SPECIFICATION FOR PERMANENT GROUND ANCHOR FOR RETAINING STRUCTURES

1.0 GENERAL

This specification deals with permanent ground anchors and shall be read in conjunction with the conditions of contract and all other related specifications and drawings. The Contractor shall comply fully with the requirements of this specification in the design, erection and installation of ground anchors.

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).

2.0 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.

3.0 RESPONSIBILITY OF THE CONTRACTOR

The Contractor shall be experienced in permanent 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 and other works fulfilling Health & Safety Act.

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.

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. The Contractor shall also ensure the drilling and installation of the anchors does not cause problem to adjacent properties and services.

4.0 REFERENCE STANDARDS

Britain Standards Institution : BS where noted

American Standard : ASTM where noted

German Standard : DIN where noted

5.0 DESIGN BY CONTRACTOR

The Contractor shall include in the submission of the tender, for the Engineer's review, his proposed design of ground anchors in connection with the permanent earth retaining system for excavation works. 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 shopdrawings shall include the following information:

(a) Anchor layout
(b) Anchor design details
(c) Anchor structural and geotechnical design capacity
(d) Grade and properties of the tendon material
(e) Percent of tendon ultimate load at working load
(f) Method and details of anchor fabrication
(g) Details of double corrosion protection for permanent applications
(h) Method and details of proposed grouting procedure
(i) Grout/concrete - cement type, strength, additives
(j) Anchor load, length, and bond diameter
(k) Anchor free stressing length and de-bonding details
(l) Initial prestress of anchor
(m) Anchor bond design details
(n) Endorsement by a Professional Engineer registered with the Board of Engineers, Malaysia engaged by the Contractor.
(o) Any other information required by the Engineer in his review of the Contractor's design.
(p) Anchor head protection.
(q) Waler Beam design and details.

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 Engineer's specifications and conditions of contract. In matters not specifically covered by the BSI, DIN, ASTM and the Engineer'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 itemise those matters.

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

6.0 METHOD STATEMENTS FOR CONSTRUCTION OPERATIONS

Prior to commencement of works, the Contractor shall submit to the Engineer a detailed method statements for the installation of ground anchors. For the purpose of this Clause, a method statements shall be a document containing :

(a) A detailed construction sequence
(b) Proposed drilling method
(c) Proposed installation method
(d) Proposed stressing method and equipment
(e) Proposed provisions for stressing or distressing
(f) Material, plant and labour requirements at each construction stage.
(h) 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.
(i) Shopdrawings showing, among other things, details of all special requirements for the construction activities.
(j) Methods of testing.

The Engineer shall during the execution of the works require the Contractor to submit detailed method statements of other construction operations. If requested by the Engineer, the Contractor shall submit, within such times and in such detail as the Engineer 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 Engineer 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.

The Engineer shall inform the Contractor after receipt of the Contractor's method statement either

(a) that the Contractor's proposed methods have the consent of the Engineer; or
(b) in what respect, in the opinion of the Engineer, the proposed methods fail to meet the requirements of the contract.

In the latter event, the Contractor shall take such steps or make such changes in the proposed methods as may be necessary to meet the Engineer's requirements and to obtain his consent. The Contractor shall not change the methods that have received the Engineer's consent without further consent in writing of the Engineer, which shall not be unreasonably withheld. Works shall commence at such times when and not before the Engineer has given his consent to the method of construction.

Consent by the Engineer 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

7.0 EQUIPMENT AND LABOUR

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

The Contractor shall satisfy the Engineer 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.

The Engineer 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.

8.0 INSPECTION AND TESTING

The Engineer 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.

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

9.0 COMPLIANCE INSPECTION

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

10.0 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.

11.0 MATERIALS

11.1 General Requirements

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

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

All anchors shall have a double corrosion protection.

11.2 Tendons

Prestressing tendons shall comply with the following:

(a) High tensile steel wire and wire strand with a minimum tensile strength of 1860 N/mm^2 to BS 5896 : 1980.
(b) Wire steel strand to BS 4757 : 1971.
(c) Hot rolled or hot rolled and processed high tensile alloy steel bars to BS 4486 : 1980.

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

Alloy steel bars shall be straight.

A certificate shall be submitted to the Engineer containing the following particulars on the prestressing tendons :

(a) The manufacturer's name and the date and place of manufacture.
(b) Cast analysis.
(c) Diameter, cross sectional area and unit mass.
(d) 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.
(e) Results of tests for ductility of prestressing wires.

11.3 Cement Grout

Cement used for grouting anchors shall comply with M.S. 522.

Grout shall consists 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 Engineer.

Water shall be taken from the public supply of potable water and shall be at least to the quality

specified in BS 3148 : 1980

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 Engineer.

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.

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 20 N/mm^2 at 3 days and 35 N/mm^2 at 28 days. Collection of grout shall be from the grout overflowing from the drillhole unless otherwise agreed by the Engineer.

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 prestressing steel. The Contractor shall submit to the Engineer 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.

11.4 Greases

The greases used shall be formulated and manufactured for the specific purpose of corrosion protection and to provide lubrication to prestressed high tensile steel tendons. Greases shall be water displacing, self-healing, thixotropic 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.

Greases, including any used by the manufacturer of the tendons, shall comply with the requirements set down in Table 1.
The Contractor shall provide the following information:

(a) Product identification details (including name of manufacturer, brand name, type and date of manufacture of product), and
(b) Nature of the soap used (if any).

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 1. Grease shall be used in accordance with the manufacturer's instructions.

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

11.5 Plastics

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.

The finished internal and external surfaces of the sheathing and ducting shall be smooth, clean and free from flaws, pinholes, 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.

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

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

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.

The Contractor shall also provide the following information:

(a) Product identification details (including name of manufacturer, brand name, type and date of manufacture of product)
(b) Outer and inner diameter
(c) Wall thickness
(d) Amplitude and pitch, in mm, for corrugated sheathing or ducting
(e) Standard length in m
(f) Jointing details

11.6 Metal Ducting

Metal ducting shall only be used with the agreement of the Engineer.

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.

The information specified in Clause 11.5 shall also be provided for metal ducting.

11.7 Rubber Rings

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

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.

12.0 CORROSION PROTECTION

12.1 General

Recommendations concerning some commonly used protective systems for anchorage components as stated in Clause 8.2.4.2 to Clause 8.2.4.5 of BS 8081 : 1989 shall be followed in the Contractor's proposal on the corrosion protection unless otherwise agreed by the Engineer.

A. Tendon

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.

In the zone defined by the free tendon length, the corrosion protection shall not affect the

freedom of the tendon to expand.

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.

Prestressing steel tendons shall not develop more than rust bloom up to the time the anchorage is installed. Prestressing 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.

B. Joints in Tendon

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.

C. 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 restressing or inspection during the service life, care shall be taken to ensure that regrouting at the anchor head is possible.

D. Waler

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

12.2 Corrosion Protection of Permanent Anchorages

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

This proof shall, among other things,

(a) provide information on whether the components of the corrosion protection system are compatible;
(b) state that the system provides a degree of corrosion protection equivalent to that of proven systems;
(c) state that the corrosion-protective agent will not adversely affect the properties of the tendon neither during its application nor subsequently under service conditions;
(d) state that the protection of the tendon extends over the full length of the sheathing, and the tendon is tightly sealed;
(e) state that in the anchored zone the corrosion protection does not affect the freedom of the tendon to expand.

Cementitious grout shall be deemed adequate corrosion protection if in close contact with the tendon and if enclosed in a sheath that, under service conditions, resists 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.

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

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.

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, etc. are used for corrosion protection, loose particles need not be removed from the tendon prior to the corrosion protection treatment.

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.

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.

13.0 SYSTEM COMPONENTS

13.1 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.

13.2 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.

13.3 Spacers and Centralisers

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.

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.

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

(a) Within the fixed anchor length, the tendon shall be positioned in the grout column so that a minimum grout cover to the tendon of 10 mm is maintained.

(b) Within the design free anchor length, there shall be a minimum clearance of 10 mm between the tendon and the sides of the drill hole or casing.

13.4 Anchor Head Components

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

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.

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.

14.0 SUBMISSION OF ALTERNATE SYSTEMS FOR APPROVAL

Alternate systems if any, shall be included in the submission of the tender for the Engineer's review. If the design is agreed in principle, the alternate system shall be included in the contract documents.

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.

15.0 ANCHORAGES

Anchor plates and nuts shall be compatible with the prestressing system use. Anchorage components shall develop at least 95% of the minimum guaranteed ultimate strength of the tendon.

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.

16.0 EQUIPMENT

16.1 General

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.

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 Engineer will direct the use of load cell to recalibrate stressing equipment or reject the equipment if the calibration submitted is not acceptable.

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.

16.2 Fabricating and Placing

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

16.3 Grouting Equipment

The grouting equipment shall be capable of continuous mechanical mixing to produce a grout free of lumps and undispersed cement. A manifold system with a series of valves and calibrated pressure gauge with a capacity of 10 N/mm^2 shall permit continuous circulation and pumping of grouting with accurate control of grout pressure.

16.4 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.

17.0 ANCHOR FABRICATION

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.

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

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

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

18.0 DRILLING

Holes for anchors may be formed by driving or drilling method. The selection of drilling method by the Contractor shall ensure that the works do not cause and problem to adjacent properties and services. The drilling method used shall be subjected to the agreement of the Engineer. 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 Engineer.

Drillholes for ground anchors shall be provided in accordance with the Drawings. The drillhole 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 drillhole.

The Contractor shall keep a record of all drilling procedures and times, which shall be made available to the Engineer.

No drilling through the reinforcement of contiguous bored pile is allowed.

19.0 ANCHOR INSTALLATION

19.1 General

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 Engineer before commencement of work.

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.

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.

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

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 Engineer on the following stages

(i) End of bore
(ii) Insertion of tendon
(iii) Grouting
(iv) Completion of installation

19.2 Water Testing and Pregrouting

The drillhole shall be subjected to a water test to determine the likelihood of grout loss around the fixed length. However, the Engineer may agree to omit this test in exceptional ground conditions and/or where the Anchor System installation method statement provides an alternative.

Subject to the agreement of the Engineer, the Contractor may pre-grout the fixed length prior to the water testing.

The test shall be carried out by the application of a net water pressure of one atmosphere (100 kPa), or a lower pressure agreed by the Engineer, 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 drillhole.

The test may be undertaken using a drillhole packer to seal off the section under test. Alternatively, it may be carried out by using the net pressure defined above through filling the drillhole 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.

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

A full record of the water test shall be submitted to the Engineer.

19.3 Insertion of Anchor

The Engineer shall be given assistance in his inspection of the drillhole and shall be provided with the records for drilling and water testing prior to the Contractor seeking his approval.

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

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

The anchor shall be positioned in accordance with the requirements of Clause 13.4 and shall be secured to prevent further movement.

20.0 GROUTING

20.1 General

Grout shall consist of materials specified in Clause 11.3.

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.

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

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 a low strength bentonite cement grout.

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

20.2 Bleeding, Free Expansion and Fluidity

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.

Fluidity of the grout shall be tested in accordance with methods agreed by the Engineer. Except with the prior agreement of the Engineer, for grouts containing admixtures, the afflux time of the grout shall not be less than 15 seconds.

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

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 Engineer, the grout may have to be sampled from the fresh grout flow out from the drillhole 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.

A set of three grout cubes shall be prepared for cube strength determination in accordance with Clause 11.3 from each sample of grout taken.

20.4 Trial Grout Mixes

A trial grout mix shall be carried out in accordance with Clause 20.5 using the designed water-cement ratio and admixtures (if any) and the proposed grouting equipment to be used for the Contract.

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 20.2.

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 11.3.

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 11.3.

Results of the trial grout mix tests showing the degree of compliance with the Specification shall be submitted to the Engineer at least two weeks before the commencement of grouting.

20.5 Grout Mixing

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

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

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.

The grout mixing process shall utilise a recirculating 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.

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 Engineer.

20.6 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 flowmeter and a pressure gauge shall be provided. The Engineer's approval of the equipment shall be obtained prior to its use.

20.7 Grouting Procedures

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

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.

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.

20.8 Grouting Records

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

21.0 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.

22.0 ANCHOR TESTING

22.1 General

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

(a) proving tests
(b) on-site suitability tests
(c) on-site acceptance tests

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 materials used and the levels of safety that the design provides.

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 prestress or creep fluctuations stabilise within tolerable limits. These tests indicate the results that should be obtained from the working anchorages.

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.

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 Engineer.

22.2 Proving Tests

Before any anchorage is employed, proving tests shall be carried out on trial anchorages to demonstrate to the Engineer 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.

Proving tests should be carried out to investigate the behaviour and performance of the proposed 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.

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

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 Engineer. The anchorages shall have structural capacities of at least three times the geotechnical working capacity.

22.3 On-Site Suitability Tests

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.

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

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

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 Engineer.

22.4 On-Site Acceptance Tests

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.

Acceptance tests shall include creep testing and lift off test.

The Contractor shall maintain access and have the capability to conduct lift off tests, and to restress or destress anchors at any location as requested by the Engineer.

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 both for the anchor tendon and for the anchorage bond of grout to soil.

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 Engineer.

23.0 MONITORING

23.1 Requirements for Monitoring

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.

The Contractor shall monitor the anchors up to the end of the Contract Period in accordance with the programme and procedure given in Clauses 23.2 and 23.3

23.2 Load Measurement

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.

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, defective load cells shall be replaced.

23.3 Programme

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

23.4 Procedures

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 Engineer 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.

Should the variation in the residual load exceed ± 10% of that measured immediately after locking-off, the Contractor shall immediately inform the Engineer and await his further instruction.

23.5 Monitoring Records

A monitoring record shall be submitted to the Engineer within 72 hours of completion of monitoring, both hardcopy & softcopy in the format approved by the Engineer.

TABLE 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]	5 ppm by mass max.
Nitrate ion content	ASTM D 4327 - 84 [3]	5 ppm by mass max.
Sulphide ion content	APHA : Part 427 : 1985 [3]	5 ppm 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)	ASTM D 1743 - 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 of salt spray testing (1mm thick layer 500 hrs)	ASTM B 117 - 85	No corrosion

TABLE 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 hot plate until the grease dissolves.

(c) Add about 100ml of distilled and deionized 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 ion 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 is completely dissolved.

(b) Add 30ml of distilled and deionized water to 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 deionized 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 3/4 of the bottom aqueous layer, filter through a 0.2μm filter paper and reserve the filtrate for determination of the contents of chloride, nitrate and sulphide.

(f) Carry out a blank determination, following the same procedure with the same amount of reagents.

TABLE 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 G 22 - 76 (1980) procedure `B'	-	No bacterial growth on surface of specimen		
Water absorption at 23± 1°C	ASTM D 570 - 81 (Long term immersion)	% increase in weight	Max. 0.5%		
Hydrostatic pressure resistance	BS 6437 : 1984	-	No localised swelling leaking or weeping		

Note : (1) PVC = polyvinyl chloride ; PP = polypropylene; HDPE = high density polyethylene.

(2) Observed traces of fungal growth shall not cover more than 10% of the surface area.

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

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