JKR/SPJ/2013-S16
JKR 21300-0055-14

KERAJAAN MALAYSIA
JABATAN KERJA RAYA MALAYSIA

STANDARD SPECIFICATION FOR ROAD WORKS

Section 16: Slope Stabilisation



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FOREWORD

As practices in road construction change over time, it is imperative for Jabatan Kerja Raya (JKR) to continuously update and improve their standard specifications. These new specifications are not only aimed at keeping abreast with current technologies but also helping in improving the quality of constructed product. In unison, these new specifications have a significant positive impact on the construction industry especially with the incorporation of new products and technologies.

Standard Specification for Road Works is an essential component in the road infrastructure construction industry. This specification provides an improved guidance in the material selection and the production of good quality workmanship and products, based on current best practices. The purpose of this standard specification is to establish uniformity in road works to be used by road designers, road authorities, manufacturers and suppliers of road related products.

This document "Standard Specification for Road Works - Section 16: Slope Stabilisation" is a new section to the Standard Specification for Road Works. The compilation of this document was carried out through many discussions by the technical committee members. Additionally it has been presented at a technical workshop held on 11th – 12th May 2011. Feedbacks and comments received were carefully considered and incorporated in the specification where appropriate.

This Specification had also been presented in the *Mesyuarat Jawatankuasa Spesifikasi Piawai JKR bagi Kerja-kerja Jalan Bil.* 1/2013 on 9th January 2013 and finally approved in the *Mesyuarat Jawatankuasa Pemandu Pengurusan Bil.* 16/2013 on 23th July 2013.

This document will be reviewed and updated from time to time to cater for any changes on policies and current requirements. In this respect, any comments and feedback regarding this specification should be forwarded to Unit Standard & Spesifikasi, Cawangan Kejuruteraan Jalan & Geoteknik.

Published by: -

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January 2014

ACKNOWLEDGEMENT

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Special thanks and appreciation to the following proof reader: -

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Finally, the publisher would like to express its gratitude to the above committee members for their substantial contributions towards the successful completion of this document.

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16.1 HORIZONTAL DRAINS INSTALLATION

16.1.1 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.

16.1.2 Materials

16.1.2.1 Polyvinyl Chloride (PVC) Pipes

(a) 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.

(b) 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.

(c) At least two 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.

16.1.2.2 Filter Cloth

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

(a) 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.

(b) Physical Property Requirements

The physical properties of the filter cloth shall comply with Table 16.1.1.

TABLE 16.1.1 – PHYSICAL PROPERTY REQUIREMENTS FOR FILTER CLOTH

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

(c) 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.

16.1.2.3 Perforations

(a) Perforations consist of two 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.

(b) 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.

16.1.3 Construction

16.1.3.1 Requirements

(a) 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.

(b) 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.

(c) 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.

(d) The contractor shall provide the S.O with suitable means of making a linear determination of the quantity of drain material used.

16.1.3.2 Drilling

(a) 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 in the Drawings and as specified in this specification.

(b) 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.

(c) The temporary drilling platform shall be erected firmly on the ground/slope, such that no excessive movements or sway occurs during drilling.

(d) 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.

(e) 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 Clause 16.1.3.5.

(f) 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.

16.1.3.3 Pipe Installation

(a) 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 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.

(b) 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.

16.1.3.4 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.

16.1.3.5 Submittals

(a) 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.

(b) 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

16.1.3.6 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.

16.1.3.7 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

16.2 GEOCELL

16.2 GEOCELL

16.2.1 General

16.2.1.1 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 contract drawings.

16.2.1.2 Contractor's Responsibilities

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.

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 contract drawings.

16.2.2 Material Properties

16.2.2.1 Product and Applications

(a) 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.

(b) 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.

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

16.2.2.2 Technical Properties

The properties of the geocell shall meet or exceed the minimum values corresponding to the respectively test methods as shown in Tables 16.2.1 and Table 16.2.2.

TABLE 16.2.1 – 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 16.2.2 – 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

16.2.2.3 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.

16.2.2.4 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.

16.2.3 Testing

16.2.3.1 General

(a) 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.

(b) 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.

(c) 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.

16.2.3.2 Consignment Certificate

(a) 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

16.2.4 Packaging and Storage

16.2.4.1 Product Labelling

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

(a) Product Brand Name

(b) Product Type

(c) Panel Width and Length

(d) Batch Serial Number

16.2.4.2 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.

16.2.4.3 Storage at Site

(a) 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.

(b) 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.

16.2.5 Installation

16.2.5.1 General

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

16.2.5.2 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.

16.2.5.3 Infill Material Placement

(a) Suitable infill materials shall be as specified on contract drawings or shall consist of one of the following: -

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

(ii) Fertilised soil

(iii) Concrete Grade 25

(b) 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 contract drawing.

16.3 SOIL NAILING

16.3 SOIL NAILING

16.3.1 General

(a) 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 in the Drawings or as directed by the S.O.

(b) 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.

(c) 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 Clause 16.3.8 at locations selected by the S.O.

16.3.2 General Requirements

16.3.2.1 Setting Out

Setting out shall be as shown in the Drawing 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.

16.3.2.2 Position

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

16.3.2.3 Alignment of Nail

The drilling machine shall be attached with suitable alignment control devise set to attain the finished nail direction or inclination shown on the drawing 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.

16.3.2.4 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.

16.3.2.5 Submittals

(a) 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.

(b) 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

(c) Grouting records shall include :-

(i) Type & model of colloidal mixer & paddle mixer

(ii) Type & model of pump

(iii) Grout mix design details (W/C ratio, admixture, etc)

(iv) Results of bleeding, flow cone efflux time and strength tests

(v) Conditions of pull-out check on centralisers (photos and description as per Clause 16.3.5)

(vi) Time of start & completion of grouting

(vii) Volume of grout consumed

(viii) Observed exceptions (loss of grout, etc)

(d) Format and details of record and layout of nail shall be approved by the S.O. Other important submittals are method statement [Clause 16.3.1(b)], test certificates [Clause 16.3.3(c)], pull-out test reports (Clause 16.3.8), 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.

16.3.3 Materials

16.3.3.1 Reinforcement

(a) 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.

(b) The tensile strength and galvanized rebar quality of the coupled nail bar shall be not less than 410N/mm^2 or specified on Drawings.

(c) 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.

16.3.3.2 Cement Grout

(a) Cement for grouting shall be Ordinary Portland Cement complying with MS 522.

(b) 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.

(c) 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.

(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).

(d) 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 (Clause 16.3.8) at the contractor's own cost.

16.3.3.3 Centralisers

(a) Centralisers shall be tightly fixed to the rebar at the spacing as shown on the Drawing. 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)

(b) 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.

16.3.3.4 Corrugated HDPE Sheath

(a) The size, shape and length of the sheath to protect the rebar shall be as shown on the Drawing 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) > 29MPa

(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

(b) 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.

16.3.3.5 Materials Handling and Storage

(a) 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.

(b) 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.

16.3.4 Drilling

(a) 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 in the Drawings and as specified in this specification.

(b) 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 Clause 16.3.2.5.

(c) 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.

(d) 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.

16.3.5 Insertion of Reinforcement

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

(b) 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.

16.3.6 Grouting

Grout mix shall be prepared and tested according to Clause 16.3.3.2. 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 two 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.

16.3.7 Nail Head Construction

(a) 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.

(b) 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 in 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).

16.3.8 Pull-Out Tests

(a) 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.

(b) 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 Clause 16.3.1 shall also be submitted. The location of soil nail to be tested shall be selected by the S.O.

(c) Purpose of pull-out test up to 2.0 times the design pull-out resistance/load or as specified on 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 drawing or determined by the S.O at site.

(d) 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 center 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.

(e) 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 on drawing 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.

(f) 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.

(g) The loading schedule for verification test is as shown in Table 16.3.1:-

TABLE 16.3.1 – 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 x πd
= Design allowable pull-out resistance (kN/m) specified in the Drawing or by the Designer. f_a = design allowable bond stress (kN/m^2), d = diameter of nail in m.

(h) 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.

(i) 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 .

(j) A pull-out test is deemed satisfactory and acceptable when all the following criteria are met :-

(i) 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.

(ii) 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.

(iii) 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 (mm^2) and E = rebar's modulus = 200,000 MPa).

(k) 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.

(l) 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.

(m) 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.

16.3.9 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.

16.4 GUNITING

16.4 GUNITING

16.4.1 General

(a) 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.

(b) The Contractor shall apply gunite to the excavated slope surfaces at locations shown on the drawings or at locations directed by the S.O.

(c) "GUNITE" 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.

(d) "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.

(e) "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.

16.4.2 Materials

16.4.2.1 Cement

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

16.4.2.2 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 16.4.1: -

TABLE 16.4.1 – 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

16.4.2.3 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.

16.4.2.4 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.

16.4.2.5 Mix

(a) 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.

(b) Mixed dry aggregate and cement, which are not applied on slope surfaces within 30 minutes after mixing, shall be discarded.

(c) Admixtures shall be added at 3 – 5% by weight of cement to speed the setting rate of cement, when directed by the S.O.

(d) All constituents shall be uniformly dispersed throughout the mix. Mixing by hand is **NOT** allowed.

16.4.3 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 Clause 16.4.10 (a).

16.4.4 Preconstruction Test Panels

(a) 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.

(b) 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.

(c) 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.

(d) 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.

16.4.5 Interface Preparations

(a) 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.

(b) 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.

(c) 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.

(d) 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.

16.4.6 Normal Guniting Procedure

(a) 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.

(b) 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.

(c) 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.

(d) Whenever the spraying operation becomes irregular, the nozzle shall be directed away from the works area and all spraying shall stop.

(e) 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.

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

16.4.7 Rebound

(a) 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.

(b) All surfaces which are not to receive gunite shall be protected by approved methods.

16.4.8 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°.

16.4.9 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.

16.4.10 Quality Control

(a) 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.

(b) 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 nozzleman if the results of any cube or any rebound hammer test are below the specified strength shown on the drawing.

(c) For every 300m^2 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.

(d) All the weep holes shall be marked by red paint to show the required effective thickness of gunite specified on the drawings.

(e) Prior to spraying of gunite, the Contractor shall request inspection by the S.O. and a photo (minimum one photo for every 300m^2) 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 at a rate of one core per 500m^2 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 200m^2) shall be carried out at Contractor's own costs if defective works are detected.

(f) 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.

16.5 ROCK BOLTS AND ROCK DOWEL

16.5 ROCK BOLTS AND ROCK DOWEL

16.5.1 Description

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

16.5.2 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: -

(i) Proposed construction schedule and sequence.

(ii) Proposed drilling methods and equipment.

(iii) 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.

(iv) Proposed drill hole diameter.

(v) Proposed grout mix design, with polyester, resin, or epoxy specifications including manufacturer's data sheets. Include the procedures for placing the grout.

(vi) Proposed corrosion protection for the rock reinforcing bolt and rock reinforcing dowel systems.

(vii) Proposed installation, stressing procedures, torque wrench, test jack, and pressure gauge to be used.

(viii) 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 ± 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.

16.5.3 Material

(a) 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.

(b) 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.

16.5.4 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.

16.5.5 Labour

(a) 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 two 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.

(b) 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.

16.5.6 Construction

16.5.6.1 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.

16.5.6.2 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.

(a) 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 Clause 16.5.7(a). 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.

(b) 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 Clause 16.5.7(b). After testing, cut the bolt off, if necessary, so that no more than 75mm extends beyond the nut.

16.5.7 Proof Testing

Perform proof testing according to the following: -

(a) 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.

(b) 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.

16.6 GROUND ANCHOR

16.6 GROUND ANCHOR

16.6.1 General

(a) 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.

(b) 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.

16.6.2 Scope of Works

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

(a) 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.

(b) Any other incidental works necessary to ensure the safety and satisfactory performance of the permanent earth retaining system.

16.6.3 Responsibility of the Contractor

(a) 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.

(b) 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.

(c) 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.

16.6.4 Designed By Specialist Contractor

(a) 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 : -

(i) Anchor layout

(ii) Anchor design details

(iii) Anchor structural and geotechnical design capacity

(iv) Grade and properties of the tendon material

(v) Percentage of tendon ultimate load at working load

(vi) Method and details of anchor fabrication

(vii) Details of double corrosion protection for permanent applications

(viii) Method and details of proposed grouting procedure

(ix) Grout/concrete - cement type, strength, additives

(x) Anchor load, length, and bond diameter

(xi) Anchor free stressing length and de-bonding details

(xii) Initial pre-stress of anchor

(xiii) Anchor bond design details

(xiv) Endorsement by the Contractor's Professional Engineer

(xv) Any other information required by the S.O. in his review of the Contractor's design

(xvi) Anchor head protection

(xvii) Waller Beam design and details (if required)

(b) 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.

(c) 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.

16.6.5 Method Statements for Construction Operations

(a) 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 Clause, a method statement shall be a document containing : -

(i) A detailed construction sequence

(ii) Proposed drilling method

(iii) Proposed installation method

(iv) Proposed stressing method and equipment

(v) Proposed provisions for stressing or distressing

(vi) Material, plant and labour requirements at each construction stage

(vii) 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

(viii) Shop drawings showing, among other things, details of all special requirements for the construction activities

(ix) 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.

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

(i) The Contractor's proposed methods have the consent of the S.O.; or

(ii) In what respect, in the opinion of the S.O., the proposed methods fail to meet the requirements of the contract.

(c) 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.

(d) Consent by the S.O. of the Contractor's proposed methods of construction in accordance with this Clause shall not in any way relieve the Contractor of any of his duties or responsibilities under the contract.

16.6.6 Equipment and Labour

(a) The Contractor shall provide all frames, equipment, lifting devices and labour necessary for the installation and grouting of anchors.

(b) 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.

(c) 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.

16.6.7 Inspection and Testing

(a) 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.

(b) The testing of concrete and grout shall be in accordance with the provisions for works concrete in the General Concrete Specification.

16.6.8 Compliance Inspection

The S.O. shall carry out inspection to ensure that the Contractor follows the approved shop drawings and good engineering practice.

16.6.9 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 require reassessment of the anchor design and installation practices.

16.6.10 Materials

16.6.10.1 General Requirements

(a) The requirements listed in the following clauses 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.

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

(c) All anchors shall have a double corrosion protection.

16.6.10.2 Tendons

(a) Pre-stressing tendons shall comply with the following: -

(i) High tensile steel wire and wire strand with a minimum tensile strength of 1860 N/mm^2 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

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

(c) Alloy steel bars shall be straight.

(d) 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

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

16.6.10.3 Cement Grout

(a) Cement used for grouting anchors shall comply with MS 522.

(b) 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..

(c) Water shall be taken from the public supply of potable water and shall be at least to the quality specified in MS 28.

(d) 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..

(e) 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.

(f) 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/mm^2 at 3 days and 35N/mm^2 at 28 days. Collection of grout shall be from the grout overflowing from the drill holes unless otherwise agreed by the S.O.

(g) 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.

16.6.10.4 Greases

(a) 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.

(b) Greases, including any used by the manufacturer of the tendons, shall comply with the requirements set down in **Table 16.6.1**. 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)

(c) 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 16.6.1**. Grease shall be used in accordance with the manufacturer's instructions.

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

16.6.10.5 Plastics

(a) 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.

(b) 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.

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

(d) 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 **Table 16.6.2**. Plastics shall be used in accordance with the manufacturer's instructions.

(e) 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.

(f) 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

16.6.10.6 Metal Ducting

(a) Metal ducting shall only be used with the agreement of the S.O..

(b) 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.

16.6.10.7 Rubber Rings

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

(b) 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.

16.6.11 Corrosion Protection

16.6.11.1 General

(a) 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

1. 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.

2. In the zone defined by the free tendon length, the corrosion protection shall not affect the freedom of the tendon to expand.

3. 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.

4. 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.

16.6.11.2 Corrosion Protection of Permanent Anchorages

(a) Proof of suitability of the corrosion protection system shall be provided for permanent anchorages.

(b) 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.

(c) 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.

(d) The corrosion protection of the tendon and the anchorage components shall be factory applied.

(e) 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.

(f) 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.

(g) 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.

(h) 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.

16.6.12 System Components

16.6.12.1 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.

16.6.12.2 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.

16.6.12.3 Spacers and Centralisers

(a) 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.

(b) 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.

(c) 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.

16.6.12.4 Anchor Head Components

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

(b) 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.

(c) 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.

16.6.13 Submission of Alternative Systems for Approval

(a) 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.

(b) 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.

16.6.14 Anchorages

(a) 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.

(b) 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.

16.6.15 Equipment

16.6.15.1 General

(a) 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.

(b) 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.

(c) 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.

16.6.15.2 Fabricating and Placing

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

16.6.15.3 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/mm^2 shall permit continuous circulation and pumping of grouting with accurate control of grout pressure.

16.6.15.4 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 ± 3% of the load applied.

16.6.16 Anchor Fabrication

(a) 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.

(b) Anchors shall be free of dirt, detrimental rust or any other deleterious substance.

(c) Anchors shall be handled and protected prior to installation in such a manner as to avoid corrosion and physical damage thereto.

(d) All field joints of the corrosion protection shall be made watertight by an epoxy bonding compound or equivalent.

16.6.17 Drilling

(a) 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 continue. Any alternative method shall be approved by the S.O.

(b) 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 ± 75mm. Deviation in alignment shall not exceed 1 in 30. Deviation from straight shall not exceed 20mm in any 3m length of drill hole.

(c) 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.

16.6.18 Anchor Installation

16.6.18.1 General

(a) 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.

(b) 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.

(c) 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.

(d) All anchors shall be installed through the casing to avoid damage to the corrosion protection.

(e) 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

16.6.18.2 Water Testing and Pre-Grouting

(a) 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.

(b) Subject to the agreement of the S.O., the Contractor may pre-grout the fixed length prior to the water testing.

(c) 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.

(d) 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.

(e) 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.

(f) A full record of the water test shall be submitted to the S.O.

16.6.18.3 Insertion of Anchor

(a) 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.

(b) 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.

(c) 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.

(d) The anchor shall be positioned in accordance with the requirements of Clause 16.6.12.4 and shall be secured to prevent further movement.

16.6.19 Grouting

16.6.19.1 General

(a) Grout shall consist of materials specified in Clause 16.6.10.3. 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.

(b) 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 $0.02N/mm^2$ per vertical metre and this shall be considered when assessing the effective grout pressure at the lowest point of the bond length.

(c) 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.

(d) After grouting, the anchors shall remain in an undisturbed condition until the necessary grout strengths have been achieved.

16.6.19.2 Bleeding, Free Expansion and Fluidity

(a) 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.

(b) 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.

16.6.19.3 Sampling for Tests on Bleeding, Free Expansion, Fluidity and Strength

(a) 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 one 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.

(b) A set of three grout cubes shall be prepared for cube strength determination in accordance with Clause 16.6.10.3 from each sample of grout taken.

16.6.19.4 Trial Grout Mixes

(a) A trial grout mix shall be carried out in accordance with Clause 16.6.19.5 using the designed water-cement ratio and admixtures (if any) and the proposed grouting equipment to be used for the Contract.

(b) One 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 bleeding, free expansion and fluidity requirements stated in Clause 16.6.19.2.

(c) 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 Clause 16.6.10.3.

(d) One 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 Clause 16.6.10.3.

(e) 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 weeks before the commencement of grouting.

16.6.19.5 Grout Mixing

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

(b) 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, follow by the remaining third of cement.

(c) 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 five minutes.

(d) 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.

(e) 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.

16.6.19.6 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 meter and a pressure gauge shall be provided. The S.O.'s approval of the equipment shall be obtained prior to its use.

16.6.19.7 Grouting Procedures

(a) 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.

(b) 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.

(c) 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 one minute.

16.6.19.8 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.

16.6.20 Fitting Anchor Head

The anchor head and its associated components shall be fitted concentrically to the tendon within a tolerance of ± 5mm and perpendicular to the tendon within a tolerance of ± 3°. Any leakage of water/fluid from the anchor hole or anchor head shall be sealed by approved method.

16.6.21 Anchor Testing

16.6.21.1 General

(a) There are three classes of tests for all anchorages as follows: -

(i) Proving tests

(ii) On-site suitability tests

(iii) On-site acceptance tests

(b) 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.

(c) 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.

(d) 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.

(e) 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.

16.6.21.2 Proving Tests

(a) 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.

(b) 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.

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

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

16.6.21.3 On-Site Suitability Tests

(a) 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.

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

(c) 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.

(d) 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.

16.6.21.4 On-Site Acceptance Tests

(a) 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.

(b) Acceptance tests shall include creep testing and lift off test.

(c) 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.

(d) 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.

(e) 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.

16.6.22 Monitoring

16.6.22.1 Requirements for Monitoring

(a) 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.

(b) The Contractor shall monitor the anchors up to the end of the Contract Period in accordance with the programme and procedure given in Clauses 16.6.22.3 and 16.6.22.4.

16.6.22.2 Load Measurement

(a) 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

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

16.6.22.3 Programme

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

16.6.22.4 Procedures

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

(b) Should the variation in the residual load exceed ± 10% of that measured immediately after locking-off, the Contractor shall immediately inform the S.O. and await her/his further instructions.

16.6.22.5 Monitoring Records

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

TABLE 16.6.1 - PROPERTIES OF GREASE (SHEET 1 OF 2)

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

TABLE 16.6.1 - PROPERTIES OF GREASE (SHEET 2 OF 2)

Notes : (1) Manufacturer's certificates in respect of all the properties listed in the table shall be presented to show compliance with this Specification.

(2) Modified procedure for base number determination :

(a) Weigh accurately 1 to 1.5g of sample into a 500ml conical flask. Add 20ml isopropanol and 5ml toluene.
(b) Place a glass funnel on the top of the flask and heat the flask on a plate until the grease dissolves.
(c) Add about 100ml of distilled and de-ionized water and pipette 10ml of 1N sulphuric acid to the flask. Heat the solution for 30 min. at temperature 80 – 90°C.
(d) Add a few drops of phenolphthalein indicator solution and titrate with 1N sodium hydroxide solution until the sample solution turns pink. Record the volume of the titre added.
(e) Calculate the base number of the grease sample using the following equation :

$$\text{Base number} = \frac{56.1\,(10-V)}{M}\ \text{mg KOH/g}$$

where V = volume of 1N sodium hydroxide solution used (ml)
m = mass of sample (g)

(f) Apply correction factors to the volumes of the acid and alkali if they are not exactly 1N.
(g) Carry out a blank determination and correct the result accordingly.

(3) Procedure for extraction of water soluble ions from grease for chloride, nitrate and sulphide ions contents determination :

(a) Weigh, accurate to 0.001g, about 5g of grease into a separating funnel, add 70ml of xylene and shake the mixture until the grease for chloride, nitrate and sulphide ions contents is determined.
(b) Add 30ml of distilled and de-ionized water the funnel, shake for 10 min, and allow the organic and aqueous layers to separate. Run the bottom aqueous layer (and emulsion if present) to a second separating funnel.
(c) Repeat step (b) using separately 30ml and 40ml of distilled and de-ionized water for further extraction.
(d) Add, to the second separating funnel containing the combined water extract, About 20 – 30ml of xylene, gently swirl the mixture and again allow for complete separation of the 2 layers.
(e) To avoid inclusion of the organic solvent in the water extract, collect about ¾ of the bottom aqueous layer, filter through a 0.2pm filter paper and reserve the filtrate for determination of the contents of chloride, nitrate and sulphide.
(f) Carry out a blank determination, following the same procedure with the same amount of reagents.

TABLE 16.6.2 – PROPERTIES OF PLASTICS

Property	Test Method	Unit	Acceptance Criterion		
			PVC	PP	HDPE
Density	BS 2782 : Part 6 : 1980, Method 620A	Kg/m^3	1350-1400	900-910	950-940
Tensile strength at yield at 23˚C (Straining rate 50mm/min)	BS 2782 : Part 3 : 1976, Method 320C	MPa	≥45	≥30	≥29
Softening point (Vicat)	BS 2782 : Part 1 : 1976, Method 120A	˚C	≥75	≥150	≥110
Hardness (Shore D)	BS 2782 : Part 3 : 1981, Method 365B	-	≥65		
Brittleness Temperature	ASTM D 746 - 79	˚C	≤5˚C		
Environmental Stress cracking resistance	ASTM D 1693 – 70 (1980)	hrs	200 (No cracking)		
Fungal resistance	ASTM G 21 – 70 (1980)	-	Rating 1 or less (2)		
Bacteria resistance	ASTm D G 22 – 76 (1980) Procedure 'B'	-	No bacterial growth on surface of specimen		
Water absorption at 23 ± 1˚C	ASTM D 570 – 81 (Long term immersion)	% increase in weight	Max. 0.5%		
Hydrostatic pressure resistance	BS 6437 : 1984	-	No localised swelling leaking or weeping		

Note : (1) PVC = polyvinyl chloride ; PP = polypropylene;
HDPE = high density polyethylene
(2) Observed traces of fungal growth shall not cover more than 10% of the surface area.
(3) Manufacturer's certificates in respect of all the properties listed in the table shall be presented to show compliance with this Specification.

16.7 REINFORCED SOIL STRUCTURES AND SLOPE

16.7 REINFORCED SOIL STRUCTURES AND SLOPE

16.7.1 General

16.7.1.1 Scope

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

16.7.1.2 Contractor's Responsibilities

The Contractor shall provide all necessary resources including materials, skilled workers, and plants/equipment to execute and complete the works as shown on the drawings.

The Contractor shall be responsible for the true and proper setting-out of the areas to which the Reinforced Soil Structure is to be placed and for the correctness of the lines, widths, levels and slopes as shown on the contract drawings.

16.7.2 Materials

16.7.2.1 Facing Materials

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

(a) Reinforced concrete conforming to BS 8110: 1990

(b) Carbon steel strips or sheets conforming to BS 1449:1991; BS EN 10025: 1993 or BS EN 10130: 1999. The fabricated components shall be hot-dip galvanised in accordance with Clause 16.7.2.3 of this Specification.

(c) Structural steel sections conforming to BS EN 10025: 1993. The fabricated components shall be hot-dip galvanised in accordance with Clause 16.7.2.3 of the Specification.

(d) Segmental block units conforming to the requirements of the Contract.

(e) Proprietary product with reinforced fill product certificate.

16.7.2.2 Reinforcing Elements and Connections

(a) Reinforcing elements shall be one of more of the following: -

(i) Metallic reinforcing elements formed from carbon steel conforming to BS 1449: 1991 or BS EN 10130: 1999. The fabricated components shall be hot-dip galvanised in accordance with Clause 16.7.2.3 of the Specification.

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

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

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

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

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

(b) Connections shall comprise one or more of the following: -

(i) Precision hexagonal bolts, screw and nuts conforming to BS 3692:2001.

(ii) Black hexagonal bolts and nuts conforming to BS 4190: 2001.

(iii) Plain washers conforming to BS 4320: 1968.

(iv) Dowels and rods which shall be made from either steel bar conforming to BS 4449: 1997 or steel conforming to BS EN 10025: 1999.

(v) Tie strips which shall be made from carbon steel strip conforming to BS 4449: Part 1: 1991; BS EN 10130: 1999 or BS EN 10025:1993.

(vi) Proprietary connections covered by a reinforced fill product certificate applicable to the polymeric reinforcing elements to be used.

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

(d) Where components for connections are made from steel, these components shall be hot-dip galvanised in accordance with Clause 16.7.2.3 of the Specification.

16.7.2.3 Hot-dip Galvanising

Hot-dip galvanising shall be to BS EN ISO 1461, except that the minimum average zinc coating weight for the steel reinforcing elements specified in Clause 16.7.2.2 above shall be 610g/m^2 (85 microns) for land-based structures or slopes and 1000g/m^2 (140 microns) for structures of slopes that are periodically submerged in water.

16.7.2.4 Joint Filler and Sealant

(a) Joint filler shall be composed of durable, inert material resistant to atmospheric attack and shall comprise the following materials: -

(i) For horizontal joint fillers, resin-bonded cork strip to ASTM D1752-84 Type II.

(ii) For vertical joint fillers, closed cell polyethylene foam strip or closed cell polyurethane foam strip approved by the S.O.

(b) Proprietary joint fillers shall be purpose-made to size for the appropriate location shown on the Drawings.

(c) The materials for filling, priming and sealing of joints should be obtained from a single supplier.

16.7.2.5 Fill Material

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

(b) Fill material shall not contain any of the following: -

(i) Material susceptible to volume change, including marine mud, soil with a liquid limit exceeding 65% or a plasticity index exceeding 35%, swelling clays and collapsible clays

(ii) Peat, vegetation, timber, organic, soluble or perishable material

(iii) Dangerous or toxic material or material susceptible to combustion, and

(iv) Metal, rubber, plastic or synthetic material

(c) The grading and index properties of the selected fill shall be in accordance with the requirement specified in Table 16.7.1.

(d) Selected fill for reinforced fill structures or slopes which contain hot-dip galvanised steel reinforcing elements shall comply with the electrical and chemical limits specified in Table 16.7.2.

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

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

TABLE 16.7.1: PARTICLE SIZE DISTRIBUTION OF SELECTED FILL

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

TABLE 16.7.2: ALLOWABLE ELECTRICAL AND CHEMICAL LIMITS OF SELECTED FILL AND GRANULAR FILTER

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

16.7.2.6 Granular Filter

(a) Granular filter material for reinforced fill structures or slopes which contain hot-dip galvanised steel reinforcing elements shall comply with the electrical and chemical limits specified in Table 16.7.2.

(b) Granular filter material shall any additional given in the Drawings.

16.7.3 Submissions

16.7.3.1 Particulars of Reinforced Fill Structure and Slope

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

(i) Details of construction plant

(ii) Sequence of construction

(iii) Programme of work

(iv) Details of compaction method including the thickness of compacted fill layers and capacities of the earthmoving and compaction equipment

(v) Methods of supporting the facing units during construction

(vi) Details of all necessary temporary works for the construction of the reinforced fill structures or slopes

(vii) Names and records of experience of the Contractor's supervisory staff to be employed on the works

(viii) Arrangements for stockpiling fill material

(ix) Methods of controlling the moisture content of fill material

(x) Methods of controlling surface water and groundwater

(xi) Methods of protecting earthworks and earthworks materials from damage due to water and from weather conditions which may affect the earthworks or earthworks materials

(xii) Methods of monitoring groundwater levels

(xiii) Methods of monitoring the ground and structures for movements

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

16.7.3.2 Particulars of Facing Units

(a) The following particulars of the proposed facing units shall be submitted to the S.O: -

(i) Manufacturer's literature on the proposed facing units

(ii) Method of construction, including details of corner and facing connections

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

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

16.7.3.3 Particulars of Reinforcing Elements and Connections

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

(i) Name and location of the galvanising plant

(ii) A certificate from the manufacturer showing the date and place of application of the zinc coating and showing that the galvanisation conforming to the requirements stated in the Contract and including results of tests for: -

- Weight of coating
- Uniformity of coating

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

16.7.3.4 Particulars of Joint Filler and Sealant

(a) The following particulars of the proposed joint fillers and sealant shall be submitted to the S.O: -

(i) Manufacturer's literature on the material and the proposed method of installation

(ii) A certificate for the manufacturer shows the date and place of application of the zinc coating and showing that the galvanisation conforming to the requirements stated in the Contract and including results of tests specified by the S.O

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

16.7.3.5 Particulars of Fill Material

(a) The following particulars of the proposed fill material shall be submitted to the S.O for approval: -

(i) A statement identifying each source of supply and showing that sufficient suitable materials are available for the works

(ii) For material from borrow areas, a plan showing the location and extent of each proposed borrow area, and the location, depth and the test results of each sample obtained and each in-situ test carried out

(iii) Certification from a laboratory approved by the S.O which show that each material proposed for use complies with the requirements of the Contract and has been tested in accordance with the appropriate test methods given in this Specification

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

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

16.7.4 Handling, Delivery and Storage of Materials

16.7.4.1 Handling and Storage of Facing Units

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

16.7.4.2 Handling and Storage of Reinforcing Elements

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

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

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

(d) Polymeric reinforcing elements shall be properly stored and protected from precipitation, extended ultraviolet radiation, direct sunlight, chemicals that are strong acids or strong bases, flames including welding sparks, temperatures in excess of 50°C, and any

other environmental condition that may damage the physical property values.

16.7.4.3 Handling and Storage of Fill Material

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

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

16.7.5 Foundation Preparation

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

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

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

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

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

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

16.7.6 Erection of Facing

16.7.6.1 Erection of Elemental Facing

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

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

(c) As placed, all elemental facing units except those at the bottom course shall be inclined towards the fill to compensate for outward movement during or subsequent to compaction of the fill material. The degree of inclination shall be adjusted where necessary as placement and compaction of the fill material proceeds to ensure that the tolerances specified in Clause 16.7.11 of this Specification are met.

16.7.6.2 Erection of Full Height Facing

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

(b) The degree of inclination of the full height facing shall be adjusted to ensure that the tolerances specified in Clause 16.7.11 of this Specification are met.

16.7.6.3 Erection of Segmental Block Facing

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

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

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

16.7.7 Placement of Reinforcing Elements

16.7.7.1 Placement and Connection of Reinforcing Elements

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

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

(c) Polymeric reinforcing elements shall be pulled tight to eliminate waves and wrinkles and secured in place as necessary by staples, pins, sand bags, backfill or as directed by the S.O after placement.

(d) After a layer of polymeric reinforcing element has been placed, the next succeeding layer of fill material shall be placed and compacted as soon as practicable to prevent potential damage or extended exposure to direct sunlight. No polymeric elements shall be left exposed for more than 8 hours after placement unless approved by the S.O.

(e) Unless otherwise specified in the Drawings or as approved by the S.O, no splices or seams shall be made in the primary direction of tensile strength in the polymeric reinforcing elements. When splices are approved, they shall be made for the full width of the polymeric reinforcing elements by using a similar material with similar strength. Spices shall not be placed within 1.5m of the facing unit or slope face, with 1.5m below top of structure or slope, nor within 1.5m horizontally adjacent to another splice.

(f) Unless otherwise specified, adjacent rolls of polymeric reinforcing elements in reinforced fill slopes shall be butted together to maintain 100% horizontal coverage. When used in a wrap-around facing system, adjacent rolls of polymeric reinforcing elements shall be overlapped with a minimum width of 150mm.

(g) Reinforcing elements at corners and radii shall be placed in accordance with the Drawings.

16.7.7.2 Installation of Geogrid and Polymeric Materials for Reinforced Soil Slope

(a) At each level of geogrid reinforcement, backfill shall be roughly leveled before placing the geogrids. Compaction shall be carried out to the requirements of the Specifications.

(b) During backfill placement, trucks and heavy vehicles shall be kept back at least 2m from the face of the Geogrid Reinforced Slope.

(c) The deposition, spreading, levelling and compaction of the fill shall be carried out generally in a direction parallel to the facing and shall be executed in stages to alternate with the placing and fixing of the reinforcing elements and the facing.

(d) Care shall be taken to ensure that the reinforcing elements and facing are not damaged or displaced during deposition, spreading, levelling and compaction of the fill. The program of filling shall be arranged so that no machines or vehicles run on the reinforcing elements.

(e) The fill within 2m of the face of the Geogrid Reinforced Slope shall be compacted using one of the following: -

(i) Vibro tamper

(ii) Vibrating plate compacter having a mass not exceeding 1000kg, and

(iii) Vibrating roller having a mass per metre width of not more than 1300kg and a total mass of not more than 1000kg

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

16.7.8 Installation of Joint Filler and Sealant

(a) Horizontal joint filler conforming to Clause 16.7.2.4 of this Specification shall be placed on the cleaned top edge of each facing unit prior to the placing of the mating facing unit. No joint filler is required between the strip footing and the bottom course of the facing units.

(b) Vertical joint filler conforming to Clause 16.7.2.4 of this Specification shall be inserted only from the fill side on the structure.

(c) Sealants shall be used to protect joint filler from the ingress of external materials. They shall not be used for joints which will be below the finished ground level.

16.7.9 Deposition and Compaction of Fill Material

16.7.9.1 Deposition and Compaction of Fill Material

(a) Fill shall be placed and compacted in near horizontal layers of the thicknesses required to achieve the specified end product and shall, as far as practicable, be brought up at a uniform rate so that all parts of the Site reach finished formation level at the same time.

(b) The fill material beyond 1.5m of the back face of the structure may be raised in thicker layers than that within the 1.5m zone provided that this is compatible with the arrangement of the reinforcing elements and the difference is compacted levels does not exceed 300mm.

(c) The fill material shall be deposited, spread, levelled and compacted in layers of thickness appropriate to the compaction methods to be used and so that each reinforcing element can be fixed at the required level on top of the compacted fill material without any voids forming directly underneath the reinforcing element. Unless otherwise permitted by the S.O, layers of fill material shall be horizontal, except for any gradient required for drainage, and the thickness of each layer shall be uniform over the area to be filled.

(d) The placement and compaction of fill material shall be carried out in a direction parallel to the face of the structure and shall be completed in stages to follow closely the erection of facing units and the placement of the reinforcing elements.

(e) The fill material shall be compacted as soon as practicable after being deposited and in a manner appropriate to the location and to the material to be compacted. The in-situ dry density of the compacted fill material shall be at least 95% of the maximum dry density. Compaction shall continue until the whole layer of fill material has attained the minimum in-situ dry density specified above.

(f) Cobbles, boulders, rock or waste fragments whose largest dimension is greater than two-thirds of the loose layer thickness shall not be incorporated into the fill.

(g) The Contractor shall ensure that the reinforcing elements and facing units are not damaged or displaced during placement and compaction of the fill material. Tracked machines or vehicles shall not be operated on top of reinforcing elements which are not covered by at least 150mm of fill material.

(h) No fill shall be placed and left uncompacted at the end of a working day. Compacted fill shall be graded to falls to ensure free runoff of rainwater without ponding.

16.7.9.2 Moisture Content of Fill Material

(a) The fill material shall be at optimum moisture content during compaction. The tolerance on the optimum moisture content shall be ± 3% provided that the fill material is capable of being compacted in accordance with the specified requirement to form a stable mass of fill. All necessary measures shall be taken to achieve and maintain the specified moisture content. The moisture content of the compacted surfaces shall be controlled to prevent cracking due to drying.

(b) The Contractor shall take all necessary steps to ensure that the fill is placed at the moisture content necessary to achieve the specified level of compaction and shall, where necessary, add water to or dry the fill, in order to obtain this value. Where it is necessary to add water, this shall be done as a fine spray and in such a way that there is time for the water to be absorbed into the fill before being rolled by the compaction plant.

(c) The Contractor shall examine the placed fill and remove any deteriorated material prior to recommencement of filling.

16.7.9.3 Compaction Plant

(a) All vehicles and all construction equipment weighing more than 1000kg shall be kept at least 1.5m away from the face of the structure.

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

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

(i) Vibro tamper

(ii) Vibrating plate compactor having a mass not exceeding 1000kg, or

(iii) Vibrating roller having a mass per metre width of not more than 1300kg and a total mass of not more than 1000kg

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

16.7.9.4 Compaction Adjacent to Structures

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

16.7.10 Damage to Components

16.7.10.1 Damage to Components

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

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

16.7.10.2 Protection of Completed Geogrid Reinforced Slopes from Erosion

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

16.7.11 Tolerances

(a) Reinforced fill structures constructed using elemental facing units, full-height facings, cast-in-place facings and segmental facing shall be within the tolerances stated in Table 16.7.3 for the specified lines and levels.

(b) The location of referencing elements shall be within ± 50mm of the specified lines and levels.

TABLE 16.7.3 - TOLERANCES OF REINFORCED FILL STRUCTURE

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

16.7.12 Testing: Reinforcing Elements – General Requirements

16.7.12.1 General

(a) Prior to the procurement of materials, the contractor shall provide a sample and the Manufacturer's Independent Test Report (ITR), showing full compliance of the proposed geogrid to all the above-specified property values corresponding to their respective test methods, for the approval of the S.O.

(b) 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.

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

16.7.12.2 Batch: Reinforcing Elements

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

16.7.12.3 Samples: Reinforcing Elements

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

(b) For strip reinforcing elements, either 3 samples from each batch of the reinforcing elements or samples taken at the rate of 1 sample per $100m^2$ of area of facing shall be provided for testing, whichever is the larger.

(c) For grid of sheet reinforcing elements, either $0.5m^2$ of sample from each batch of the reinforcing element or samples taken at the rate of $0.5m^2$ per $100m^2$ of area of facing shall be provided for testing, whichever is the larger.

(d) For reinforcement connections, either 3 samples from each batch of the reinforcing element or samples taken at the rate of 1 sample per $100m^2$ of area of facing shall be provided for testing, whichever is the larger.

16.7.12.4 Testing: Reinforcing Elements

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

(i) Tensile strength

(ii) Weight and uniformity of galvanised coating

(b) Polymeric reinforcing elements for reinforced fill structures shall be tested for the following: -

(i) Tensile strength

(ii) Elongation

(iii) Weight

16.7.12.5 Non-Compliance: Reinforcing Elements

If the result of any test of a reinforcing element does not comply with the specified requirements for the property, additional samples shall be provided from the same batch and additional tests for the property shall be carried out. The number of additional samples shall be in accordance with Clause 16.7.12.3 of the Specification.

16.7.13 Testing: Reinforcing Element – Tensile Test

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

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

16.7.14 Testing: Fill Material – General Requirements

16.7.14.1 Samples: Fill Material

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

(b) The location and frequency of in-situ dry density and moisture content tests shall be as required by the S.O but shall not be less than that given in this Clause. Testing shall be carried out for each layer of compacted fill material in the reinforced fill structure, in which there shall be a minimum of one test on the filter material and two tests on the fill material and, where the plan area of the structure exceeds 800m^2, one additional test on the filter material and two additional tests on the fill material shall be carried out for each additional 800m^2 or part thereof. Samples of the fill material to be tested for moisture content shall be taken during deposition and compaction of fill material and shall be delivered to the S.O not more than 1 hour after the fill material has been deposited in its final position.

(c) The location and frequency of all other tests specified in Clause 16.7.14.2 or Clause 16.7.14.3 of this Specification shall be as required by the S.O but shall not be less than that given in this Clause. Testing shall be carried out for the top and bottom compacted layer of fill in reinforced fill structures which are up to 5m high, and also for the middle compacted layer in reinforced fill structures higher than 5m. In each of these layers, a minimum of one sample of filter material and two samples of selected fill material shall be tested; for structure with plan area exceeding 800m^2, on additional sample of filter material and two additional

samples of selected fill material shall be tested for each additional 800m^2 or part thereof.

(d) Sampling and testing shall be in positions specified by the S.O.

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

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

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

(b) Particle size distribution.

(c) Liquid limit and plasticity index of the fill material

(d) Coefficient of uniformity

(e) Resistivity

(f) Redox potential

(g) pH

(h) Chloride ion content

(i) Total sulphate content

(j) Sulphate ion content

(k) Total sulphide content

(l) Any other tests as specified by the S.O.

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

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

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

(b) Particle size distribution

(c) Liquid limit and plasticity index for the fill material

(d) Coefficient of uniformity

(e) Any other tests as specified by the S.O.

16.7.14.4 Non-Compliance: Fill Material

If the result of any tests for fill material does not comply with the specified requirements for the property, additional samples shall be provided from the same batch and additional tests for the property shall be carried out. The number of additional samples shall be in accordance with Clause 16.7.14.1 of this Specification.

16.7.15 Testing: Fill Material - Resistivity

(a) Each sample of fill material as stated in Clause 16.7.14.1 of this Specification shall be tested to determine resistivity.

(b) The method of testing shall be in accordance with the method as specified in ASTM G187-05: Standard Test Method for Measurement of Soil Resistivity using the Two-Electrode Soil Box Method.

16.7.16 Testing: Fill Material – Redox Potential

(a) Each sample of fill material as stated in Clause 16.7.14.1 of this Specification shall be tested to determine redox potential.

(b) The method of testing shall be in accordance with the method as specified in ASTM G200-09: Standard Test Method of Oxidation-Reduction Potential of Soil.

16.7.17 Testing: Fill Material – Total Sulphide Content

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

16.7.18 Testing: Fill Material – Shear Strength

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

16.7.19 Testing: Fill – Reinforcement Interaction – General Requirement

16.7.19.1 Samples: Fill – Reinforcement Interaction

Each sample of reinforcing element tested in accordance with Clause 16.7.12.3 of this Specification shall also be tested for fill – reinforcing element interaction. Samples for testing shall be delivered to the Site at least 14 days before installation of the reinforcing element in the structure or slope starts.

16.7.19.2 Testing: Fill – Reinforcement Interaction

Reinforcing elements shall be tested for the following: -

(a) Pull out resistance

(b) Direct sliding resistance

The method of testing shall be in accordance with the method stated in Clauses 16.7.20 and 16.7.21.1 of this Specification.

16.7.19.3 Non-Compliance: Fill–Renforcement Interaction

If the result of any tests for fill – reinforcement interaction does not comply with the specified requirements for the property, additional samples shall be provided from the same batch and additional tests for the property shall be carried out. The number of additional samples shall be in accordance with Clause 16.7.14.1 of this Specification.

16.7.20 Testing: Coefficient Of Friction between Fill Material and Reinforcement - Pullout

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

16.7.21 Testing: Coefficient Of Friction between Fill Material and Reinforcement – Direct Sliding

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

(a) The weight of fill material required to prepare a compacted test specimen 300mm x 300mm x 75mm shall be calculated.

(b) For strip reinforcing elements, the strips shall be cut to tightly fit the interior plan shape of the lower half of the shear box. Ribbed strips

shall be cut so that the ribs can be placed as far away from the edge of the box as possible. For plane strips, the top surface and for ribbed strips, shall be at least 1mm and not more than 3mm below the top edge of the lower half of the shear box. The reinforcing elements shall be aligned so that shearing can occur in a direction parallel to their longitudinal axes. The strips shall then be placed and secured in the lower shear box by filling the lower shear box with plaster of Paris so that the strips remain fixed at all stages of the test.

(c) For grid or sheet reinforcing elements, the fill material shall be compacted into the lower shear box in accordance with BS1399:1990, except that the surface of the second compacted layer shall be between 1mm and 2mm below the top edge of the lower shear box. The grid or sheet shall then be cut and fitted to match the width of the shear box and to allow it to be secured below the top edge of the lower shear box. The reinforcing elements shall be aligned so that shearing can occur in a direction parallel to their longitudinal axes.

(d) The fill material shall be placed over the reinforcing element and compacted in two equal layers until about 20mm of the compacted fill projects above the top edge of the upper box, if vibratory compaction is used; or in two equal layers until the top of the compacted surface is approximately 20mm below the top of the shear box, if static compaction is used.

(e) Shearing shall be carried out until the horizontal displacement is twice the displacement recorded at peak shear stress or until ant rib comes into contact with the edge of the shear box, whichever occurs first.

(f) The result of the test shall be taken as the maximum ratio between the shear stress and the normal stress.

16.8 TIEBACK WORKS

16.8 TIEBACK WORKS

16.8.1 General

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

16.8.2 Performance Specification

(a) A performance specification which establishes a quality level and describes the desired end-results enables the designer and the contractor to use their experience and expertise. The designer establishes those things which affect his design, and he specifies a tieback testing procedure and monitoring requirements to verify performance. The installation methods and the development of the tieback capacity should be the responsibility of the contractor. This enables the contractor to provide his most economical tieback, and still satisfy the requirements of the design. The designer and the contractor will share the responsibility for the work.

(b) The designer is required to: -

(i) Provide a detailed geotechnical site investigation

(ii) Determine the design load

(iii) Specify a testing procedure and acceptance criterion

(iv) Estimate the settlement of adjacent structures and establish permissible deformations

(v) Specify the tieback clearance around utilities

(vi) Provide installation tolerances

(vii) Rate the risk associated with the work, and establish the safety factors

(viii) Determine the un-bonded length, and minimum total length

(ix) Determine the lock-off load

(x) Determine the monitoring requirements

(xi) Describe the level of corrosion protection required and evaluate the contractor's proposed corrosion protection system

(c) The contractor is required to: -

(i) Design the tendon

(ii) Select the installation method

(iii) Select the anchor length

(iv) Propose the corrosion protection system

(v) Be responsible for the contract compliance of the materials used

(vi) Guarantee the tieback capacity

(vii) Obtain the required un-bonded length

(viii) Provide the required records

16.8.3 Prequalification

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

16.8.4 Permanent Tieback Specification

16.8.4.1 Scope of the Work

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

16.8.4.2 Tieback Capacity

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

(a) Alternative A: The contract drawings contain a loading diagram which the contractor shall use to determine the number and capacity of the tiebacks. The anchor zones of the tiebacks shall be at least 1.5m apart.

(b) Alternative B: The contract drawing contains tieback loadings per linear foot of wall. The contractor shall use these loadings to determine the number and capacity of the tiebacks. The anchor zones of the tiebacks shall be at least 1.5m apart.

(c) Alternative C: The contract drawings indicate the location and capacity of tiebacks.

16.8.4.3 Minimum Un-bonded Length and Tieback Angle

Each tieback shall have a minimum un-bonded length of 4.5m. The contract drawings shall indicate the un-bonded length required for each tier of tiebacks. The tieback shall be installed at an angle varying between 10° and 30° downward from the horizontal.

16.8.4.4 Total Tieback Length and Minimum Anchor Length

The minimum total tieback lengths shall be indicated on the contract drawing. In no case shall the anchor length be less than 3m. The tieback must not extend beyond the easement shown on the contract drawing.

16.8.4.5 Prequalification

Twenty (20) working days prior to the bid date, the tieback contractor shall submit a proposal describing the tieback system he intends to provide to the S.O. for review and approval. The submission shall include: -

(a) Qualifications if required

(b) A description of the tieback installation includes drilling, grouting and stressing information

(c) Estimated tieback capacity

(d) Tendon type and capacity

(e) Anchorage type

(f) Corrosion protection details-shop drawings required

(g) Exceptions to the specification and reasons for exceptions

(h) The S.O. will review the submission and give written comments to the prospective contractors within five (5) working days after receipt of the submission. Within five (5) working days, the contractor can resubmit a revised proposal. The S.O. will notify the contractor by writing within five (5) working days before bid date whether or not his tieback system and corrosion protection meets the requirements of the specification.

16.8.4.6 Materials

(a) Tieback tendons shall be fabricated from single or multiple elements of the following: -

(i) Steel bars conforming to ASTM Designation A 722, "Uncoated High-Strength Steel Bars for Prestressed Concrete"

(ii) Seven-wire strand conforming to ASTM Designation A 416, "Uncoated Seven Wire Stress-Relieved Strand for Prestressed Concrete"

(iii) Wires conforming to ASTM Designation A 421, "Uncoated Stress-Relieved Wire for Prestressed Concrete"

(iv) Compact seven-wire strands conforming to ASTM Designation A 779-80, "Uncoated Seven-Wire Compacted, Stress-Relieved Steel Strand for Prestressed Concrete"

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

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

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

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

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

(g) Water for mixing grout should be potable.

(h) Grout additives should be avoided. Accelerators should not be used. Expansive admixtures should only be used for secondary grouting, and filling trumpets and anchorage covers. Admixtures which control bleed and retard set may be used. Additives shall be mixed and placed in accordance with the manufacturer's recommendations.

(i) The sheath or bond breaker shall be either a steel, PVC, polyethylene, or polypropylene pipe or tube. The sheath may surround individual tendon elements or the entire tendon. The material shall be capable of withstanding damage during shipping, handling, and installation. The material is subject to the approval of the S.O..

(j) Grease injected under the sheath shall be formulated to provide lubrication and inhibit corrosion. The chlorides, nitrates, and sulfides present in the grease shall not exceed the following limits: -

(i) Chlorides 10ppm

(ii) Nitrates 10ppm

(iii) Sulfides 10ppm

(k) The contract documents should indicate if simple or encapsulation corrosion protection is required. A simple protected tieback tendon shall be provided. Details of the protection system shall be submitted to the S.O.s for review and approval. The contract drawings shall show details of a simple corrosion protected tieback. The ends of the grease filled sheath shall be sealed with tape, heat shrinkable tubes, or other means subject to the approval of the S.O. A plastic trumpet shall be used to make the transition from the bearing plate to the corrosion protection over the unbonded length. A tight fitting seal shall be provided at the end of the trumpet.

Insulating bearing strips shall be provided under the bearing plate. The bearing strips material must: -

(i) Be an electrical insulator

(ii) Be resistant to attack from cement, grease or aggressive environments

(iii) Be non-detrimental to the prestressing steel

(iv) Have compressive strengths greater than concrete

(v) Not be susceptible to significant creep deformations

(l) Manufacturer's literature describing the bearing material shall be submitted to the S.O. for review and approval.

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

(i) An electrical insulator

(ii) Resistant to attack from cement, grease, or aggressive environments

(iii) Nondetrimental to the prestressing steel

(iv) Capable of withstanding atmospheric exposure and ultraviolet light if the-anchor head is intended to remain exposed

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

(i) Capable of transferring stresses from the encapsulation grout to the anchor grout

(ii) Accommodate movement during testing, and after lock-off

(iii) Resistant to chemical attack from aggressive environments, grout, or grease

(iv) Fabricated from materials nondetrimental to the tendon

(v) Capable of withstanding abrasion, impact, and bending during handling and installation

(vi) Leak proof

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

(i) Accommodate movement during testing and after lock-off

(ii) Resistant to chemical attack from aggressive environments, grout or grease

(iii) Fabricated from materials non detrimental to the tendon

(iv) Capable of withstanding abrasion, impact and bending during handling and installation

(v) Leak proof

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

1) Tendon Fabrication

(i) Prestressing steel shall be protected from dirt, rust, or deleterious substances. A light coating of rust on the steel will not affect its function. Heavy corrosion or pitting shall be cause for tendon rejection. If there is a question about the extent of the corrosion, the steel can be tested to determine if it still meets the appropriate ASTM specification.

(ii) Tendons can be either shop or field fabricated.

(iii) Tendons shall be stored and handled in such a manner as to avoid damage or corrosion.

2) Installation

(i) Core drilling, rotary drilling, or percussion drilling can be used to drill rock foundations. Auger drilling, rotary drilling, or percussion driven casing can be used for soil tiebacks. The drill hole shall be located within 76mm of the desired location.

(ii) The engineer may specify water-tightness test for rock tiebacks. The test is not necessary for every tieback. Cavernous limestone formations, open jointed or fractured rock, and formations where water loss or gain was observed during exploratory drilling should be checked for water-tightness. The engineer should determine the number of tests to be performed. If the need for water-tightness testing is uncertain, then the initial drill holes need to be tested. If it is certain that the formation is open, then water-tightness testing may be required for each tieback. Pressure grouting the anchor zone using the casing or a packer to seal the hole can be used in lieu of water-tightness test. If pressure grouting is used in rock, the engineer should specify a minimum refusal pressure.

(iii) After drilling the permanent rock tieback hole to the desired depth, water-tightness test shall be performed to determine the tightness of the drill hole. If the unbonded soil, a packer or casing shall be used to isolate the anchor length so it can be tested. The hole shall be filled with water and subjected to a pressure of 34.5kPa in excess of the hydrostatic head measured at the top of the drill hole. If the leakage rate from the drill hole exceeds 19l in a 10 minute period, then the hole should be consolidated grouted, re-drilled or water flushed, and retested. If the second water-tightness test fails, the process should be repeated. The water level in adjacent drill holes should be observed during the test.

(iv) The water cement ratio of the consolidation grout may be adjusted as required to seal the hole.

(v) If flowing water is observed in the drill hole or artesian water flows out of the hole, then the consolidation grout should be pressurized.

(vi) The contractor shall submit for review and approval a description of the water-tightness test procedures and equipment.

3) The anchor grout shall have a water cement ratio between 0.35 and 0.50. The grouting equipment should include a mixer capable of producing a grout free of lumps and undispersed cement. A positive displacement grout pump shall be used. The pump shall be equipped with a pressure gauge to monitor

grout pressures. The grouting equipment shall be sized to enable the tieback to be grouted in one continuous operation. Neat cement grouts should be screened to remove lumps. The maximum size of the screen openings shall be 6.4mm. Mixing and storage times should not cause excessive temperature build in the grout. The mixer should be capable of continuously agitating the grout.

4) The anchor grout shall be injected from the lowest point of the tieback. The grout may be placed using grout tubes, casing, or drill rods. The grout can be placed before or after insertion of the tendon. The quantity of the grout and the grout pressures shall be recorded. The grout pressures and grout takes shall be controlled to prevent excessive heave in cohesive soils or fractured rock.

5) The tieback shall remain undisturbed for a minimum of 3 days or until the grout has cured.

16.8.4.7 Testing

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

16.8.4.8 Monitoring

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

16.8.4.9 Records

The contractor shall provide the S.O. with the following records: -

(a) Drawings showing the location of the tiebacks, total tieback length, anchor length and unbonded length

(b) Steel and grout certifications and/or mill reports

(c) Grouting records indicating the cement type, quantity injected and the grout pressures

(d) Tieback test results

(e) Monitoring results

16.9 GABIONS

16.9 GABIONS

16.9.1 Description

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

16.9.2 Materials

16.9.2.1 Wire Mesh Gabions

(a) Gabions shall be rectangular baskets of the required dimensions as shown on the Drawings or ordered by the S.O. Unless otherwise specified, they shall be of the following standard dimensions: -

(i) Width – 1.2m

(ii) Length - 1, 2 or 3m

(iii) Height - 0.5 or 0.8m

(b) Gabions longer than 1m shall be divided into compartments of equal length not exceeding 1m by wire mesh diaphragms securely tied along all edges. Each gabion or compartment of a gabion shall be provided with at least 4 cross-connecting wires if its height is 0.5m or less, and with at least 8 cross-connecting wires if its height is in the range 0.5m to 1m.

(c) Gabions shall be fabricated from steel wire manufactured in accordance with BS 1052 and galvanised in accordance with MS 407, or such similar standards as S.O. shall approve. The galvanised wire sizes used shall be in accordance with Table 16.9.1.

TABLE 16.9.1 – GALVANISED WIRE SIZES FOR GABIONS

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

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

Double-twist mesh is demonstrated in **Figure 16.9.1**: -

FIGURE 16.9.1 – DOUBLE-TWIST MESH

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

16.9.2.2 Zinc Coating

(a) All wire used in the fabrication of the gabions and in the wiring operations during construction shall be heavily galvanised and exceed MS 407, or such similar standards as the S.O. shall approve. The minimum mass of the zinc coating shall be according to the figures shown in the **Table 16.9.2**: -

TABLE 16.9.2 – MINIMUM MASS OF ZINC COATING FOR GABIONS

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

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

16.9.2.3 Polyvinyl Chloride Coating

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

16.9.2.4 Geotextile

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

16.9.2.5 Stone

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

16.9.3 Construction Methods

(a) Prior to placing gabions, the surface on and against, which they are to be constructed shall have been prepared and finished in accordance with the relevant provisions of the appropriate Sections of this Specification. Notwithstanding any earlier approval of these finished surfaces, any damage to or deterioration of them shall be made good to the satisfaction of the S.O. before gabions are placed.

(b) Each gabion basket shall be put in place in its turn, completely fabricated except for the fastening down of the lid, stretched to the correct shape and dimensions, and fastened securely to all contiguous baskets along each edge with tying wire. The basket shall then be tightly packed with approved stone by hand in such a manner that voids are kept to a practicable minimum and are uniformly

distributed in the stone mass. Finally, the lid of the basket shall be securely fastened down with tying wire along all hitherto unfastened edges, all to the satisfaction of the S.O. In no case shall the weight of the finished gabion be less than 1300kg/m^3.

(c) As a gabion structure is built up, backfilling against finished gabions shall be carried out as necessary for proper progressive construction, all in accordance with the relevant provisions of the appropriate Sections of this Specification. Unless otherwise specified, vertical joints between gabions shall be staggered in gabion structures in a pattern similar to the joints in running bond brickwork.

16.10 GABION REINFORCED EARTH SYSTEM

16.10 GABION REINFORCED EARTH SYSTEM

16.10.1 Materials Specification

16.10.1.1 Introduction

(a) The specification below applies to Gabion Reinforced Earth System units and to the materials from which these are manufactured.

(b) For simplicity the word "GRES" is used.

16.10.1.2 Definitions

(a) GRES is defined as PVC coated heavily galvanized steel wire mesh box-shaped basket with a section of the mesh extending into the soil to act as soil reinforcement into the backfill soil. The basket is filled on site with clean-hard stones.

(b) The selvedges of the GRES are the thicker perimeter and edge wires to which the wire mesh is securely tied to withstand sudden or gradual stress from any direction.

(c) The diaphragms are the internal wire mesh partitions which divide the GRES box into approximately equal sized cells.

(d) Lacing and bracing wire is the wire used to assemble and join the GRES units.

(e) Connecting wires are the internal wires used to prevent the GRES from bulging during filling.

16.10.1.3 General Description

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

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

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

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

16.10.1.4 Steel Wire

I. General

All steel wire used in the fabrication of the GRES, and also in the wiring operations during construction, shall be to BS 1052, having a tensile strength of not less than 380N/mm^2 and not exceed 550N/mm^2.

II. Wire Diameter

Wire diameters and relevant tolerances shall be in accordance with the **Table 16.10.1**: -

TABLE 16.10.1 – WIRE DIAMETER AND TOLERANCE

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

III. Zinc Coating

(a) All wire used in the fabrication of the GRES and in the wiring operations during construction shall be heavily galvanized and exceed MS 407, or such similar standards as the S.O. shall approve, the minimum mass of the zinc coating shall be according to the figures shown in the **Table 16.10.2**: -

TABLE 16.10.2 – MINIMUM MASS OF ZINC COATING OF WIRE

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

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

IV. PVC Coating

(a) All wire used in the fabrication of GRES and in the wiring operations during construction shall have extruded onto it (after coating it with zinc in accordance with the foregoing specification)

a coating of Poly Vinyl Chloride, otherwise referred to as "PVC", or other plastic material having superior characteristics than PVC as otherwise approved.

(b) The coating shall be 0.50mm average thickness with a tolerance of ± 0.05mm, and nowhere shall be less than 0.40mm thickness.

(c) The PVC shall be grey in colour.

(d) It shall be capable of resisting deleterious effects of natural weather exposure, immersion in salt water and not show any material difference in its initial characteristics which are: -

(i) Specific Gravity
- Shall be 1.30 to 1.35 in accordance with ASTM D 792-91

(ii) Durometer Hardness
- Shall be 50 to 60 shore D, in accordance with ASTM D 2240-91 (ISO 868-1985)

(iii) Volatile Loss
- At 105 °C for 24 hours - Shall not be greater than 5% in accordance with ASTM D 2287-92 E2. Residual Ashes shall be less than 2% according to ASTM D2124-62T

(iv) Tensile Strength
- Shall not be less than 210kg/cm^2 in accordance with ASTM D 412-92

(v) Elongation
- Shall not be less than 200% and not greater than 280% in accordance with ASTM D 412-92

(vi) Modulus of Elasticity at 100% of Elongation
- Shall not be less than 190kg/cm^2 in accordance with ASTM D 412-87

(vii) Resistance of Abrasion
- The loss in volume shall be less than 0.30cm^3 in accordance with ASTM D 1242-56

(viii) Creeping Corrosion
- Maximum penetration of corrosion of the wire core from a square cut end shall not be greater than 25mm when the specimen has been immersed for 2000 hours in a 50% solution of HCL (Hydrochloric Acid 12 BE).

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

(i) Salt Spray
- According to ASTM B 117-90
- Period of test = 1500 hours

(ii) Exposure to Ultraviolet Light
- According to ASTM D 1499-92 and ASTM G 23(93) apparatus type E
- Period of test = 2000 hours at 63°C

(iii) Exposure at High Temperature
- According to ASTM D 1203-89, (ISO 176-1976) and ASTM D 2287-(92) E2
- Period of test = 240 hours at 105°C

(iv) Brittleness temperature: cold bend less than -30°C test method BS2782-104A; cold flex less than +15°C in accordance with BS2782-151A (84)

(f) After the above tests have been performed, the PVC coating shall exhibit the following properties: -

(i) Appearance
- The vinyl coating shall not crack, blister or split and shall not show any marked change in colour

(ii) Specific Gravity
- Shall not show change higher than 6% of its initial value

(iii) Durometer Hardness
- Shall not show change higher than 10% of its initial value

(iv) Tensile Strength
- Shall not show change higher than 25% of its initial value

(v) Elongation
- Shall not show change higher than 25% of its initial value

(vi) Resistance to Abrasion
- Shall not show change higher than 10% of its initial value

(vii) Brittleness Temperatures
- Cold-bend not exceeding -20°C; cold-flex not exceeding +18°C

16.10.1.5 Wire Mesh

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

(b) Double-twist mesh is demonstrated in **Figure 16.10.1**: -

FIGURE 16.10.1 – DOUBLE-TWIST MESH

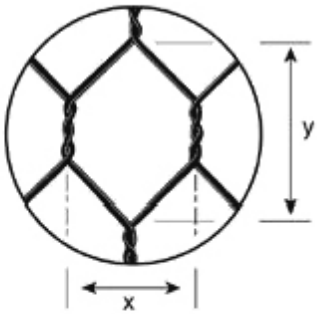
(c) The tightness of the twisted joints shall be such that a force of not less than 1.7kN is required when pulling on one wire to separate it from the other wire, provided each wire is prevented from turning under the applied forces, and the wire is all in the same plane.

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

Certain other wire diameters may be utilised if specified by the S.O.

The wire mesh dimensional layout is as per **Figure 16.10.2**:-

FIGURE 16.10.2 – WIRE MESH DIMENSIONAL LAYOUT



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

16.10.1.6 Selvedges

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

(b) The side selvedge of all and any mesh panels shall be woven integrally with the main mesh as described in the above clause 16.10.1.5 with a selvedge wire of at least 3.40mm in diameter.

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

16.10.1.7 Diaphragms and End Panels

(a) The rear/side panels shall be selvedged on the top, bottom and vertical sides as described in clause 16.10.1.6. The diaphragms shall be selvedged on the top and vertical sides.

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

16.10.1.8 Lacing and Bracing Wire

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

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

16.10.1.9 Unit Sizes

(a) GRES shall be mechanically pre-fabricated in such a manner that the sides, ends and diaphragms can be assembled at the construction site into rectangular baskets of the standard sizes indicated in **Table 16.10.3** or as specified and shown in the contract drawings.

TABLE 16.10.3 – STANDARD SIZE OF GRES

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

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

16.10.1.10 Stone Fill for Facing Box

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

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

16.10.1.11 Structural Embankment

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

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

(i) Not more than 15% by mass of total material to be finer than 75 micron sieve opening

(ii) At least 90% by mass of total material to be finer than the 100mm sieve opening, and

(iii) Maximum particle size to be limited to 125mm

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

(d) The soil should not exhibit any deterioration in these characteristics with time.

16.10.2 Assembly and Erection Specification for Gabion Reinforced Earth System

16.10.2.1 Scope

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

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

16.10.2.2 Preparation

(a) The site shall be surveyed, cleared, trimmed level and the ground compacted accordingly.

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

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

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

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

16.10.2.3 Erection

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

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

(c) Adjacent panels shall be laced longitudinally to provide a homogeneous reinforcement layer.

(d) All lacing wire shall be PVC coated.

16.10.2.4 Geotextile

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

0.5m below the panel directly above the unit, to prevent migration of fines.

16.10.2.5 Stretching

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

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

16.10.2.6 Filling

(a) Filling shall be carried out whilst gabion boxes are under tension.

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

(c) Internal bracing wires shall be provided on the exposed faces at the rate of $4/m^3$ at 330mm centres to prevent distortion of the units during filling and in the completed structure. These bracing wires shall be wrapped around two of the mesh wires and extend from front to back. Additional bracing wires shall be provided on exposed ends at a rate of $4/m^2$ of face.

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

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

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

16.10.2.7 Structural Embankment Material

Select backfill shall be placed between each subsequent mesh panel layer to the full extent of the mesh reinforcement at each level as specified in Clause 16.10.1.11.

16.10.2.8 Compaction of Backfill

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

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

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

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

16.11 HYDROSEEDING

16.11 HYDROSEEDING

16.11.1 General

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

16.11.2 Seeding

Seeding or hydroseeding shall be carried out as soon as practicable on slopes and other areas as shown on the Drawings and/ or directed by the S.O. Unless otherwise approved by the S.O, hydroseeding shall be carried out within 14 days after the slope is cut or filled. The surface before hydroseeding shall be free of loose or soft materials. Cut slope surface shall have some horizontal grooves (about 20mm deep) at about 200mm intervals. Vertical grooves shall be avoided.

Seeding shall be carried out by means of a proper hydroseeder where approved slurry of seeds, mulch, fertilisers, binders and organic matter is sprayed on to the prepared soil surface.

16.11.3 Seed Mixtures

(a) Application rate for grass seeds (dry weight) shall be 30 ± 50g/m^2. The seed mixtures shall comprise the following combinations (by dry weight) or similar as instructed by the S.O.

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

(i)	Japanese millet (Echinochloa Utilis)	15%
(ii)	Bermuda grass (Cynoden dactylon)	25%

(iii) Signal grass (Brachiaria desumbars) 50%
(iv) Centro (Centrosuma pubescens) 10%

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

(i) Bermuda grass (Cynoden dactylon) 50%
(ii) Carpet grass broadleaf (Axonopus compressus) 50%

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

(i) Centro (Centrosuma pubescens) 30%
(ii) Signal grass (Brachiaria decumbars) 70%

(b) Fertilisers and Soil Amenders

(i) The NPK fertilisers and soil amenders shall be mixed in the hydroseeder and the application rate shall be 100 ± 5g/m^2.

(ii) Not less than 90% of the GML (Ground Magnesium Lime) soil amender shall pass through a 40 mesh sieve and 50% shall pass through a 100 mesh sieve. (About ± 50g/m^2).

(c) Mulchfibres

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

TABLE 16.11.1 – MULCHFIBRES APPLICATION RATE FOR NORMAL SOIL

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

(ii) For hard material (SPT N value greater than 50) the rate of application of mulchfibres shall be as shown in Table 16.11.2:-

TABLE 16.11.2 – MULCHFIBRES APPLICATION RATE FOR HARD MATERIAL

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

(d) Binder

(i) The binder must be able to fix all ingredients onto the soil surface and to protect the areas treated against erosion until complete establishment of the vegetation cover. It may be of organic or mineral origin but must be non-polluting and having no delaying action on the germination of the seeds. The binder shall be bio gradable.

(ii) The Contractor shall submit to the S.O for his consideration and prior written approval the type and amounts of binding agent to be applied with the seeds, mulch, fertilisers, etc.

(e) Mixtures

(i) All above ingredients shall be mixed with water to form homogeneous slurry and kept agitated until finally applied to the slope surface. All water used shall be free of injurious chemicals and other toxic substances harmful to plant life.

(ii) The pH value of the water shall be above 6.0. The Contractor shall test the different water points to control the quality.

(iii) All mixtures shall be used within 4 hours from the time they are mixed.

16.11.4 <u>Spraying Equipment</u>

(a) The equipment shall consist of a water tank or container fitted with an engine; agitator and high pressure pump with sufficient power to reach the slope surface. The mechanical power drive agitator shall be capable of keeping all ingredients in suspension at all times.

(b) All pump passage and pipe lines shall be capable of providing a clearance of solids of minimum 15mm.

(c) At least two different types of nozzles (long range and close range) shall be supplied so that the mixture may be properly sprayed over distances varying from 5 to 60m. The nozzles shall be connected to

the nozzle pipe or to the eventual extension hoses by quick release couplings.

16.11.5 Biodegradable Mat (BM)

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

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

Nominal mass (ASTM D3776):		Not less than 150g/m^2 or as shown on drawing
Thickness (ASTM D1777)	:	Not less than 3mm or as shown on drawing
Roll width	:	2.0 to 3.5m
Roll size	:	50 to 200m^2

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

16.11.6 Installation of BM Blanket

(a) Prior to installation of BM, the slope or other soil surface shall be prepared as in Clause 16.11.6 and seeded as in Clause 16.11.2 and 16.11.3.

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

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

(d) The general pattern of stapling is at not more than 2.5m intervals staggered. Extra stapling is required in the backfilled trench at the top of the slope, and wherever necessary to accommodate the surface undulations.

16.11.7 Preparation of the soil surface prior to hydroseeding

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

(b) Gullies or localized washouts shall be backfilled with suitable material placed in layers of up to 200mm thick, each layer being compacted by hand ramming or by lightweight vibration plate compactors. For localized washout exceeding $1m^3$ backfilling shall be by sand bags or rock pitching or as shown on drawing.

(c) Large clods of earth and stones greater than 50mm shall be removed.

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

16.11.8 Protection of trimmed slopes

(a) All cut and fill slopes shall be treated by hydromulching (and BM where specified) within 14 days of initiating the final trim. Any area of cut or fill of over 6m vertical height shall also be protected within 14 days.

(b) Temporary and/ or permanent drainage systems shall be installed immediately after the final trim is made to a slope, and before hydromulching and the application of BM.

(c) The contractor shall ensure that his sequence of earth moving operations is such that suitable access is available for plant, labour and materials to enable installation of erosion protection measures.

16.11.9 Maintenance during liability period

The Contractor shall carry out daily watering (except lancing days) for at least 1 week is to ensure the full establishment of rooting and ground cover by taking the necessary maintenance procedures such as regular,

fertilising, and reseeding of failed areas. The Contractor shall guarantee the success of the seeding work. Any dead grass spot shall be immediately replaced or resprayed at contractors' own expenses. In areas where rooting and ground cover cannot be established even after several trials, the Contractor shall report to the S.O for necessary direction.

16.11.10 Quality Control

The following quality controls and acceptance criteria shall be complied and approved by the S.O.

(a) The rate of application of grass seeds, fertilisers, mulch etc shall be verified at field by 1m x 1m plywood and field records. (minimum 1 test daily or per 3,000m^2). The whole slope shall be resprayed if any test result is found below the value specified in Clause 16.11.3. pH value of water used shall be checked daily.

(b) Certificates related to type, origin, quality and validity of seeds for EACH source or supplier. All seeds and fertilizers shall be from suppliers approved by the S.O.

(c) Calibrated weighting machine/balance with 1% or ± 2g accuracy shall be used for all weighting.

(d) Minimum one sample per 5000m^2 of Biodegradable mat (BM) shall be sampled by the S.O for measurements/prospective verification at site to ensure compliance of specification as per Clause 16.11.5. All rolls of BM shall be tested if any sample fails any requirement. Rolls of BM below specification shall be rejected and removed from the site.

ISBN 978-967-5957-33-8