6.3. The S.O. shall order the removal or replacement of any equipment or staff whenever he is of the opinion that such equipment and staff are not suitable for the works. Equipment found to have a consistent record of breakdowns shall be removed from the Site.
- 6.7. Inspection and Testing
- 6.7.1. The S.O. shall inspect the installation of anchors and will monitor anchor stressing acceptance tests to ensure that the Contractor's anchor design and construction method will produce the suitable anchorage system in the soil/rock conditions encountered on site.
- 6.7.2. The testing of concrete and grout shall be in accordance with the provisions for works concrete in the General Concrete Specification.
- 6.8. Compliance Inspection
- The S.O. shall carry out inspection to ensure that the Contractor follows the approved shop drawings and good engineering practice.

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6.9. Acceptability

Acceptance test shall be carried out on all permanent ground anchors in accordance to BS 8081. Failure of any anchor to meet acceptance test criteria will result in rejection of the anchor in question. Consistent failure of a given anchor type requires reassessment of the anchor design and installation practices.

6.10. Materials

6.10.1. General Requirements

6.10.1.1. The requirements listed in the following sub-sections shall apply, wherever relevant, to materials used in all anchors except when otherwise agreed by the S.O.. The handling, storage and use of materials shall comply with manufacturers' instructions.

6.10.1.2. An anchor shall not contain materials that are mutually incompatible with each other and the surrounding environment.

6.10.1.3. All anchors shall have a double corrosion protection.

6.10.2. Tendons

6.10.2.1. Pre-stressing tendons shall comply with the following:

- (i) High tensile steel wire and wire strand with a minimum tensile strength of 1860 N/mm² to BS 5896: 1980
- (ii) Wire steel strand to BS 4757: 1971
- (iii) Hot rolled or hot rolled and processed high tensile alloy steel bars to BS 4486: 1980

6.10.2.2. Steel wire and wire strand shall be in coils of sufficiently large diameter to ensure that the steel wire and wire strand payoff straight.

6.10.2.3. Alloy steel bars shall be straight.

6.10.2.4. A certificate shall be submitted to the S.O. containing the following particulars on the pre-stressing tendons:

- (i) The manufacturer's name and the date and place of manufacture
- (ii) Cast analysis
- (iii) Diameter, cross sectional area and unit mass
- (iv) Results of test for mechanical properties, including the characteristic breaking load, characteristic 0.1% proof load, elongation at maximum load, relaxation and modulus of elasticity

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(v) Results of tests for ductility of pre-stressing wires

6.10.3. Cement Grout

- 6.10.3.1. Cement used for grouting anchors shall comply with MS 522.
- 6.10.3.2. Grout shall consist of Ordinary Portland Cement and water with a water/cement ratio of 0.40/0.45. Sand, PFA and High alumina cement shall not be used unless approved by the S.O..
- 6.10.3.3. Water shall be taken from the public supply of potable water and shall be at least to the quality specified in MS 28.
- 6.10.3.4. Admixtures shall comply with the requirements of BS 5075: Part 1: 1982 and BS 5075: Part 3: 1985 and shall only be used with the prior agreement of the S.O..
- 6.10.3.5. The total sulphate (SO_3), chloride and nitrate contents of the grout shall not exceed 4%, 0.1% and 0.1% expressed as a percentage between the respective ion content and the cement content by mass in the grout. The total sulphate (SO_3) and chloride contents shall be determined by the method described in BS 1881: Part 6: 1971. The total nitrate content shall be determined by the method described in ASTM D 4327-84.
- 6.10.3.6. Grout cubes of 100mm size shall be prepared and cured in accordance with BS 1881: Part 3: 1970 and the strength of grout cubes shall be tested in accordance with BS 1881: Part 4: 1970. The grout shall have a minimum compressive strength measured on 100mm cubes 20N/mm² at 3 days and 35N/mm² at 28 days. Collection of grout shall be from the grout overflowing from the drill holes unless otherwise agreed by the S.O..
- 6.10.3.7. Admixture, if used, shall be provided at the Contractor's own expense. Admixtures shall impart to the grout the properties of low water content, good flow ability, minimum bleeding and controlled expansion. Its formulation shall contain no chlorides or other chemicals in quantities that may have harmful effects on the cement or pre-stressing steel. The Contractor shall submit to the S.O. the manufacturer's literature indicating the type of admixture and the manufacturer's recommendations for mixing the admixture with the grout. All admixtures shall be used in accordance with the instructions of the manufacturer.

6.10.4. Greases

- 6.10.4.1. The greases used shall be formulated and manufactured for the specific purpose of corrosion protection and to provide lubrication to pre-stressed high tensile steel tendons. Greases shall be water displacing, self-healing, and shall be resistant to microbiological degradation. The properties of the grease shall be such that, in the process of pumping, voids are filled and intimate contact is established between the grease and all the steel surfaces of a strand or tendon.

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6.10.4.2. Greases, including any used by the manufacturer of the tendons, shall comply with the requirements set down in **TABLE R6**. The Contractor shall provide the following information:

- (i) Product identification details (including name of manufacturer, brand name, type and date of manufacture), and
- (ii) Nature of the soap used (if any)

6.10.4.3. Any grease to be used in the Contract shall be accompanied by test certificates which show that it complies with the requirements stated in **TABLE R6**. Grease shall be used in accordance with the manufacturer's instructions.

6.10.4.4. Different types of grease shall not be allowed to come into contact with each other in any part of the anchor.

6.10.5. Plastics

6.10.5.1. Sheathing, ducting and other plastic components for tendon protection shall be made from high density thermoplastic material and the wall thickness shall be at least 1.0mm.

6.10.5.2. The finished internal and external surfaces of the sheathing and ducting shall be smooth, clean and free from flaws, pin holes, bubbles, cracks and other defects. The material used shall be homogeneous, thermally stable and chemically inert and shall be resistant to chemical, bacterial and fungal attack. Sheathing, ducting and other plastic protective components shall not contain any substances that will promote corrosion.

6.10.5.3. Plastic components shall be covered to prevent exposure to ultraviolet light from direct or indirect sunlight.

6.10.5.4. All plastics to be used in an anchor shall be accompanied by test certificates to show that the material complies with the requirements stated in

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6.10.5.6. **TABLE R7.** Plastics shall be used in accordance with the manufacturer's instructions.

6.10.5.7. Plastics shall be used in accordance with the manufacturer's instructions.

6.10.5.8. All plastics used in an anchor shall be resistant to slip in the region of the fixed anchor length and shall be capable of withstanding the effect of load transfer.

6.10.5.9. The Contractor shall also provide the following information:

- (i) Product identification details (including name of manufacturer, brand name, type and date of manufacture of product)
- (ii) Outer and inner diameter
- (iii) Wall thickness
- (iv) Amplitude and pitch, in (mm), for corrugated sheathing or ducting
- (v) Standard length in (m)
- (vi) Jointing details

6.10.6. Metal Ducting

6.10.6.1. Metal ducting shall only be used with the agreement of the S.O..

6.10.6.2. Metal ducting shall be suitably protected against corrosion, resistant to slip in the region of the fixed anchor length, and capable of withstanding the effect of load transfer.

6.10.7. Rubber Rings

6.10.7.1. Rubber rings used in the corrosion protection system shall be manufactured from materials which comply with BS 2494: 1986.

6.10.7.2. Product identification details (including name of manufacturer, brand name, type and date of manufacturer of product), and evidence that the product complies with BS 2494: 1986, shall be provided.

6.11. Corrosion Protection

6.11.1. General

6.11.1.1. Recommendations concerning some commonly used protective systems for anchorage components shall be followed in the Contractor's proposal on the corrosion protection unless otherwise agreed by the S.O..

- (i) Tendon

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- (a) The tendon shall be given adequate corrosion protection which shall remain effective throughout the design service life of the anchorage. The effectiveness of the protection shall not be impaired during storage, transport, installation and stressing of the anchorage. The steel shall not suffer mechanical damage when the plastic sheathing is removed.
- (b) In the zone defined by the free tendon length, the corrosion protection shall not affect the freedom of the tendon to expand.
- (c) Before the corrosion protection is applied, any substances (e.g. dirt, grease, ice or loose rust particles) likely to impair the serviceability of the tendon (e.g. bond or corrosion resistance) shall be removed from its surface.
- (d) Pre-stressing steel tendons shall not develop more than rust bloom up to the time the anchorage is installed. Pre-stressing steel and preassembled anchorages shall be stored in a dry place.

Note: Rust bloom is defined as a uniform layer of rust without wide pitting, visible to the naked eye and removable by wiping with a dry cloth.

(ii) Tendon Joint

The corrosion protective system applied to the joint assembly shall be at least equivalent to that given to the free tendon length and shall not hinder deformation of the tendon.

(iii) Anchor Head

The anchor head shall be protected against corrosion. The end cap for protection of the anchor head shall be made of galvanised or stainless steel. The corrosion protection between anchor head and the proximal end of the plastic sheathing in the zone defined by the free tendon length shall include the seal at the proximal end. If anchorages require re-stressing or inspection during the service life, care shall be taken to ensure that re-grouting at the anchor head is possible.

(iv) Waler

All the steel components of waler beam, anchor head and bracket system shall be galvanised steel.

6.11.2. Corrosion Protection of Permanent Anchorages

6.11.2.1. Proof of suitability of the corrosion protection system shall be provided for permanent anchorages.

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6.11.2.2. This proof shall, among other things:

- (i) Provide information on whether the components of the corrosion protection system are compatible.
- (ii) State that the system provides a degree of corrosion protection equivalent to that of proven systems
- (iii) State the corrosion-protective agent will not adversely affect the properties of the tendon during its application or subsequently under service conditions
- (iv) States that the protection of the tendon extends over the full length of the sheathing, and the tendon is tightly sealed
- (v) State that in the anchored zone the corrosion protection does not affect the freedom of the tendon to expand.

6.11.2.3. Cementitious grout shall be deemed adequate corrosion protection if in close corrosion and does not permit the penetration of water. Normally, the minimum grout cover shall be 10mm; anchorage design and type of sheath may require a thicker cover.

6.11.2.4. The corrosion protection of the tendon and the anchorage components shall be factory applied.

6.11.2.5. Where a corrugated sheath is used, the grout cover in the anchorage zone shall be 10mm minimum, the same thickness being required in the case of compression anchorages.

6.11.2.6. Where the corrosion protection is applied in the form of a coating, the specifications of DIN 55 928 Parts 4 to 6 shall be observed. If grout sealing compounds are used for corrosion protection, loose particles need not be removed from the tendon prior to the corrosion protection treatment.

6.11.2.7. If the anchorage or part of it is protected against corrosion after installation (e.g. corrosion protection of anchor head after grouting), this work shall be supervised to ensure that proper workmanship is maintained.

6.11.2.8. If plastic compounds are used for corrosion protection, spacers shall be fitted to ensure an adequate thickness of the compound enclosing the tendon. Where the corrosion protection is applied in the form of a coating, a material shall be introduced into the space between the tendon and sheath so as to fill it completely and permanently unless it has been verified that the seals fitted between tendon and sheath are capable of maintaining their function after stressing of the anchorage. Where grouting material is used for corrosion protection purposes, the sheath shall be deemed adequate mechanical protection if it is made of a material that does not permit penetration of water.

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6.12. System Components

6.12.1. General

The anchor shall be designed to provide an ultimate load holding capacity of not less than specified. The anchor shall be designed and constructed so that compressive forces within the free length will not damage the corrosion protection.

6.12.2. Free and Fixed Anchor Length

The free anchor length is the distance between the anchor head and the proximal end of the grout. The fixed anchor length is the length of anchorage over which the tensile load is capable of being transmitted to the surrounding ground. The fixed anchor length shall not be less than 3m for all anchors subjected to acceptance tests.

6.12.3. Spacers and Centralisers

6.12.3.1. Spacers shall be provided on multi-tendon anchors to ensure separation between the individual components, and to ensure individual tendons are positioned uniformly over the cross-section of the drill hole.

6.12.3.2. Centralisers shall be provided on multi-tendon anchors to ensure separation between the individual components, and to ensure individual tendons are positioned uniformly over the cross-section of the drill hole.

6.12.3.3. Centralisers shall be provided on the tendon at suitable intervals to meet the following requirements:

- (i) Within the fixed anchor length, the tendon shall be positioned in the grout column so that a minimum grout cover to the tendon of 10mm is maintained.
- (ii) Within the design free anchor length, there shall be a minimum clearance of 10mm between the tendon and the sides of the drill hole or casing.

6.12.4. Anchor Head Components

6.12.4.1. The anchor head components which retain the force in the stressed tendon shall comply with the requirements of BS 4447:1973.

6.12.4.2. The anchor head shall be designed so as not to induce secondary stresses in the tendon. Wedges (or spherical washers) should be fitted between anchor head and support plinth, unless the anchor head permits compensation for angular deviations of the tendon from the axial position. A check shall be made whether, in addition to protection against corrosion, anchor heads should be given mechanical protection.

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6.12.4.3. Proof of the suitability of the anchor head design shall be provided (e.g. by submitting an agreement). The anchor head design for permanent anchorages shall permit in-service tests to be made as long as such tests are required.

6.13. Submission of Alternative Systems for Approval

- 6.13.1. Alternative systems if any, shall be included in the submission of the tender for the S.O.'s review. If the design is agreed in principle, the alternative system shall be included in the contract documents.
- 6.13.2. In principle, acceptance of a design submission does not relieve the Contractor in any way from providing an anchor system of adequate performance and consistent with the specification.

6.14. Anchorages

- 6.14.1. Anchor plates and nuts shall be compatible with the pre-stressing system use. Anchorage components shall develop at least 95% of the minimum guaranteed ultimate strength of the tendon.
- 6.14.2. Both smooth and corrugated plastic sheathing shall terminate inside a metal sleeve attached to the back of the anchor plate. Enough unsheathed length of the tendon shall be left within the metal sleeve to allow tightening of the anchor nut when the tendon elongates during stressing. All free room inside the sleeve shall be filled with grease prior to stressing.

6.15. Equipment

6.15.1. General

- 6.15.1.1. All stressing equipment must be used in accordance with the specifications of the manufacturer and Clause 9 of BS 8081:1989 and must at all times be maintained in good condition.
- 6.15.1.2. The pumps, jacks and all tensioning equipment shall be calibrated. All calibrations must be conducted by an approved laboratory with the necessary equipment and must be certified. The calibrations shall be carried out no longer than 3 months prior to using the equipment on site. If any incident occurs during transportation, handling or tensioning which may have caused damage, the equipment must be recalibrated. The S.O. will direct the use of load cell to recalibrate stressing equipment or reject the equipment if the calibration submitted is not acceptable.
- 6.15.1.3. Anchor stressing shall be in the manner specified in the approved shop drawings. Stressing shall not be carried out until the grout has reached its specific strength.

6.15.2. Fabricating and Placing

All equipment used for fabrication, handling and placing shall be such that it will not damage the anchor tendons.

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6.15.3. Grouting Equipment

The grouting equipment shall be capable of continuous mechanical mixing to produce a grout free of lumps and un-dispersed cement. A manifold system with a series of valves and calibrated pressure gauge with a capacity of 10N/mm² shall permit continuous circulation and pumping of grouting with accurate control of grout pressure.

6.15.4. Stressing Equipment

Stressing equipment shall be capable of applying at least the specified test load to the anchor tendon. A calibrated pressure gauge indicating the hydraulic jack pressure should, as a minimum requirement, comply with Class 2 of BS 1780. They should be supplied with a calibration certificate and shall read to an accuracy of at least $\pm 3\%$ of the load applied.

6.16. Anchor Fabrication

- 6.16.1. Anchors shall be either shop fabricated, or field fabricated in accordance with approved shop drawings, using personnel trained and qualified in this type of work.
- 6.16.2. Anchors shall be free of dirt, detrimental rust or any other deleterious substance.
- 6.16.3. Anchors shall be handled and protected prior to installation in such a manner as to avoid corrosion and physical damage thereto.
- 6.16.4. All field joints of the corrosion protection shall be made watertight by an epoxy bonding compound or equivalent.

6.17. Drilling

- 6.17.1. Holes for anchors may be formed by driving or drilling method. The drilling method used shall be subjected to the agreement of the S.O. Full temporary casing shall be installed to maintain a clean and open shaft and prevent wash out of fines outside the casing in all holes. Grouting shall be carried out with the temporary casing inside the hole and after fresh grout emerge from the hole, then only the temporary casing can be slowly retrieved while grouting continues. Any alternative method shall be approved by the S.O..
- 6.17.2. Drill holes for ground anchors shall be provided in accordance with the Drawings. The drill hole entry point shall be positioned within a tolerance of $\pm 75\text{mm}$. Deviation in alignment shall not exceed 1 in 30. Deviation from straight shall not exceed 20mm in any 3m length of drill hole.
- 6.17.3. The Contractor shall keep a record of all drilling procedures and times, which shall be made available to the S.O.. No drilling through the reinforcement of contiguous bored pile is allowed.

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6.18. Anchor Installation

6.18.1. General

- 6.18.1.1. The installation of the tendons shall be supervised by suitably qualified personnel familiar with this type of work. The curricular vitae of the personnel shall be submitted to the S.O. before commencement of work.
- 6.18.1.2. All equipment used for handling and insertion of the anchor shall be such that it will not damage the anchor tendon and corrosion protection. Grout tubes shall be flushed with water or compressed air to ensure that they are clear.
- 6.18.1.3. The anchor bonded lengths as indicated in the approved design submissions shall be considered the minimum bonded lengths and shall be located within the specified bond zone of the anchorage stratum.
- 6.18.1.4. All anchors shall be installed through the casing to avoid damage to the corrosion protection.
- 6.18.1.5. The Contractor shall maintain a record showing the anchor type, length, position and installation date for each anchor. The installation of anchor should be inspected or witnessed by the S.O. on the following stages:
 - (i) End of bore
 - (ii) Insertion of tendon
 - (iii) Grouting
 - (iv) Completion of installation

6.18.2. Water Testing and Pre-Grouting

- 6.18.2.1. The drill hole shall be subjected to a water test to determine the likelihood of grout loss around the fixed length. However, the S.O. may agree to omit this test in exceptional ground conditions and/or where the Anchor System installation method statement provides an alternative.
- 6.18.2.2. Subject to the agreement of the S.O., the Contractor may pre-grout the fixed length prior to the water testing.
- 6.18.2.3. The test shall be carried out by the application of a net water pressure of one atmosphere (100kPa), or a lower pressure agreed by the S.O., at the proximal end of the fixed length which shall be maintained for a period of ten minutes. The water loss in this period shall not exceed 50 litres. The net water pressure shall be the difference between the applied test pressure and the existing water pressure in the drill hole.

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6.18.2.4. The test may be undertaken using a drill hole packer to seal off the section under test. Alternatively, it may be carried out by using the net pressure defined above through filling the drill hole with water. The volume of water required to maintain a constant head shall then be measured and shall not exceed 50 litres over ten minutes.

6.18.2.5. Should the test fail, the fixed anchor length shall be grouted under a pressure not exceeding a pressure agreed by the S.O.. The drill hole shall then be flushed or drilled out, and the water test re-applied.

6.18.2.6. A full record of the water test shall be submitted to the S.O..

6.18.3. Insertion of Anchor

6.18.3.1. The S.O. shall be given assistance in his inspection of the drill hole and shall be provided with the records for drilling and water testing prior to the Contractor seeking his approval.

6.18.3.2. If the drill hole proves unacceptable, the Contractor shall seek instruction from the S.O. as to whether the hole is to be grouted and re-drilled, re-provided as a drainage hole or grouted and abandoned. Once the drill hole has been accepted, the Contractor shall proceed to insert the anchor.

6.18.3.3. The anchor shall be inserted within 24 hours of completion of the drilling except where otherwise agreed by the S.O.. The anchor shall be handled with care. During insertion, it shall be installed at a controlled rate to avoid damage to itself and the drill hole.

6.18.3.4. The anchor shall be positioned in accordance with the requirements of sub-section 6.12.4 and shall be secured to prevent further movement.

6.19. Grouting

6.19.1. General

6.19.1.1. Grout shall consist of materials specified in sub-section 6.10.3. The grout shall not remain in the mixer for a period exceeding 45 minutes, failing which it shall be rejected. Pressure grouting to the bonded section of the anchor is required to ensure the grout will not be washed away from the tendon.

6.19.1.2. The primary grout shall be pumped into the anchor hole through a grout pipe provided for that purpose until the hole is filled to the top of the anchorage zone. The grout shall always be injected at the lowest point on the bond length. Provisions shall be made for determining the level of the top of the primary grout to assure adequate anchorage. After grouting, the hydrostatic pressure due to gravity of the grout body will be 0.02N/mm² per vertical metre and this shall be considered when assessing the effective grout pressure at the lowest point of the bond length.

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- 6.19.1.3. The free stressing length shall be flushed out to remove any access grout above the bond length with specially provided flushing tubes. The void of the free-stressing length shall be filled with low strength bentonite cement grout.
- 6.19.1.4. After grouting, the anchors shall remain in an undisturbed condition until the necessary grout strengths have been achieved.
- 6.19.2. Bleeding, Free Expansion and Fluidity
- 6.19.2.1. The grout shall not be subjected to bleeding in excess of 0.5% by volume three hours after mixing or 1% maximum when measured at 20°C in a covered glass or metal cylinder of 100mm internal diameter and with a grout depth of approximately 100mm. In addition the water shall be re-absorbed within 24 hours. Free expansion of the grout shall not exceed 10% at the ambient temperature.
- 6.19.2.2. Fluidity of the grout shall be tested in accordance with methods agreed by the S.O.. Except with the prior agreement of the S.O., for grouts containing admixtures, the afflux time of the grout shall not be less than 15 seconds.
- 6.19.3. Sampling for Tests on Bleeding, Free Expansion, Fluidity and Strength
- 6.19.3.1. At least one sample of grout shall be obtained for each Acceptance Test anchor. In the case of Acceptance Test anchors, at least one sample shall be taken from each fresh grout batch used to grout the first five anchors. Thereafter, another sample shall be taken for every five additional anchors grouted with the same batch. The samples shall be taken not more than 1 hour after the grout has been mixed. If directed by the S.O., the grout may have to be sampled from the fresh grout flow out from the drill hole when the grouting process is near completion. Each sample of grout taken shall be divided into three specimens. Each specimen shall be tested to determine the amount of bleeding, free expansion and fluidity.
- 6.19.3.2. A set of three grout cubes shall be prepared for cube strength determination in accordance with sub-section 6.10.3 from each sample of grout taken.
- 6.19.4. Trial Grout Mixes
- 6.19.4.1. A trial grout mix shall be carried out in accordance with sub-section 6.19.5 using the designed water-cement ratio and admixtures (if any) and the proposed grouting equipment to be used for the Contract.

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6.19.4.2. One sample of the grout from the trial mix shall be divided into three (3) specimens and each specimen shall be tested to show compliance with the bleeding, free expansion and fluidity requirements stated in sub-section 6.19.2.

6.19.4.3. One sample of the grout from the trial mix shall be taken for determination of the grout cube strength to show compliance with the requirements in sub-section 6.10.3.

6.19.4.4. One (1) sample of the grout from the trial mix shall be divided into three specimens and each specimen shall be tested to show compliance with the total sulphate (SO_3), chloride and nitrate contents requirements stated in sub-section 6.10.3.

6.19.4.5. Results of the trial grout mix tests showing the degree of compliance with the Specification shall be submitted to the S.O. at least two (2) weeks before the commencement of grouting.

6.19.5. Grout Mixing

6.19.5.1. Batching of the dry materials shall be by weight. The amount of water used shall be measured by a calibrated flow metre or a measuring tank.

6.19.5.2. The procedure to be followed for mixing the grout shall be that approximately two-thirds of the cement shall be added to the water, followed by the admixtures, if any, followed by the remaining third of cement.

6.19.5.3. The grout shall be mixed in a mechanical mixer capable of imparting a high shear action to the grout components so that a colloidal grout of uniform consistency is produced in a mixing time of less than 5 minutes.

6.19.5.4. The grout mixing process shall utilise a re-circulating system where the grout is continuously discharged and recharged into the mixing unit during the mixing period. After mixing, the grout shall be kept continuously agitated.

6.19.5.5. The grout shall be passed through a nominal 1.2mm sieve prior to injection. The grout shall be used as soon as possible after mixing and in any case within 30 minutes of adding cement unless otherwise agreed by the S.O..

6.19.6. Grout Injection Equipment

The pump used for grout injection shall be of the positive displacement type, i.e. it shall be actuated by a piston or screw. A flow metre and a pressure gauge shall be provided. The S.O.'s approval of the equipment shall be obtained prior to its use.

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6.19.7. Grouting Procedures

6.19.7.1. The grouting operation shall be undertaken within 24 hours of the anchor being inserted except where otherwise agreed by the S.O.. The procedure adopted shall ensure that there are no air or water inclusions left in the grouted zone.

6.19.7.2. The grouting pressure adopted shall be the minimum consistent with undertaking the operation and shall avoid damage to surrounding buildings, land, structure, street and services.

6.19.7.3. Grouting shall proceed at a slow, steady rate and shall continue until injected grout of the same composition and consistency as that mixed has been emerging from the outlet for at least 1 minute.

6.19.8. Grouting Records

A record giving full details of the grouting operation for each anchor shall be supplied to the S.O. prior to a request seeking his acceptance of the anchor.

6.20. Fitting Anchor Head

The anchor head and its associated components shall be fitted concentrically to the tendon within a tolerance of $\pm 5\text{mm}$ and perpendicular to the tendon within a tolerance of $\pm 3^\circ$. Any leakage of water/fluid from the anchor hole or anchor head shall be sealed by approved method.

6.21. Anchor Testing

6.21.1. General

6.21.1.1. There are three (3) classes of tests for all anchorages as follows:

- (i) Proving tests
- (ii) On-site suitability tests
- (iii) On-site acceptance tests

6.21.1.2. Proving tests are required to demonstrate or investigate, in advance of the installation of working anchorages, the quality and adequacy of the design in relation to the ground conditions and material used and the levels of safety that the design provides.

6.21.1.3. On-site suitability tests are carried out on anchorages constructed under identical conditions as the working anchorages and loaded in the same way to the same level. These may be carried out in advance of the main contract or on selected working anchorages during the course of the construction. The period of monitoring should be sufficient to ensure that pre-stress or creep fluctuations stabilise within tolerable limits. These tests indicate the results that should be obtained from the working anchorages.

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6.21.1.4. On-site acceptance tests are carried out on all anchorages and demonstrate the short-term ability of the anchorage to support a load that is greater than the design working load and the efficiency of load transmission to the fixed anchor zone. A proper comparison of the short-term results with those of the on-site suitability tests provides a guide to longer term behaviour.

6.21.1.5. Anchor testing shall be carried out in accordance with British Standard for Ground Anchorages BS 8081:1989. Testing of anchor shall not be carried out until the grout has reached its specified strength. For all testing, load cell shall be used to measure the load and measurement of displacement shall be carried out using both steel ruler and dial gauges unless otherwise agreed by the S.O..

6.21.2. Proving Tests

6.21.2.1. Before any anchorage is employed, proving tests shall be carried out on trial anchorages to demonstrate to the S.O. the suitability of materials, components, methods of construction and workmanship. The scope of the proving tests shall be sufficient to demonstrate the satisfactory performance of the anchorage for use under the conditions for which it is proposed.

6.21.2.2. Proving tests should be carried out to investigate the behaviour and performance working anchorage, the quality and adequacy of the design and the level of safety that the design provides. In particular, the tests should investigate such factors as the load capacity, load extension behaviour, relaxation and creep. Consideration should also be given to the corrosion protection and its resistance to physical damage during handling, storage, installation and stressing; together with an overall assessment of performance.

6.21.2.3. The suitability of all materials, components and methods of construction shall be demonstrated to the designer before acceptance of any anchorage scheme.

6.21.2.4. Proving tests shall be carried out and interpreted in accordance with British Standard Code of Practice for Ground Anchorages BS 8081: 1989 sub-section 11.2 unless otherwise agreed by the S.O.. The anchorages shall have structural capacities of at least three times the geotechnical working capacity.

6.21.3. On-Site Suitability Tests

6.21.3.1. On-site suitability tests shall be carried out to prove the suitability of the anchorages for the conditions on site. On-site suitability tests may be applied to anchorages to be used in the works or they may be additional and provided under the contract. The anchorages shall be constructed in exactly the same way and located in the same ground conditions as the working anchorages and shall be used as reference anchorages against which the performance of the working anchorages can be judged.

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6.21.3.2. At least three (3) anchorages shall be subjected to suitability tests with further tests for each category of anchorages envisaged in the works.

6.21.3.3. Anchorages for suitability tests shall be proof loaded to 1.5 to 2 times the working loads subject to the agreement of the S.O..

6.21.3.4. Suitability tests shall be carried out and interpreted in accordance with British Standard Code of Practice for Ground Anchorages BS 8081: 1989 Clause 11.3 unless otherwise agreed by the S.O..

6.21.4. On-Site Acceptance Tests

6.21.4.1. All anchorages shall be subjected to acceptance test before locking off at transfer load. Acceptance tests shall be carried out and interpreted in accordance with British Standard Code of Practice for Ground Anchorages BS 8081: 1989 Clause 11.4 unless otherwise stated in this specification.

6.21.4.2. Acceptance tests shall include creep testing and lift off test.

6.21.4.3. The Contractor shall maintain access and have the capability to conduct lift off test and to re-stress or de-stress anchors at any location as requested by the S.O..

6.21.4.4. The anchors shall be capable of sustaining over the entire period of construction the design working load with a factor of safety of 2.0.

6.21.4.5. Failure to meet the acceptance criteria shall constitute a failure of the anchor installation. In this event, the Contractor shall submit his method of remedial work or replacement of anchor to the satisfaction of the S.O..

6.22. Monitoring

6.22.1. Requirements for Monitoring

6.22.1.1. All anchors shall be installed so that the residual load in the tendon can be monitored. All monitoring operations shall be undertaken so that there is no overloading or damage to the anchor. Specification of Instrumentation and Monitoring for Retaining Structures and Excavation shall be followed.

6.22.1.2. The Contractor shall monitor the anchors up to the end of the Contract Period in accordance with the programme and procedure given in sub-section 6.22.3 and 6.22.4.

6.22.2. Load Measurement

6.22.2.1. Load cells shall be provided to monitor the residual loads of the anchor. The load cells shall be robust and appropriately protected for site work.