GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS

SECTION 7
GEOTECHNICAL WORKS
## SECTION 7

### GEOTECHNICAL WORKS

#### PART 1: GENERAL REQUIREMENTS

### GENERAL

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<td>The works and materials specified in Clauses 7.02 to 7.05 shall comply with the sections stated, unless otherwise stated in this Section.</td>
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### TRIALS

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<td>Trials for geotechnical works</td>
<td>7.08</td>
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## GLOSSARY OF TERMS

<table>
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<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>Block Sample</td>
<td>A Block Sample is an undisturbed sample recovered by in-situ hand trimming of a block of material from the surrounding soil.</td>
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<tr>
<td>Bulk Sample</td>
<td>A Bulk Sample is a sample of at least 10 kg mass, which is representative of the grading of the material at the point of sampling.</td>
</tr>
<tr>
<td>Inspection Pit</td>
<td>An Inspection Pit is a pit for locating and identifying underground utilities and structures.</td>
</tr>
<tr>
<td>Jar Sample</td>
<td>A Jar Sample is a disturbed sample of at least 0.7 kg mass contained in a transparent airtight jar, which has a screw cap with an airtight sealing ring.</td>
</tr>
<tr>
<td>Sample</td>
<td>A Sample is any quantity of material obtained from the ground for the purposes of inspection, logging or testing.</td>
</tr>
<tr>
<td>Slope Surface Stripping</td>
<td>Slope Surface Stripping is the removal of surface protection and vegetation from existing slopes to expose underlying soil or rock for inspection.</td>
</tr>
<tr>
<td>Trial Pit</td>
<td>A Trial Pit is a pit for inspecting and logging the ground and in which to carry out in-situ testing and sampling.</td>
</tr>
<tr>
<td>Trial Trench</td>
<td>A Trial trench is any excavation with dimensions larger than a trial pit on plan.</td>
</tr>
<tr>
<td>U76/U100 Sample</td>
<td>A U76/U100 Sample is an undisturbed sample recovered by advancing a thin-walled tube of approximately 76 mm/100 mm diameter with a cutting edge into the soil.</td>
</tr>
<tr>
<td>Undisturbed Soil Sample</td>
<td>An Undisturbed Soil Sample is a sample complying with Class 1 or Class 2 of BS 5930.</td>
</tr>
<tr>
<td>Ground Investigation</td>
<td>Ground Investigation is the works carried out on site to investigate the subsurface conditions.</td>
</tr>
<tr>
<td>Ground Investigation Site</td>
<td>A Ground Investigation Site is the area required to be investigated as indicated on the drawings issued from time to time by the Engineer,</td>
</tr>
<tr>
<td>Investigation Station</td>
<td>An Investigation Station is the area within 2m from the specified point or area.</td>
</tr>
<tr>
<td>Common Ground</td>
<td>Common Ground is material of clay, silt, sand, gravel, cobbles and all other types of material other than rock or boulders.</td>
</tr>
<tr>
<td>Rock</td>
<td>Rock is material of decomposition Grades I to IV (refer to Geoguide 3, Table 4).</td>
</tr>
<tr>
<td>Boulders</td>
<td>Boulders are fragments of hard strata over 200 mm in size.</td>
</tr>
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</table>
**Cobbles** 7.25 Cobbles are fragments of hard strata over 60 mm and up to 200 mm in size.

**Gravel** 7.26 Gravel is fragments of hard strata over 2 mm and up to 60 mm in size.

**Hard Strata** 7.27 Hard Strata are natural or man-made materials which cannot be penetrated except by the use of rotary drilling or powered breaking tools.

**AGS Digital Format** 7.28 AGS Digital Format is a data format that complies with the Third Edition of the Association of Geotechnical and Geoenvironmental Specialists (AGS) publication "Electronic Transfer of Geotechnical and Geoenvironmental Data".

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### SUBMISSIONS

**Particulars of ground investigation** 7.29 (1) The following particulars of proposed materials and methods for ground investigation shall be submitted to the Engineer:

   (a) Details of drilling and in-situ testing equipment,

   (b) Details of sampling equipment, and

   (c) Details of filter materials and fill materials for drilling and testing,

(2) The particulars shall be submitted to the Engineer for approval at least 7 days before the relevant work starts.

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### INSPECTION PITS, TRIAL PITS AND SLOPE SURFACE STRIPPING

**Inspection pits** 7.30 (1) Inspection pits shall not be less than 0.25 m² in plan and not less than 1.5 m deep, unless otherwise instructed by the Engineer.

(2) Small disturbed samples shall be taken every 0.5 m in all Common Ground layers encountered in the inspection pit for logging purposes, commencing at ground level or below any concrete or road surfacing layers.

**Trial pits and trial trenches** 7.31 (1) Trial pits shall have nominal plan dimensions of 1.5 m x 1.5 m to their full depth of excavation, unless otherwise instructed by the Engineer or due to restricted space at the pit location or where prevented by the presence of hard strata. Where trial pits are excavated on sloping ground the base of each pit shall be horizontal and any instructed termination depth shall be taken as the depth of excavation at the mid-point of the base to original ground level.

(2) Any trial pit or trial trench left open overnight, shall be provided with both a strong wooden cover securely battened down and appropriate fencing to prevent persons and animals from falling into the excavation.
(3) Before commencing any excavation, three dynamic probing tests shall be performed in a triangular pattern not more than 800 mm apart around the centre of each proposed trial pit, unless otherwise instructed by the Engineer. In trial trenches, one dynamic probing test shall be carried out for each 1.0 m² of plan area of the excavation, equally spaced, unless otherwise instructed by the Engineer. All probes shall be terminated at the initial instructed depth of the trial pit or trial trench. On sloping ground, each individual dynamic probing test shall be terminated at the instructed base of the trial pit or trial trench. A second attempt shall be made for each test if refusal is met before the instructed termination depth, at a distance of not less than 150 mm from the original position. Dynamic probing tests shall be carried out in accordance with Clause 7.69.

(4) The preliminary results of the dynamic probing tests carried out prior to excavation shall be submitted to the Engineer, with the relevant daily site records for each trial pit or trial trench excavated. They shall be included in the Final Field Work Report and provided in AGS digital format.

(5) Trial pits and trial trenches shall be excavated vertically by manual methods to the termination requirements or depths instructed by the Engineer. Benching and shoring shall be carried out as necessary and as agreed by the Engineer. Hardwood shall not be used for shoring purposes. Powered tools shall only be used with the agreement of the Engineer.

(6) Steel ladders or products having equivalent functions or performance as agreed by the Engineer shall be provided as necessary.

(7) If instructed by the Engineer, the excavated material shall be removed from the site and the same or similar material shall be imported for subsequent backfilling. Otherwise, material excavated from trial pits and trial trenches shall be safely stockpiled and protected from the weather. For excavations on sloping ground, the material shall be protected in such a manner that it does not fall or wash downhill or in any way enter surface water drainage systems. All necessary measures shall be taken to prevent the ingress of surface water into the excavations.

(8) No logging or photography of each trial pit or trial trench shall be carried out until the termination of each excavation has been approved by the Engineer.

**Pumping from trial pits and trial trenches**

7.32

Trial pit and trial trench excavations shall be kept free from water. The base of each excavation shall be clearly visible during logging and taking photographs.

**Backfilling of inspection pits, trial pits or trial trenches**

7.33

(1) Inspection pits shall be plugged at the bottom with concrete or similar material, and backfilled on completion of the drillhole. Trial pits and trial trenches shall be backfilled within 2 working days of the date of issue of an instruction from the Engineer. The backfill material shall not contain material exceeding 200mm in size, refuse, metal, rubber or synthetic material, peat, vegetation, perishable material or toxic material or material susceptible to
Slope surface protection stripping 7.34 (1) Surface protection, including that containing reinforcement shall be stripped and disposed of, from slopes to expose underlying Common Ground or rock. The width of stripping shall be 500 mm, unless otherwise instructed by the Engineer, with the axis of the strip parallel to the dip of the slope. The underlying Common Ground shall be excavated to a minimum depth of 100 mm and up to 300 mm as instructed by the Engineer. All excavation shall be
terminated if boulders, rock or hard strata are encountered, unless otherwise instructed by the Engineer. The stripping shall start at the top of the slope or where instructed by the Engineer and shall proceed downwards.

(2) If instructed by the Engineer, the stripping shall be limited to specified intervals (windows) along the instructed length. A record for the full instructed length of the stripping shall be provided to the Engineer.

**Access**

7.35 Access shall be provided for inspection by the Engineer.

**Protection of stripped surface**

7.36 Stripped areas shall be covered up at the end of each working day and during rainstorms to prevent the ingress of water into the slope and to minimise the channelling of rainwater run-off.

**Reinstatement of stripped surface**

7.37 Stripped areas shall be reinstated in form, colour and conditions similar to the original. The permission of the Engineer shall be obtained before reinstatement starts.

**Disturbed samples from trial pits, trial trenches or slope stripping**

7.38 (1) Small disturbed samples shall be taken in all trial pits and trial trenches at the top of each Common Ground layer encountered and then at intervals of 0.5 m in any layer thicker than 0.5 m. Small disturbed samples shall be taken in Common Ground every 0.5 m along each stripping, commencing at the base. The disturbed samples shall be representative of the composition of the Common Ground exposed. Samples of material predominantly coarser grained than sand, or if instructed by the Engineer, shall be placed in large polythene bags. Other material shall be placed in airtight plastic containers, of minimum 100 mm diameter, with a screw top. Sufficient material shall be taken to fill the bag or container, which shall be sealed immediately after recovery. Each sample shall be labelled as specified in Clause 7.55, including the face number from which the sample was taken.

(2) Large disturbed samples of at least 25 kg shall be taken in trial pits, trial trenches or from slope stripping, if instructed by the Engineer. All large disturbed samples shall be placed in heavy-duty polythene bags immediately after they are taken, and securely fastened. Before taking samples from slope stripping, a minimum of 100 mm of material, or other thickness, as instructed by the Engineer, shall be removed first.

**Records of inspection pits**

7.39 Details of each inspection pit shall be included in the relevant daily site record and drillhole record. A photograph taken vertically downwards into each inspection pit shall be submitted together with the daily site record for the relevant drillhole. A board showing the contract number and drillhole number, and the depth indicator used shall be clearly visible in the photograph.

**Records of trial pits and trial trenches**

7.40 (1) The format of daily site records shall be similar to figure 7 of “Geoguide 2” and to the approval of the Engineer. The following additional shall be included:

(a) Contractor’s name, Contract number and Ground Investigation title,
(b) weather conditions,

(c) depths and details of all sampling and field testing including total blow count for driven samples and sample recovery, and

(d) any other relevant information e.g. comments on stability, maximum and average trial pit and trial trench depths and plan dimensions, water inflow, powered tools used.

(2) Preliminary and final records shall show the following information:

(a) for trial pits, the co-ordinates of the centre of the pit, for trial trenches, coordinates of both ends of the longer axis,

(b) for trial pits located on level or sloping ground, the reduced level at the centre of the pit; for trial trenches, the reduced levels of both ends of the longer axis,

(c) water levels with full details of fluctuation and seepage. If no groundwater is encountered then this shall be stated,

(d) a hand drawn (preliminary) and computer-generated (final) representation of the features and material types encountered in each face and the base of the trial pit or trial trench. Fill shall be shown as its constituent materials in the face sketch and its legend pattern in the legend column,

(e) stability conditions during excavation,

(f) the size and orientation of any services encountered,

(g) a sketch showing the dimensions of any sub-surface structures, including foundations exposed in the excavations, and

(h) a remarks section which shall include groundwater and wall stability observations, average and maximum depths, use of shoring and details of any obstruction encountered. If the required number of dynamic probing tests was not carried out, the excavation was terminated earlier than specified, or the plan area of the excavation was reduced, these facts shall be noted with reasons.

Photographs of trial pits or trial trenches

(1) Within 2 working days of the date of approval of any trial pit or trial trench it shall be photographed using a reference board with maximum dimensions of 300 mm (width) by 450 mm (length). Each face and the base shall be photographed.

(2) Each photograph shall cover a length of the excavated face of between 1.5 m and 2.0 m in both vertical and horizontal directions. Where more than one photograph is required to cover the full excavated depth or length of a face, the overlap between adjacent photographs shall be between 10% and 20%.
(3) Each photograph shall identify the face of the excavation and shall contain a natural scale. In the case of trial trenches, it shall also identify the location of the photograph by the metrage along the face of the excavation.

(4) One colour print of minimum size 85 mm x 125 mm of each trial pit or trial trench photograph shall be supplied with the preliminary records. Each copy of the Final Field Work Report shall contain colour photocopies of A4 mounted prints of minimum size 125 mm x 175 mm. Within 3 weeks of the award of the Contract, the name(s) of the suppliers and samples of the colour photocopies shall be submitted for the Engineer’s approval. The quality of the colour photocopies shall be maintained as approved throughout the Contract.

Slope stripping records 7.42 Preliminary and final slope stripping records shall be either a hard copy or soft copy as determined by the Engineer. A hard-copy record shall be printed double sided on recycled paper. A soft copy record shall be in read-only format. Each record shall include descriptions of strata (including decomposed rock) encountered and levels and co-ordinates of the top and bottom of strips, berms, benches and changes in type of slope surfacing. The survey results shall include all points on each strip where there is a change in gradient. Any other salient features shall be noted e.g. dip and dip direction of joints. The direction and bearing of the slope and the results of any in situ testing carried out shall be shown on the record. The record shall include a dimensioned sketch of the strip cross-section.

DRILLING FOR GROUND INVESTIGATION

Drilling rigs for ground investigation 7.43 Drilling rigs shall meet the following requirements:

(a) drilling rigs shall be of the hydraulic feed type having the capacity to drill in the sizes and to the termination requirements or depths instructed,

(b) drilling rigs shall be capable of providing stable drill-string rotation at speeds in the range 50-1250 rpm and have a minimum ram stroke length of 400 mm if applicable. The rigs shall be fitted with a tachometer, a hydraulic feed pressure gauge of an appropriate scale and a pressure gauge for reading water flushing pressure. The hydraulic feed pressure readings shall be readily converted to loads transferred to the bit in pounds or kilograms according to the manufacturer's specification. In order to provide a means of measuring penetration and estimating the rate of advance, a rigid rod, clearly graduated in 10 mm increments, shall be permanently attached to, and parallel with, the hydraulic feed rams, and

(c) if the flushing medium is water, the pump shall be equipped with a gearbox and shall be capable of delivering up to 2 L/s. It shall incorporate a surge bottle to reduce fluctuations in water pressure and the suction hose shall be fitted with a suitable filter. It shall have a by-pass system allowing full control of water flow at all pump delivery rates.
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<td>7.44</td>
<td>(1)</td>
<td>The core barrels, drill rods and drill bits of drilling equipment for ground investigation shall be of a type appropriate to the purpose of the drilling and sampling. Drill bits shall be diamond, tungsten carbide or combination tipped core bits, of a type appropriate to the purpose of the drilling and sampling and suitable for the percentage core recovery and diameters required by the Contract. Triple tube core barrels shall be provided with bits suitable for air-foam flush. The type and make of core barrels shall be approved by the Engineer.</td>
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<td></td>
<td>(2)</td>
<td>The size of casings shall be appropriate to the drilling, coring, sampling, testing and other installation requirements.</td>
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<td></td>
<td>(3)</td>
<td>Only standard nominal lengths of casing and drill rods shall be used. The mixing of standard nominal imperial and metric lengths shall not be permitted.</td>
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<tr>
<td></td>
<td>(4)</td>
<td>Casings and drill rods shall be straight, in good condition, clean at the time of drilling and free from scale, dirt and other loose material.</td>
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<td></td>
<td>(5)</td>
<td>All accessories and spare parts shall be as supplied or recommended by the same manufacturer unless otherwise approved by the Engineer. They shall be compatible with the equipment in use and with each other. Sufficient spares for core barrels, core bits, core lifters and other accessories shall be available for use on site without causing any delay to drilling operations. The condition of the core bit in use shall be carefully monitored and if any damage occurs, such as breaking of teeth, it shall be replaced immediately.</td>
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<td></td>
<td>(6)</td>
<td>Core barrels shall always be maintained in proper working order and particular attention shall be paid to the condition of the extrusion piston. The rubber O-rings shall be maintained in good condition so that no water escapes past the piston during extrusion of the cores.</td>
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<td></td>
<td>(7)</td>
<td>Sediment catcher tubes attached to the top of the core barrels shall be used if instructed by the Engineer. The tube shall have the same external diameter as the core barrel, and be approximately 0.75 m long.</td>
</tr>
<tr>
<td></td>
<td>(8)</td>
<td>Core barrels and drill rods shall be stored on steel frame trestles.</td>
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<tr>
<td>7.45</td>
<td>(1)</td>
<td>Drillholes for ground investigation shall be sunk by rotary methods. The methods and equipment used shall be such that:</td>
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<tr>
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<td></td>
<td>( \text{(a)} ) The soil encountered and the levels at which changes in ground conditions occur can be accurately identified,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{(b)} ) The specified sampling requirements can be achieved,</td>
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<tr>
<td></td>
<td></td>
<td>( \text{(c)} ) In-situ tests can be carried out and field installations can be incorporated at any depth in the drillhole, and</td>
</tr>
<tr>
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<td></td>
<td>( \text{(d)} ) Consistency of measurement and minimal disturbance of the ground is achieved.</td>
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(2) No nominally vertical hole shall deviate from the vertical direction by more than 0.5° unless otherwise agreed by the Engineer. For inclined drillholes, neither the inclination nor the bearing shall differ from the instructed values by more than ±2° throughout the length of the hole.

(3) The type and state of the core bit, feed rates and management of the drill string shall be such that the specified minimum acceptable core recovery in any single core run can be obtained where the condition of the ground permits.

(4) In Grade III rock or better, 3 m core runs may be used. For Grade IV or V, maximum core run lengths shall be limited to 1.5 m. If the percentage core recovery in a core run is less than that specified in Clause 7.6 the following run shall be reduced by 50%, to a minimum length of 0.5 m. Notwithstanding this requirement, with the approval of the Engineer, the core barrel shall be withdrawn and core removed more frequently as necessary to secure the maximum possible core recovery.

(5) Common Ground around the bottom of a drillhole shall not be unduly disturbed by water entering or leaving the hole, or by stress relief. The water level in a drillhole shall be kept at least 1 m to 2 m above the ambient groundwater level at all times, unless otherwise instructed by the Engineer. Rapid withdrawal of rods and sampling equipment, causing rapid fluctuation in the water level inside the casing, shall be avoided.

(6) Casings shall be advanced concurrently with the removal of material in such a manner that loss of ground is avoided. Larger casings shall be set concentric with drillholes that are being reamed.

(7) Drilling lubricants other than clean water shall not be used, unless otherwise instructed by the Engineer.

### Categories of core drilling

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<th>Categories of core drilling</th>
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<td>Three categories of core drilling shall be available:</td>
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<tr>
<td>(a) Category “A” - Water/Air-foam flush with triple tube core barrels using split inner tube (4C-MLC, HMLC or NMLC).</td>
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<tr>
<td>(b) Category “B” - Water/Air-foam flush with double tube core barrels (T2-101, TNW or products having equivalent functions or performance approved), and</td>
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<tr>
<td>(c) Category “C” - Water/Air-foam flush with single tube core barrels.</td>
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### Rotary open hole drilling

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<tr>
<td>A hole up to 170 mm in diameter, to a maximum depth of 40 m in Common Ground or Rock, Hard Strata without the recovery of core or samples, shall be advanced, if instructed, by means of a tricone roller bit, drag bit or other non-coring bit with water as the flushing medium.</td>
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### Air-Foam Drilling

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<tr>
<td>An appropriate air-compressor and all necessary ancillary equipment shall be provided to carry out drilling with air-foam flush to the Engineer’s satisfaction. The foam return shall be the consistency of thick shaving cream and the hole shall be kept full of foam at all times. The foam shall either be fully biodegradable or water soluble and arrangements shall be made for the collection and removal or dispersal of the foam returns, if required. The proposed foam additive and mixes</td>
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</table>
shall be to the approval of the Engineer. A typical arrangement of air-foam mixing and flushing system is shown in Figure 12, Geoguide 2.

The flushing medium for drilling shall be passed through a sedimentation basin to remove drilling cuttings/arising and shall either be reused or, where permitted, be discharged to surface drains or natural stream courses. Measures shall be taken to prevent the flushing medium seeping through the ground. Re-circulation pits or re-circulation tanks shall be provided at the drillhole locations if the flush returns cannot be discharged safely or if instructed by the Engineer.

Disposal of flush returns 7.49

Disposal of flush returns

Backfilling of drillholes and rotary open holes 7.50

(1) All drillholes and rotary open holes in which no instrumentation will be installed shall be backfilled with cement bentonite grout within one working day of the completion of the hole. The grout shall be a pumpable mix of cement and bentonite in the proportion of 4:1 by dry weight, or an alternative mix agreed by the Engineer. The water content of the grout shall be limited to that necessary for proper mixing and placement. In no case shall the water cement ratio exceed 3. The resulting grout shall be free of lumps and foreign material. A method statement shall be submitted for the Engineer’s approval. A demonstration of the proposed equipment, material, mixing, handling and placement procedures including appropriate quality controls and checks to be adopted shall be given.

(2) For each drillhole backfilled with grout, the viscosity of the grout measured by Marsh Funnel and specific gravity of the grout measured by Mud Balance or any instrument of sufficient accuracy to permit measurement within ±0.01 g/cc shall be recorded. A labelled jar sample of grout from each hole shall be kept.

(3) Unless otherwise instructed by the Engineer, the grout shall be fed into the bottom of the hole using a suitable pump and a tremie pipe, the end of which shall always be maintained below the grout/water interface. Casing shall be removed in stages during grouting to ensure that the entire hole is backfilled. Grout level shall be checked at least 24 hours after initial grouting, and any significant drop in grout level shall be topped up with additional grout, or backfilled with material agreed by the Engineer. Any subsequent depression shall be levelled and compacted.

(4) Only if instructed by the Engineer shall granular material, cement mortar or other materials be used to backfill the holes. Under no circumstances shall cement-bentonite balls (i.e. mixed paste) be used to backfill the hole.

(5) A complete record of backfilling operations including the quantity of grout placed, the drop in grout level after 24 hours, the viscosity and specific gravity of the grout and any other relevant information shall be included in the Daily Site Record and shall be submitted to the Engineer within 3 days of completion of backfilling.

(6) For backfilling involving an Excavation Permit, the work shall comply with the requirements set out in the Conditions of the Excavation Permit. If there are any discrepancies between this clause and the Conditions of the Excavation Permit, the more stringent requirement shall prevail.
Sampling from drillholes 7.51

(1) Jar samples from drillholes shall be taken from the cutting shoe of each undisturbed sample, from any anomalous material, from each standard penetration test and at other locations as instructed by the Engineer.

(2) All loose material and material disturbed by drilling or in-situ tests shall be removed from the sides and bottom of the drillhole before each undisturbed sample is taken.

Records of drillholes 7.52

(1) Records of drillholes for ground investigation shall be kept on the Site. Drillhole logs shall be comprehensive and shall be in a form similar to that shown in Figure 44 of ‘Geoguide 2: Guide to Site Investigation’, Hong Kong Government, 1987. Soil and rock descriptions shall comply with those stated in the insert titled ‘Checklist for Soil Descriptions’ and ‘Checklist for Rock Descriptions’ in ‘Geoguide 3: Guide to Rock and Soil Descriptions’, Hong Kong Government, 1988 or with any other system agreed by the Engineer.

(2) Drillhole logs shall be drawn to a constant vertical scale of 1:50 unless otherwise agreed by the Engineer and shall contain the following details:

(a) Information shown and in the format in Figure 44 and paragraphs 40.2.6 (2), (4) and (5) of ‘Geoguide 2: Guide to Site Investigation’, Hong Kong Government, 1987,

(b) Reduced levels of observation well bases, piezometer tips, and sand filter layers,

(c) Details of utilities identified in the inspection pit excavated at the drillhole location.

Supply of sampling equipment and containers 7.53

All the sampling equipment and containers shall conform to the requirements of Geoguide 2 and this General Specification. Specifications and examples of the proposed equipment and containers to use shall be submitted to the Engineer for approval prior to the commencement of the Contract.

(a) For general purpose open tube samples and thin-walled samples, the sample tube and cutting shoe shall be free of rust, pitting, burring or any other defect. The use of oil inside the sampler shall be limited to the minimum practical. Each sample tube shall have a unique reference number and the word ‘TOP’ engraved on its exterior at one end. The sample tube shall be driven with the end marked ‘TOP’ uppermost. The dimensions, construction and condition of each sample tube; cutting shoe and adaptor head shall be approved by the Engineer prior to sampling. The adaptor head shall be fitted with a ball valve to permit the exit of air or water during driving and to assist in retaining the sample during withdrawal, and it shall have an allowance for over-driving. In soil of low cohesion such as silt and silty fine sand the sampler shall be equipped with a basket core retainer to enhance core recovery.
(b) U100, U76 and U40 thin-walled samplers shall be approved 102 mm (for U100), 78 mm (for U76) and 42 mm (for U40) diameter open drive sample tubes made from thin-walled seamless cadmium plated or stainless steel. They shall be not less than 450 mm (for U100), 350 mm (for U76) and 200 mm (for U40) in length fitted with a cutting shoe tapered at an angle not exceeding 20°. The area ratio of the sampler as defined in Figure 13 of ‘Geoguide 2: Guide to Site Investigation’, Hong Kong Government, 1987 shall not exceed 30%.

(c) Piston samplers shall be a thin-walled fixed piston sampler to the approval of the Engineer. The piston sampler shall be capable of operating to a depth of at least 20 m below ground level with no lateral movement during the actual sampling operation. The design and maintenance of the sampler shall be such that a partial vacuum is formed over the retained sample in the tube. The minimum recovered sample length shall be 900 mm. The thin-walled tube shall have an external diameter of 75 mm or 100 mm as instructed by the Engineer. The area ratio of the sampler as defined in Figure 13 of ‘Geoguide 2: Guide to Site Investigation’, Hong Kong Government, 1987 shall not exceed 10%.

### General sampling requirements

7.54 (1) Both disturbed and undisturbed samples shall be taken from an Investigation Station at the depths and intervals instructed by the Engineer. All samples shall be transported and delivered in core boxes or in any other containers as specified.

(2) Small disturbed samples shall be taken in drillholes from the cutting shoe of each undisturbed sample, from any anomalous material, from each standard penetration test and at other locations as instructed by the Engineer.

(3) In all drillholes, small disturbed samples of Common Ground shall be taken on entering each new stratum (including decomposed rock) and every 1.0 m in between other small disturbed samples from cutting shoes or core bits. They shall be taken with a driven sample tube or other method approved by the Engineer. The disturbed sample shall be representative of the composition of the Common Ground.

### Numbering and labelling of samples

7.55 (1) A reference number shall be assigned to each Common Ground sample (both disturbed and undisturbed) and groundwater samples taken, commencing with samples obtained from the inspection pit, if excavated. The number shall be unique for that Investigation Station and shall be in order of depth below ground level. The number shall also be shown on the records adjacent to the sample symbol.

(2) All sample containers and tube samples shall be clearly marked both on the side and the top of the sample with a permanent marker pen with the following information:
(a) Works Order number, if any,
(b) Reference number of the Investigation Station,
(c) Reference number of the sample,
(d) Date of sampling, and
(e) Depth of the top of the sample below existing ground level.

(3) Each core box shall be identified by the following information, which shall be clearly marked on the top, both ends and beneath the core box lid using waterproof ink or paint:

(a) Contract number,
(b) Works Order number, if any,
(c) Ground Investigation title,
(d) Investigation Station number,
(e) Depths of material contained, and
(f) Core box number.

(4) The depths at which each core run started and finished shall be recorded at the ends of each core run by permanent marker pen on the edge of the box or on wooden blocks which fit between the dividing slats. If a core run is contained in two sequential core boxes, the abbreviation "cont'd" shall be used on the adjacent edges of the core boxes.

Sealing of common ground tube samples

7.56  (1) Once a sample tube has been detached or removed from the sampling equipment, the visible ends of the sample shall be cleared of any disturbed material, and the edges trimmed at 45°. After cleaning the sides of the tube above the recovered sample, the ends shall be coated with three successive thin films of just molten microcrystalline wax. A metal foil disc shall then be added and followed by more molten wax to give a total thickness of not less than 20 mm. Any space remaining in the ends of the sample tube shall be solidly filled with damp sawdust or other material approved by the Engineer and the ends of the sample tube shall be covered with tight fitting rubber caps.

(2) The tubes containing samples shall be handled with care to avoid any possible disturbance, stored in a cool and dry location and protected against the sun or inclement weather whilst on site.

(3) The material from the cutting shoe/core bit shall be immediately placed in a plastic container of minimum diameter 100 mm, with a screw top. They shall be arranged securely in the corebox in their proper sequence.
**Core boxes**  7.57

Core boxes shall be 1.05 m in length, 0.45 m in width and of sound robust construction, able to withstand the weight of the cores and stacking of the boxes. The lid shall be fitted with metal hinges, hasp and staple and a locking device. Rope strands shall be attached to each end of the core box for lifting. Boxes shall be provided with rigid separating slats.

**Delivery and storage of samples**  7.58

1. All samples, including cores, obtained from Ground Investigations shall be delivered to the storage facilities location specified by the Engineer, within 3 working days of the date of completion of the field work, unless otherwise instructed by the Engineer.

2. Samples shall be stored in a cool and dry location and protected against the sun or inclement weather. Block samples shall be stored in their correct orientation. All samples recovered from vertical/sub-vertical or horizontal/sub-horizontal drillholes shall be stored and transported in their correct orientation, and in purpose-built racks which shall hold the samples securely. Core boxes shall be stacked by Investigation Station and box order.

3. Samples shall be delivered to the laboratory specified by the Engineer within 3 working days of receipt of an instruction. Any discrepancies between the laboratory testing schedule attached to the instruction and the samples, such as incorrect sample depths or reference numbers, shall be raised with the Engineer prior to delivery. A signed delivery docket shall be obtained to record the delivery and all the samples shall be checked off with a representative from the laboratory.

4. On completion of the laboratory testing, the Engineer may require the samples to be removed from the laboratory. These samples, together with any samples kept at designated storage facilities shall be delivered or disposed of as directed by the Engineer. A list of the samples delivered, agreed by the person receiving the samples where possible, shall be sent to the Engineer.

**Undisturbed tube sampling of common ground in drillholes**  7.59

Before an attempt to take an undisturbed sample from a drillhole is made, all loose material and material disturbed by drilling or field testing shall be removed from the hole. On recommencement of work at the start of each shift during the progress of a drillhole, a minimum of 0.3 m of material shall be removed before the next undisturbed sample is taken, unless otherwise instructed by the Engineer.

**Retractable triple tube core sampling**  7.60

1. Undisturbed samples of Common Ground shall be taken in drillholes using a triple tube retractable core barrel (Geoguide 2) fitted with either a detachable rigid clear ABS plastic or rigid opaque PVC or Polyethylene (PE) liner.
(2) The dimensions of the core barrel and liner shall be as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Dimension (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Barrel</td>
<td></td>
</tr>
<tr>
<td>Outer Tube OD</td>
<td>98.5 ± 2.0</td>
</tr>
<tr>
<td>Inner Tube ID</td>
<td>78.0 ± 1.0</td>
</tr>
<tr>
<td>OD</td>
<td>85.0 – 89.0</td>
</tr>
<tr>
<td>Cutting Shoe ID</td>
<td>72.5 ± 1.0</td>
</tr>
<tr>
<td>(Leading Edge) OD</td>
<td>77.2 ± 1.0</td>
</tr>
<tr>
<td>Drill Bit OD</td>
<td>101.1 ± 2.0</td>
</tr>
<tr>
<td>Liner</td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>74.0 ± 1.0</td>
</tr>
<tr>
<td>OD</td>
<td>77.0 ± 1.0</td>
</tr>
<tr>
<td>Ovality</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Bow</td>
<td>3 per metre</td>
</tr>
<tr>
<td>Length</td>
<td>1000 ± 5</td>
</tr>
<tr>
<td>Wall Thickness</td>
<td>1.5 minimum</td>
</tr>
</tbody>
</table>

(3) Face-discharge bits made of steel and set with tungsten carbide inserts in a saw tooth profile shall be used. The drill bit shall have groove cuts on the external sidewall to facilitate return of flushing fluid.

(4) The cutting shoe shall have an area ratio of 10 to 15%. The ID of the leading edge of the cutting shoe shall be smaller than the ID of the liner tube with an inside clearance between 1.5 and 3.5%. Three lengths of cutting shoes, referred to as "long", "medium" and "short" with decreasing lengths of protrusion beyond the drill bit when mounted, shall be available. The "long" shoe with a protrusion of not more than 50 mm shall be used generally for looser or softer soils, and the "medium" or "short" shoes for denser or stiffer soils.

(5) The liner shall fit tightly inside the inner tube, in both radial and longitudinal directions. The liners shall be obtained from a manufacturer approved by the Engineer. Within 3 weeks of award of the Contract, the name(s) of the suppliers, material specification and examples of the liners proposed, shall be submitted to the Engineer for approval. If approved, the quality of the liners shall be maintained for the duration of the Contract.

(6) The barrel, drill bit and cutting shoe shall be free from significant defects and in good working condition. A sediment tube may be attached to the top of the barrel to trap the cuttings falling out of suspension from the flushing medium. A core retainer of suitable design may be used only when it is necessary to reduce the risk of sample loss.

(7) Prior to lowering the barrel down the drillhole, it shall be checked to ensure that the inner barrel rotates freely, the retractor spring works and that the check valve at the top of the inner barrel is functioning properly.

(8) The bottom of the drillhole shall be cleaned out properly prior to sampling to the specified sampling commencement depth within a tolerance of ±25 mm, unless otherwise agreed by the Engineer.
(9) In order to alleviate disturbance to the soil being sampled, the applied flushing pressure shall be kept to a minimum. An optimum combination of the applied bit pressure and rotation speed shall be used to achieve a steady penetration but this shall not be so slow as to cause unnecessary disturbance by the flushing medium.

(10) Successful sampling shall mean a minimum recovery of 80% of the sampled length when water flush is being used, and 90% of the sampled length when air-foam flush is being used. If sampling is not successful, the hole shall immediately be cleared of material disturbed by the sampling process and another attempt shall be made from the level of the base of the failed attempt.

(11) If continuous retractable triple tube core sampling has been instructed and the second attempt also proves unsuccessful the Engineer shall be informed immediately, or as early as possible on the next working day, and a proposal made for improving sample recovery for the Engineer's approval.

(12) If interval sampling has been instructed and the second attempt also proves unsuccessful, a Standard Penetration Test with a liner sample shall be performed and the sampling sequence instructed shall be continued. If two consecutive sequences of failed undisturbed sampling occur in any one drillhole the Engineer shall be informed immediately, or as soon as possible the next working day. The sampling sequence shall be continued unless otherwise instructed.

**Piston sampling**

(1) Undisturbed samples of Common Ground shall be taken in drillholes using a thin-walled stationary piston sampler. The sampling tube shall be 1000 mm long, formed from stainless steel with an integral cutting edge and shall have an internal diameter of 75 mm or 100 mm (±1 mm) as directed by the Engineer. The area ratio of the tube shall not exceed 10% and the cutting edge taper angle shall not exceed 15°. No inside clearance shall be permitted. The sampling operation shall ensure the sampling tube is pushed into the soil vertically at a steady rate with no lateral deflection. The design and performance of the sampler shall be such that a vacuum is formed over the retained sample in the tube.

(2) The minimum recovery shall be 90% of the sampled length. If the length of sample recovered is less than that specified, the hole shall immediately be cleared of material disturbed by the sampling process and another attempt shall be made from the level of the base of the failed attempt. If this second sampling attempt also fails to recover the minimum specified, the sampling sequence instructed shall be continued but the Engineer shall be informed immediately, or as early as possible the next working day.

(3) Purpose-built sample boxes shall be provided for transporting and storing all piston samples in a vertical position. Each box shall be used to transport two piston samples. These boxes shall be robust, water-tight, and shall be fitted with hinged top and rope-strand lifting handles. The inside of the box shall be provided with styrofoam padding which holds the samples tightly in place.
U100 and U76 sampling

7.62 (1) General

(a) Samples of Common Ground shall be taken in drillholes, trial pits and trial trenches using 101 mm (±1 mm) [for U100] or 77 mm (±1 mm) [for U76] internal diameter open sample tubes. The tubes shall be thin walled seamless stainless steel or galvanised mild steel not less than 450 mm in length fitted with a cutting shoe tapered at an angle not exceeding 20°. The area ratio of the sample tube cutting shoes shall not exceed 30% and inside clearance between the shoe and each tube shall not exceed 2% unless a core retainer is used, in which case the inside clearance shall not exceed 4%. Each sample tube shall have the word "TOP" marked on its exterior at the end driven uppermost. The minimum recovery shall be 80% of the sampled length.

(b) The adaptor head at the top of the sample tubes shall be fitted with a ball valve to permit the exit of air or water during driving and to assist in retaining the sample during withdrawal. The use of oil inside the sample tubes shall not be permitted and care shall be taken to ensure that the sample is not compressed by over-driving.

(c) All recovered samples shall be stored and transported vertically, in their correct orientation, in purpose-built racks which shall hold the tubes securely.

(2) In Drillholes

(a) The sampler shall be driven by means of either a jarring link (i.e. drilling rods delivering the impact at the adaptor head of the sampler), a sliding hammer arrangement to the approval of the Engineer or a single ram stroke. No vertical pull-up action shall be applied to the sampling tube during the lift-up of any hammering operation. The total depth driven or pushed and, where relevant, the number of blows used shall be recorded in the daily site records. Where driven samples are instructed in Common Ground of low cohesion, such as silts and silty fine sands, a core retainer of suitable design shall be provided to improve sample recovery. In cohesive Common Ground, the initial attempt to obtain a sample shall be made without the use of a core retainer.

(b) Before withdrawal from the drillhole, the sampler shall be rotated through two complete revolutions to shear the Common Ground horizontally at the bottom of the cutting shoe. If necessary, this operation shall be delayed to allow the development of sufficient adhesion inside the tube. The sampler shall then be withdrawn smoothly so as to cause minimal disturbance to the sample.

(c) If an initial attempt to take a U100 or U76 sample in a drillhole recovers a length of sample less than specified, the hole shall immediately be cleared of material disturbed by the sampling process and another attempt shall be made from the level of the base of the failed attempt, using a core retainer. Should the second attempt also prove unsuccessful, a Standard Penetration
Test with a liner sample shall be performed, and the sampling sequence as instructed shall be continued. If two consecutive sequences of failed sampling occur in any one drillhole, the Engineer shall be informed immediately, or as soon as possible the next working day.

(3) In Trial Pits and Trial Trenches

(a) Prior to sampling in trial pits or trial trenches, all disturbed material shall be cleared in order to expose Common Ground in its natural condition. The samples shall be taken using a sliding hammer arrangement with care being taken to ensure that no lateral movement takes place during driving with the use of guide frame as necessary. The proposed method of driving shall be to the approval of the Engineer. The sample tubes shall then be removed by excavating around them.

(b) If a driven sample in a trial pit or trial trench recovers less than that specified a second attempt shall be made beside the first, but not closer than one tube diameter to the first attempt. If this second attempt fails then a third and final attempt shall be made at a distance of at least one tube diameter from any previous attempt. If the third attempt fails the Engineer shall be informed immediately, or as soon as possible the next working day.

Block samples 7.63 (1) Block samples of Common Ground shall be taken either from the sides or bottom of trial pits or trial trenches or from slope stripping. Samples shall be not less than 230 mm cube.

(2) The top and four sides of the sample, but not the base, shall be excavated, trimmed, wrapped in aluminium foil and waxed. A wooden box, with two opposite sides removed, shall then be placed over the prepared sample such that a minimum annulus of 25 mm exists between the inside of the box and the sample. The top and side annuli shall then be filled using polyurethane by means of two reagents. After hardening of the polyurethane, the top of the box shall be attached and the sample carefully broken away at its base at a depth of no less than 50 mm below the base of the sample. The sample shall then be carefully inverted and the "base" trimmed, wrapped in aluminium foil and waxed before the basal annulus is filled with polyurethane. After hardening, the base of the wooden box shall be attached. The top and bottom of the sample shall be clearly marked on the box, as shall the direction of magnetic north relative to the in situ sample.

Recovery of cores 7.64 Total core recovery is defined as the length of core recovered expressed as a percentage of the length of the core run carried out. The total core recoveries given below are the minimum which shall normally be accepted for the categories of drilling defined in Clause 7.46:
<table>
<thead>
<tr>
<th>Ground Conditions</th>
<th>“A” (Air-foam flush)</th>
<th>“A” (Water flush)</th>
<th>“B” (Water/Air-foam flush)</th>
<th>“C” (Water/Air-foam flush)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock of Decomposition Grade I To III or Concrete</td>
<td>98</td>
<td>98</td>
<td>95</td>
<td>90</td>
</tr>
<tr>
<td>Rock of Mixed Decomposition Grade III and IV</td>
<td>90</td>
<td>85</td>
<td>85</td>
<td>70</td>
</tr>
<tr>
<td>Rock of Decomposition Grade IV</td>
<td>85</td>
<td>70</td>
<td>70</td>
<td>N/A</td>
</tr>
<tr>
<td>Common Ground</td>
<td>75</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Extrusion and handling of cores**

7.65

(1) All cores shall be removed from double tube core barrels using a hydraulic extruder, unless otherwise instructed by the Engineer. Under no circumstances shall air pressure be used for the extrusion of cores. The extruder shall apply a continuous pressure to one end of the core whilst the barrel is in a horizontal position. Only gentle hammering with a wooden mallet on the side of the core barrel to free wedged pieces shall be permitted.

(2) Cores from single and double tube core barrels shall be carefully extruded onto split plastic piping of similar diameter to the core such that the core fits tightly into the pipe and is not free to rotate. If instructed by the Engineer, or if the recovered core is heavily jointed or fragmented and is likely to be disturbed during transportation, it shall also be wrapped in self-clinging transparent film, or similar approved by the Engineer.

(3) Cores from split inner tube triple tube core barrels shall be wrapped in self-clinging transparent film and then aluminium foil and carefully transferred into split plastic piping of the same internal diameter as the split inner tubes.

(4) As core is extruded it shall be arranged in core boxes in a proper sequence starting with the shallowest core on the left side nearest the hinge and then working along the slat and subsequently outwards towards the hasp (i.e. from left to right with the box lid on the far side of the box as the core is placed). Slats shall be positioned and secured such that the core is restrained from movement.

(5) Fractured core shall be packed securely. At no time should any core be loose in the box. Core losses in individual core runs shall be shown by wooden blocks or polystyrene of square cross section to fill the core box, of a length equal to the core lost.
Until the boxes containing the cores are transported from the site they shall be neatly stored at the drillhole locations in such a manner that inspection of the cores can easily be made. The boxes shall be stored under cover and protected from the weather. All core boxes shall be carefully transported to avoid damage and disturbance to the contents.

Photographs of core boxes

Within 3 working days of the date of completion of the drillhole, the samples and/or cores contained within each core box shall be photographed. The core shall be evenly lit with no shadows, the core box and reference board in each photograph shall fill the frame, and the focal plane of the camera and the plane of the core box shall be parallel.

The photograph shall contain a reference board of minimum dimensions 350 mm (height) by 1000 mm (length). The reference board shall contain:

(a) the Ground Investigation title,

(b) the core box number,

(c) the depth below ground level at the start and finish of all material in the core box, and

(d) a reference scale over the entire board length marked in 100mm units.

All cores, except those susceptible to deterioration on contact with water, shall be thoroughly moistened before being photographed. Where coreboxes contain disturbed samples, the lids shall be removed from the containers so that the contents are visible in the photograph. The first disturbed sample in any photographed core box shall be identified by its unique sample number and depth so that subsequent disturbed samples in that box can also be identified.

One full set of colour prints of minimum size 85 mm x 125 mm shall be supplied with the preliminary records. Colour photocopies of A4 mounted prints of minimum size 200 mm x 250 mm shall be supplied in each copy of the Final Field Work Report. Within 3 weeks of award of the Contract, the name(s) of the proposed supplier of the colour photocopies and samples shall be supplied for the Engineer’s approval. If approved, the quality of the colour photocopies shall be maintained for the duration of the Contract.

Groundwater samples

Groundwater samples shall be taken from drillholes, trial pits or trial trenches, if instructed by the Engineer. Where water has been used for drilling, a volume of water at least equivalent to that of the drillhole volume shall be bailed out before sampling. Each sample taken shall not be less than 2 litres and shall be placed in a sterilized airtight bottle of sufficient capacity. Bottles shall be flushed out twice with the water to be sampled before use.
### Standard penetration tests 7.68

1. The apparatus and procedure for standard penetration tests shall comply with BS 1377:1990 (Part 9, Test 3.3), amended by this Clause as necessary. The drive hammer shall be a type incorporating an automatic trip mechanism to ensure free fall. The steel anvil of the drive assembly shall have a diameter of \(145 \pm 5\) mm. The guide rod arrangement that permits the hammer to drop with minimal resistance shall have an outer diameter of at least 3 mm smaller than the diameter of the central hole of the hammer.

2. A cone ended adaptor with a 30° half angle shall be available to replace the open-ended driving shoe for use in gravelly Common Ground, or if instructed by the Engineer.

3. If a liner sample is required in conjunction with the test, the split barrel sampler shall have an enlarged internal diameter to accommodate a thin stainless steel or aluminium liner of 35 mm internal diameter which shall fit tightly inside. The internal diameter of the liner may be up to 0.2 mm larger but in no case be smaller than that of the drive shoe. The liner shall have a smooth internal surface and may comprise two separate sections of equal length. The enlarged split barrel shall not be used without a liner in place. After the sampler has been withdrawn from the drillhole, the liner and the retained soil shall be treated in the same manner as an undisturbed sample.

4. Standard penetration tests shall be carried out below the level of the casing. The base of the drillhole shall be fully cleaned before the test starts. Jar samples shall be taken from the split-barrel shoe after each test.

5. The number of blows of the drive hammer required to achieve each 75 mm of shoe penetration until a total penetration of 450 mm has been achieved shall be recorded. The N-value shall be recorded as the sum of the number of blows of the drive hammer required to achieve the last 300 mm of shoe penetration.

6. If the full penetration of the seating drive is not achieved after 50 blows of the drive hammer, the number of blows and the penetration achieved (in millimetres) shall be recorded and the test continued with the test drive from that point.

7. If the full penetration of the test drive is not achieved after 100 blows of the drive hammer, the number of blows and the penetration achieved (in millimetres) shall be recorded and the test terminated unless otherwise directed by the Engineer.

8. The water level in the drillhole at the time of test shall be recorded and reported. When testing below the groundwater table particular care shall be taken to maintain the water level in the drillhole at or above the ambient groundwater level.
(9) If instructed by the Engineer, the Standard Penetration Test split spoon sampler shall be provided with a liner. After withdrawing the sampler from the hole, the liner containing the Common Ground sample shall be sealed in accordance with Clause 7.56.

(10) If liner samples have not been instructed, the sample recovered from the split spoon shall be immediately placed in a plastic container of minimum diameter of 100 mm, with a screw top. It shall then be arranged securely in the core box with the core, in proper sequence.

(11) Test results shall be submitted with daily site records and with both preliminary and final drillhole records. Test results shall be reported as shown in the table below:

<table>
<thead>
<tr>
<th>Seating Drive</th>
<th>Test Drive</th>
<th>Summary</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>17,25</td>
<td>25,27,22,23</td>
<td>N=97</td>
<td>Full penetration.</td>
</tr>
<tr>
<td>17,25</td>
<td>38,62/50 mm</td>
<td>100/125 mm</td>
<td>Test terminated in increment 4.</td>
</tr>
<tr>
<td>17,25</td>
<td>35,27,38/30 mm</td>
<td>100/180 mm</td>
<td>Test terminated in increment 5.</td>
</tr>
<tr>
<td>27,23/35 mm</td>
<td>25,27,22,23</td>
<td>N=97</td>
<td>Test drive commenced after completion of 50 blows in the seating drive.</td>
</tr>
<tr>
<td>50/20 mm</td>
<td>35,27,38/30 mm</td>
<td>100/180 mm</td>
<td>Test drive commenced after completion of 50 blows in the seating drive: test terminated in increment 3.</td>
</tr>
</tbody>
</table>

**Dynamic probe tests** 7.69

(1) Dynamic probe test equipment shall be generally as shown in Geoguide 2, Figure 36 and amplified below:

(a) The mass of the hammer shall be 10.0 kg ±0.1 kg. The ratio of the length to the diameter of the hammer shall be between 1 and 2. The hammer shall be provided with an axial hole with a diameter which is 2-3 mm larger than the diameter of the guide rod,

(b) the anvil shall be rigidly fixed to the extension rods. The mass of the anvil shall be between 1.5 kg and 1.8 kg and the diameter between 60 mm and 70 mm. The combined mass of the anvil, guide rod and upper anvil shall not exceed 5.0 kg,

(c) the hammer shall fall freely and not be connected to any object which may influence the acceleration or deceleration of the hammer. The hammer shall be stationary in its upper position prior to release. The fall shall be 300 mm ±5 mm,
(d) the diameter of the rods shall be between 11 mm and 13 mm and the length 1000 mm ±10 mm. The rods shall be straight and shall be connected so as to bear against each other over their full area by means of external couplers of maximum diameter 20 mm,

(c) the diameter of the point shall be 25 mm ±0.2 mm. The cylindrical portion of the point shall have a length of 25 mm ±1 mm. The point shall have a conical tip with an apex angle of 45° ±2°.

(2) The probing shall be carried out by the method described in Appendix 7.1

(3) If refusal is met at a depth of less than 3 m, then a second test shall be carried out at a distance of between 0.3 m and 0.6 m from the first test.

(4) All probe holes shall be sealed on completion with cement grout consisting of cement and water in the proportions 0.4:1 by mass, for at least the top 600 mm.

(5) For dynamic probing tests that are not related to trial pit or trial trench excavations, preliminary results shall be submitted within 6 working days of the date of completion of all dynamic probing testing instructed or as directed by the Engineer.

Vane shear tests 7.70

(1) Vane shear tests shall be carried out as specified in BS 1377:1990 (Part 9, Test No. 4.4), amended by this Clause.

(2) Vanes capable of measuring shear strengths up to approximately 75 kPa shall be available. The area ratio of each vane blade shall be less than 12%. The torque measuring instrument shall be calibrated by a method approved by the Engineer and a copy of the most recent certified calibration chart shall be submitted with each set of vane test results and be included in the Final Field Work Report.

(3) The vane shall be advanced to the test depth and the torque applicator assembly shall be carefully connected. After a pause of 5 minutes, the vane shall be rotated at a constant rate of between 0.1 and 0.2 degrees/second. Readings shall be taken at intervals of each 5° rotation. The maximum torque required to rotate the vane shall be recorded. The vane shall then be rotated rapidly through 12 revolutions without taking any readings. After a further pause of 5 minutes, the test procedure shall then be repeated in order to obtain the remoulded (disturbed) undrained shear strength.

(4) Preliminary results shall be submitted in a format agreed by the Engineer with the corresponding Investigation Station preliminary records. Final results of undrained shear strength, corrected using the torque head calibration curve, shall be submitted with the Final Field Work Report in a format agreed by the Engineer. For tests on Common Ground, the residual value of undrained shear strength shall be reported.
In situ density tests

7.71 (1) In situ density tests shall be carried out in accordance with Geospec 3, Test 11.1 or 11.2.

(2) Preliminary results shall be submitted using a HOKLAS approved worksheet along with the Preliminary Records of the trial pit or trial trench in which the test was performed. The Final Field Work Report shall contain the results presented on a HOKLAS endorsed test report.

Falling or rising head permeability test

7.72 (1) If instructed by the Engineer, a falling or rising head permeability tests shall be performed in a drillhole. The drillhole shall be flushed prior to carrying out the test. The installation shown in Geoguide 2, Figure 27, shall be used unless otherwise instructed by the Engineer. The graded filter material and sand shall be to the approval of the Engineer and shall be placed in the hole by tremie pipe. The groundwater level shall be allowed to equalise in the completed installation for at least one hour before the test commences.

(2) The method of flushing of the bottom of the hole for field permeability tests shall be as follows:

(a) Clean water shall be introduced to the cased hole through a 38 mm diameter pipe fed from a storage tank. The feed pipe shall contain a perforated section 480 mm in length consisting of 20 rings of holes at 25 mm centres, each containing 4 holes of 6 mm diameter. The end of the perforated section of pipe shall be capped. The complete perforated section shall be positioned such that it is just below the existing ground water level in the borehole.

(b) The flushing water shall be withdrawn from the casing through a 38 mm diameter pipe positioned with its open end between 150 mm and 200 mm above the base of the borehole. The discharge shall be by means of a pump of sufficient capacity to extract the flushing water from the base of the borehole. Control of the flow of clean water and discharge water shall be by means of valves positioned on the inflow pipe and the discharge pipe.

(3) For a falling head permeability test the water level in the piezometer shall be raised by adding clean water by a minimum of 3 m, or the maximum practical. The water level shall then be allowed to equalise with the groundwater level. Water levels in the piezometer shall be measured by means of a suitable dip meter at the following elapsed times in minutes from the start of the test:

0, 0.25, 0.5, 0.75, 1, 1.5, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 45, 60, 90, 120, 150, 180.

The test shall be terminated at 180 minutes, or earlier if:

(a) the water level has returned to its initial level, or

(b) a head ratio (the ratio of water head at any time during the test to the initial head at the commencement of test) of 0.3 is achieved, or
(c) instructed by the Engineer.

(4) For a rising head permeability test, the water level in the piezometer shall be lowered by pumping by a minimum of 3 m, or the maximum practical. The water level shall then be allowed to equalise with the groundwater level. Water levels in the piezometer shall be measured following the same procedure as for a falling head test.

(5) Both types of permeability test shall be repeated once to demonstrate that consistent results have been obtained. If the results differ by more than 20% then the test shall be repeated again.

(6) Preliminary results of a falling and rising head permeability test shall be submitted on a record sheet to the approval of the Engineer, together with the corresponding Investigation Station preliminary record.

**Response test**

7.73 (1) A response test shall be performed in any piezometer or standpipe within 3 working days of the completion of the installation, in order to prove its successful operation. The test shall be carried out as for a falling head permeability test except that it shall be terminated after 60 minutes or when the water level has returned to its initial level, whichever is sooner.

(2) Preliminary results shall be submitted on a record sheet, to the approval of the Engineer, with the corresponding Investigation Station preliminary record.

**Constant head permeability test**

7.74 (1) For a constant head permeability test in a drillhole, the procedure for flushing the hole, setting up the installation and allowing the ambient groundwater level to equalise, shall be the same as for a falling or rising head permeability test.

(2) Clean water shall be fed into the piezometer at a constant rate until a constant water level is established or until the water level is 0.3 m below the top of the piezometer tube. The constant rate of inflow to maintain a constant head shall be recorded. A flow meter capable of measuring flows down to 0.1 litre shall be used.

(3) Cumulative inflow readings shall be recorded, once the constant head has been achieved, in the following sequence:

(a) 4 readings at 15 second intervals,

(b) 9 readings at 1 minute intervals,

(c) 4 readings at 5 minute intervals, and

(d) readings at 10-minute intervals until the inflow values do not differ by more than 10% in any 10 minute interval.

(4) Preliminary results shall be submitted on a record sheet, to the approval of the Engineer, with the corresponding Investigation Station preliminary record.
Packer (water absorption) test 7.75

(1) If instructed by the Engineer single or double packer tests shall be carried out in vertical or inclined drillholes in TNW and T2-101 size. Testing shall follow the method described in Geoguide 2. The general arrangement of the tests shall be as shown in Geoguide 2, Figure 31.

(2) At the commencement of the Contract, and at other times if instructed by the Engineer, calibration of the equipment for friction head loss shall be carried out by connecting the pressure gauges, flow meter and supply pipe headworks, three or four different lengths of drill rod and the packer with its tailpipe to the water supply. Water shall be pumped through the system and flow rates recorded for several values of back pressure. A graphical relationship of flow against pressure loss for the number of drill rods used shall be established and submitted to the Engineer. It shall be included in the Final Field Work Report if packer tests are carried out.

(3) A single packer test shall be carried out by expanding a hydraulic or pneumatic packer in the drillhole (not in the casing) to create a seal at the top of the test section. All rods and couplings must be watertight and the threads of drilling rods supplying the water to the test section shall be wrapped with thread sealing tape. The length of test section required shall be instructed by the Engineer. The drillhole below the packer shall be filled with water and kept full at the specified water pressure for 15 minutes immediately before the test commences. The flow meter used shall be capable of measuring flow quantities to the nearest 0.1 litre. The water levels in the drillhole above the packer shall be monitored at regular intervals during the test, by means of a suitable dip meter, to check whether leakage is occurring around the packer.

(4) The acceptance of water by the test section shall then be measured and recorded at successive pressures as instructed by the Engineer, the maximum of which will not exceed 75% of the effective overburden pressure at the mid-depth of the test section. A calibrated pressure gauge capable of measuring the required pressure to the following accuracies shall be used:

   (a) 0 - 100 kPa Maximum Value (accurate to ± 5 kPa),
   (b) 0 - 200 kPa Maximum Value (accurate to ± 10 kPa),
   (c) 0 - 500 kPa Maximum Value (accurate to ± 20 kPa), and
   (d) 0 - 1000 kPa Maximum Value (accurate to ± 20 kPa).

(5) At each pressure, the flow of water into the drillhole shall be measured over three periods, each of 5 minutes duration. If the first two readings do not differ by more than 10%, the third reading is not required. A complete test shall comprise measurement of the flow through the full cycle of pressures and any calibration tests required by the Engineer.
(6) Packer tests using single or double packers may also be required after the drillhole has been completed. The double packer test shall be performed as for a single packer test, except that the water pressure shall be applied to a specified length of drillhole isolated between two packers.

(7) Preliminary results shall be submitted on record sheets with the corresponding Investigation Station preliminary records. The record sheet used shall be to the approval of the Engineer.

**Impression packer tests 7.76**

(1) If instructed by the Engineer, a drillhole impression packer survey shall be performed in a vertical or inclined drillhole in TNW or T2-101 size, in accordance with Geoguide 2, using equipment and methods to the approval of the Engineer. The equipment shall be capable of surveying a minimum 1.5 m length of drillhole for each test.

(2) The survey shall be carried out by inserting the impression packer device into the drillhole to the depths instructed by the Engineer, expanding the packers and obtaining an impression of the drillhole wall on the thermoplastic film surrounding the packers. The survey shall be referenced to a known direction by means of a downhole compass. Sufficient time shall be allowed for the compass to set following the expansion of the packer. Great care shall be taken when placing the thermoplastic film onto the packers and when transferring the north point from the compass to the film.

(3) If an impression packer survey is instructed over a continuous length of drillhole longer than the length of the impression packer itself, successive impression packer test sections shall overlap by a minimum of 250 mm to ensure continuity of information and cross-checking of the north direction between successive test sections.

**Inclination and bearing measurements 7.77**

(1) If instructed by the Engineer, the inclination and bearing of a drillhole shall be measured using a single-shot or multi-shot photographic survey tool or similar instrument approved by the Engineer.

(2) The results of each test shall be reported on the daily site records and the average inclination and bearing over the length of the drillhole shall be stated on both the preliminary and final drillhole records. The original film data shall be submitted with the daily site records.

**REPORTS FOR GROUND INVESTIGATION**

**General 7.78**

Unless otherwise stated, records and reports may be either a hard copy or soft copy, as instructed by the Engineer. A hard-copy shall be printed double sided on recycled paper. A soft copy shall be in read-only format. The records and reports shall be in a format to the approval of the Engineer.
**Site log book**  7.79 For each Investigation Station, a Site Log Book shall be maintained in a format to the approval of the Engineer. All visitors to an Investigation Station shall sign the Site Log Book on each visit. The Site Log Book shall also be used to record all verbal requests at that particular Investigation Station and shall be countersigned by the authorized personnel making the request before the work is carried out. The Site Log Book shall be copied to the Engineer within 3 working days of the date of completion of the field work for each Investigation Station.

**Daily site records**  7.80 During the progress of any field work, one copy of all daily site records relevant to a particular Investigation Station shall be submitted to the Engineer within 3 working days, with additional copies (up to a maximum of 3) if instructed.

**Preliminary records**  7.81 (1) One copy of Investigation Station preliminary records and additional copies (up to a maximum of 3), as instructed, shall be submitted to the Engineer. Preliminary drillhole records shall be submitted within 6 working days of the date of completion of the Investigation Station excluding backfilling and reinstatement. Preliminary records of trial pit, trial trench, or slope stripping shall be submitted within 6 working days of the date of completion of coring, excavation and field testing for the Investigation Station to which they refer.

(2) Preliminary records of all field testing shall be submitted within the times specified in the Contract and on the forms specified. Preliminary records shall show all the information required for the final records except the co-ordinates and levels of the Investigation Station, which shall be submitted within 6 working days of the completion of the last Investigation Station.

**Submission of Final Field Work Report**  7.82 (1) Unless otherwise instructed by the Engineer, four copies of the Final Field Work Report, dated and certified as checked and complete, shall be submitted for approval.

(2) The Final Field Work Report shall be typed and contain all the information obtained from the investigation. Each Final Field Work Report shall contain:

(a) a factual description, prepared by the Geotechnical Engineer, of the nature and methods of the particular Ground Investigation carried out

(b) if drillholes have been sunk, a summary table of the depths and thicknesses of all strata (including decomposed rock and rock) encountered at each drillhole location and the reduced level of each stratum boundary,

(c) a copy of the location plan amended as necessary to show the exact position of each completed Investigation Station,

(d) a table of the as-drilled co-ordinates,

(e) Investigation Station final records together with data in AGS digital format to the approval of the Engineer,

(f) colour photocopies of any photographs taken,
(g) a Contract Data Summary sheet in a format to the approval of the Engineer, on the second page of each copy

(3) One copy of the Final Field Work Report shall be marked "Master Copy" and shall contain negatives and one set of colour prints of any photographs taken.

**Submission of digital image of Final Field Work Report**

<table>
<thead>
<tr>
<th>7.83</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Unless otherwise instructed by the Engineer, five copies of a digital image of the Final Field Work Report shall be delivered to the Engineer. Each digital image shall be stored in a single file on a CD-ROM and placed in a plastic protective pocket. Four copies shall be attached to the hard copy of the Final Field Work Report at the time of delivery. The fifth copy shall be provided separately at the same time.</td>
</tr>
<tr>
<td>(2) Unless otherwise agreed by the Engineer, the digital image of the Final Field Work Report shall be in Acrobat format.</td>
</tr>
<tr>
<td>(3) The first page of the digital image shall be a scanned image of the first page of the Report signed by the person certifying it as complete and checked. The digital image shall contain the complete contents of the report, including all drawings.</td>
</tr>
<tr>
<td>(4) The resolution of all colour images shall not be less than 150 dots per inch (dpi) with colour depth of 24-bit true colour. The resolution of black and white images shall not be less than 200 dpi.</td>
</tr>
<tr>
<td>(5) Each compact disc submitted shall be securely and clearly labelled.</td>
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</table>
## PART 3: SLOPE TREATMENT WORKS

### MATERIALS

<table>
<thead>
<tr>
<th>Material</th>
<th>Page</th>
<th>Description</th>
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</thead>
</table>
| **Cement mortar**              | 7.84 | (1) Cement mortar for in-filling joints in rock faces, for bedding rock for masonry infilling and for surfacing slopes shall consist of Portland Cement (PC) and sand in the proportions 1:3 by volume.  
(2) PC shall comply with BS EN 197-1.  
(3) Sand shall be natural sand or crushed natural stone complying with BS 1200.  |
| **Rock for masonry infilling** | 7.85 | Rock for masonry infilling shall not exceed 300 mm in size and shall be obtained from a source approved by the Engineer.  |
| **Soil-cement**                | 7.86 | (1) Soil-cement shall consist of PC, sand and inorganic soil in the proportions 1:3:12 by mass unless otherwise stated. The mix proportion of soil-cement is 1:3:40 by mass when it is applied to the top layer (maximum 300 mm thick) or other areas as directed or agreed by the Engineer.  
(2) PC shall comply with BS EN 197-1.  
(3) Sand shall comply with BS 1200.  
(4) Inorganic soil shall be free of organic matter and shall contain not more than 30% of soil particles passing a 63 \( \mu \)m BS test sieve.  |
| **Aggregates for sprayed concrete** | 7.87 | The nominal maximum aggregate size of aggregates for sprayed concrete shall not exceed 10 mm.  |
| **Reinforcement for sprayed concrete** | 7.88 | Unless otherwise approved by the Engineer fabric reinforcement including A393 and A252 for sprayed concrete shall comply with to BS 4483 except that the 50 mm x 50 mm x 2.7 mm (wire diameter) hot-dip galvanized steel welded mesh shall have tensile strength not less than 275N/mm\(^2\).  |
| **Protective mesh and fixings** | 7.89 | (1) Protective mesh for slopes shall be PVC coated galvanized steel wire woven into a double twist hexagonal mesh. Each hexagon shall be 80 mm x 60 mm. The steel wire shall be at least 2.2 mm diameter and the PVC coating shall be at least 0.4 mm thick. PVC coating on steel wire shall comply with BS 4102:1990 or equivalent. The colour of PVC coating is to be approved by the Engineer. Wire for protective mesh shall comply with BS 1052: (1999). Galvanized coating on wires shall comply with BS EN 10244-2:2001. The tolerance on the opening of mesh shall comply with BS EN 10223-2:1998.  
(2) Tying wire for protective mesh shall be 2.2 mm diameter PVC coated galvanized soft annealed steel wire.  
(3) Bolts for fastening protective mesh to rock or structure shall be galvanized mild steel hooks as stated in the Contract.  
(4) Stainless steel anchor bolts and accessories for fastening protective mesh to soil nail heads shall be as stated in the Contract.  |
(5) Hooks, fixing pins, steel plates and washers for fixing the protective mesh to slope face shall be as shown on the Drawings and shall be galvanized to BS EN ISO 1461:1999.

(6) Galvanizing shall comply with BS EN ISO 1461:1999.

**Rock bolts**

Rock bolts shall be a proprietary type approved by the Engineer. Rock bolts shall comply with CS 2 and shall be mild steel or high yield deformed steel as stated in the Contract. Rock bolts shall be galvanized to BS EN ISO 1461:1999. Rock bolts shall have non-corrodible centralizers capable of ensuring an even annulus of grout as approved by the Engineer.

(2) The rated working load of rock bolts shall not exceed 50% of the ultimate tensile strength. A reduction of 4 mm in the diameter of the bolt shall be taken into account for corrosion when calculating the ultimate tensile strength.

(3) Nuts for rock bolts shall be of grade 4 steel and comply with BS 4190:2001. Connectors shall comply with Section 15 of this GS. Bearing plates shall be of grade 43A steel plate and comply with BS 4360. Holes in steel plates for rock bolt heads shall be drilled perpendicular to the face of the steel plate and the centre of the hole shall be at a position of within 2 mm from the centroid of the plate. The clearance between the steel bar and the hole of the steel plate shall not be more than 2 mm. All nuts, connectors and bearing plates shall be galvanized to BS EN ISO 1461:1999. Rock bolts shall have non-corrodible centralizers capable of ensuring an even annulus of grout as approved by the Engineer. Grease shall comply with Table 1 of Geospec 1.

**Grout for rock bolts**

Grout for rock bolts shall be as stated in Clauses 7.160 and 7.168 except that the water cement ratio shall not exceed 0.45.

**Rock dowels**

Rock dowels shall comply with CS 2 and shall be galvanized to BS EN ISO 1461:1999. Rock dowels shall have non-corrodible centralizers capable of ensuring an even annulus of grout around the steel bar as approved by the Engineer.

**Grout for rock dowels**

Grout for rock dowels shall be as stated in Clauses 7.160 and 7.168 except that the water cement ratio shall not exceed 0.45.

**Soil nails**

(1) Soil nail bars shall be of high yield deformed bars and comply with CS2. Nuts shall be of Grade 4 steel and comply with BS 4190: 2001. Connectors shall comply with Section 15. Bearing plates shall be of Grade 43A steel plate and comply with BS 4360: 1986. Permanent casings shall comply with BS4019: 1974. Holes in steel plates for soil nail heads shall be drilled perpendicularly to the face of the steel plate and the centre of the hole shall be at a position of within 2 mm from the centroid of the plate. The clearance between the steel bar and the hole of the steel plate shall not be more than 2 mm. All steel components for soil nails shall be galvanized to BS EN ISO 1461:1999.

(2) Soil nails shall have non-corrodible centralizers capable of ensuring an even annulus of grout around the steel bar. The nominal diameter of the centralizers shall not differ from the specified diameter of the drillhole by more than 10 mm. Wires and ties for fixing and anchoring packers, centralizers and grout pipes etc. shall be made of non-corrodible materials. The spacing of the centralizers and the suitability of the method of fixing...
the centralizers, grout pipes and corrugated sheathing where required shall be determined by carrying out trials on site until no damage, deformation and displacement of the centralizers, grout pipes and corrugated sheathing are observed on completion of assembling all components, during inserting and withdrawing the soil nails. Once approval is given, no change to the type, method and arrangement of fixing of the centralizers, grout pipe and corrugated sheathing shall be made without the prior approval of the Engineer.

(3) For soil nails using threaded type reinforcement connectors but without galvanized coating on either the threads inside the connectors or the threads at the ends of reinforcement bars, heat-shrinkable sleeve of a proprietary type as approved by the Engineer shall be used as an alternative to galvanization as a corrosion protection measure to the connections. Any rust on the threads of reinforcement bars and connectors shall be thoroughly cleaned before being connected together.

(4) Unless otherwise specified by the manufacturer and approved by the Engineer, the heat-shrinkable sleeve for reinforcement connectors shall be made of a layer of radiation cross-linked polyethylene and a layer of anti-corrosion mastic sealant material. The properties of polyethylene and mastic sealant materials shall comply with the following requirements:

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Unit</th>
<th>Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength at 23°C</td>
<td>ISO R527</td>
<td>MPa</td>
<td>≥ 17</td>
</tr>
<tr>
<td>(Cross head speed: 50mm/min.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultimate elongation at 23°C</td>
<td>ISO R527</td>
<td>%</td>
<td>≥ 350</td>
</tr>
<tr>
<td>(Cross head speed: 50mm/min.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact brittleness</td>
<td>ISO 974</td>
<td>°C</td>
<td>≤ -40</td>
</tr>
<tr>
<td>Water absorption at 23°C, 24 hrs.</td>
<td>ISO 62</td>
<td>% increase in weight</td>
<td>≤ 0.1</td>
</tr>
</tbody>
</table>

Properties of mastic sealant material

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Unit</th>
<th>Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion effect</td>
<td>ASTM D2671 (Procedure A)</td>
<td></td>
<td>No corrosion</td>
</tr>
<tr>
<td>Peel strength to steel at 23°C</td>
<td>DIN 30672</td>
<td>N/cm</td>
<td>≥ 4</td>
</tr>
<tr>
<td>(Cross head speed: 100mm/min.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shear strength at 23°C (Cross head speed: 50mm/min.)</td>
<td>ISO 4587</td>
<td>N/cm²</td>
<td>≥ 10</td>
</tr>
<tr>
<td>Softening point</td>
<td>ASTM E28</td>
<td>°C</td>
<td>≥ 70</td>
</tr>
</tbody>
</table>
### Soil nails with double-corrosion protection

(1) Materials for soil nails with double-corrosion protection shall comply with Clause 7.94 unless otherwise specified in the following sub-clauses.

(2) Corrugated sheathing for the double corrosion protection shall be a proprietary type approved by the Engineer and shall be made of high density thermoplastic materials which shall be homogeneous, thermally stable, chemically inert and resistant to chemical, bacterial and fungal attack. The wall thickness of the sheathing shall be at least 1.0 mm. Plastic sheathing and all associated components shall comply with the requirements as stipulated in Table 2 of the Model Specification for Prestressed Ground Anchors (GEOSPEC 1).

(3) Finished internal and external surfaces of the sheathing shall be smooth, clean and free of flaws, pin-holes, bubbles, cracks and other defects. Sheathing and all associated components shall be used in accordance with the manufacturer’s instructions.

(4) Sheathing and other plastic protective components shall:

   a. not contain any substances that will promote corrosion;
   b. be covered to prevent exposure to ultra-violet light from direct or indirect sunlight;
   c. be resistant to slip; and
   d. be capable of withstanding the applied handling stresses, the hydrostatic and grouting pressures.

(5) Centralizers shall be provided on the steel bar and the sheathing at suitable intervals to meet the following requirements:

   a. The steel bar shall be positioned in the sheathing so that a minimum grout cover to the bar of 10 mm is maintained; and
   b. There shall be minimum clearance of 15 mm between the sheathing and the sides of the drillholes or casing.

(6) Corrugated sheathing shall be embedded at least 50 mm into soil nail head.

### Grout for soil nails

Grout for soil nails shall be as stated in Clauses 7.160 and 7.168 except that the water cement ratio shall not exceed 0.45 and PFA shall not be used unless agreed by the Engineer.

### Non-biodegradable mats for erosion control

(1) Non-biodegradable mats for erosion control shall be woven and ultraviolet stabilized mats. The mats shall have the material properties stated in the Contract.

(2) The mats must be produced by proprietary manufacturers and specifically designed for the erosion control of sloping ground.

(3) The colour of the mats shall be black or dark green or other colour as directed or approved by the Engineer.
Biodegradable mats for erosion control 7.98  (1) Biodegradable mats for erosion control shall be woven coir mesh mats or woven jute mats. The mats shall have the material properties stated in the Contract.

(2) The mats must be produced by proprietary manufacturers and specifically designed for the erosion control of sloping ground.

Wire mesh for erosion control 7.99  Wire mesh for erosion control shall comply with Clause 7.89(1). Unless otherwise specified in the Drawings, the wire mesh shall be fixed onto the slope surface by means of anchor bolts and/or fixing pins. The fixing pins, steel plates and washers for fixing the wire mesh to slope face shall comply with Clause 7.89. Galvanized coating on wires shall comply with BS EN 10244-2:2001. The anchor bolts, nuts and washers for fixing the wire mesh to soil nail heads shall be stainless steel complying with Section 5. Details of the anchor bolts and fixing pins shall be submitted to the Engineer for approval. Anchor bolts and accessories shall have the following properties:

(a) The minimum size of the anchor bolts shall be M8.

(b) The components of the anchor bolts shall include:

(i) Hexagonal bolt or threaded rod with hexagonal nut.

(ii) Washer with minimum diameter of 20 mm.

(c) The length and diameter of the drillholes and the minimum size and embedment depth of the anchor bolts shall be as stated in the Contract or otherwise approved by the Engineer.

(d) The mean ultimate tensile resistance and mean ultimate shear resistance of the anchor bolts shall be 31 kN and 47 kN respectively in non-crack concrete with concrete strength at 30 N/mm².

SUBMISSIONS

Particulars of access 7.100  Particulars of the proposed means of access for slope treatment works, including access structures and reinstatement, shall be submitted to the Engineer for approval at least 14 days before the slope treatment works start.

Particulars of sprayed concrete 7.101  (1) The following particulars of the proposed materials and methods of construction shall be submitted to the Engineer:

(a) Type and performance of mixing and spraying plant,

(b) Details of water sprays and associated pumps for surface spraying,

(c) Method of curing,

(d) Details of trial panels and test panels,
(e) Methods of measuring surface temperature and moisture content of the soil,

(f) Methods of achieving the specified thickness of sprayed concrete and the specified cover to reinforcement and methods of measuring the thickness and cover after spraying

(g) Method of fixing reinforcement,

(h) Details of materials and mix design,

(i) Details of dry mix process and/or wet mix process for applying sprayed concrete,

(j) Name and details of the experience of the shotcretors,

(k) Details of working platform,

(l) Method of forming expansion joints, and

(m) Sequence of spraying on sloping surfaces.

(2) The particulars shall be submitted to the Engineer for approval at least 14 days before sprayed concrete is used.

**Particulars of rock bolts**

7.102 (1) The following particulars of the materials and methods of construction for rock bolts shall be submitted to the Engineer:

(a) Details of rock bolts, nuts, washers, bearing plates, connectors, sleeves, grease and centralizers,

(b) Methods of tensioning and grouting,

(c) Proposed working loads,

(d) Previous performance records, and

(e) Details of equipment for testing rock bolts, including test and calibration certificates

(f) Details of working platform and drilling equipment, including method of drilling and size of drillholes,

(g) Details of equipment for Packer tests in drillholes including test and calibration certificates,

(h) Grout mix details and grouting equipment.

(2) The particulars shall be submitted to the Engineer for approval at least 28 days before pull-out trials start. All equipment for testing rock bolts shall be tested and calibrated by approved laboratories within 6 months prior to the date of carrying out the tests.

**Samples of materials**

7.103 A sample of a complete rock bolt shall be submitted to the Engineer for approval of the source and type of rock bolt at the same time as particulars of rock bolts are submitted.
The following particulars of materials and methods of construction for soil nails shall be submitted to the Engineer:

(a) Details of and assembled component samples comprising of soil nail bars, coupling sleeves, nuts, washers, plates, connectors, centralizers, grout pipes, corrugated sheathing, packers for isolating the bond length and plugs capable of sealing the drillholes and withstanding the pressure head maintained on the grout during grouting,

(b) Details of galvanizer to be employed for galvanizing the steel components and method of making good any damaged galvanized coating,

(c) Details of heat-shrinkable sleeve for protecting the connections between reinforcement bars if galvanized coating to either the threads inside connectors or at the ends of reinforcement bars is not applied, together with details of the heat application equipment for shrinking the sleeves.

(d) Method of repairing damaged heat shrinkable sleeves during heat application or other installation process of soil nails,

(e) Details of corrosion protection for the threaded portion of the steel bar at soil nail head,

(f) Details of working platform,

(g) Details of temporary support to drillholes,

(h) Details of permanent casing,

(i) Method of storing materials,

(j) Method of drilling and details of drilling equipment,

(k) Method of assembling soil nail bars,

(l) Method of installing soil nail bars into drillholes,

(m) Method of grouting and details of grouting equipment,

(n) Details of equipment for measuring the volume of grout injected into each drillhole together with the accuracy and method of calibrating the equipment,

(o) Details of equipment for testing soil nails, including test and calibration certificates,

(p) Details of testing assembly including details of datum for deformation measurement and bearing pad, and

(q) Method of constructing soil nail heads.
The particulars shall be submitted to the Engineer for approval at least 28 days before pull out tests commence.

**Mats for erosion control** 7.105

The following particulars of materials and methods of construction for mats for erosion control shall be submitted to the Engineer for approval at least 14 days prior to installation:

(a) Details and samples of materials,

(b) Manufacturer’s literature including recommended sequence of mats installation and hydroseeding,

(c) Method of drilling holes, lapping, fixing and anchor,

(d) Method of placing and tamping of soft soil into the mats, if required,

(e) Details of equipment, and

(f) A certificate from the manufacturer on the compliance of the materials, as and where appropriate.

**Wire mesh for erosion control** 7.106

The following particulars of materials of wire mesh, anchor bolts and method of construction shall be submitted to the Engineer for approval at least 14 days prior to installation:

(a) Details and samples of wire mesh and anchor bolts,

(b) Method of drilling holes for the bolts and details of drilling equipment, and

(c) Certificates from the manufacturer showing that the wire mesh and anchor bolts comply with requirements as stated in the Contract.

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**PRELIMINARY WORKS**

**Access to slopes** 7.107

(1) Means of access consisting of scaffolding constructed of sound bamboo, metal or other materials agreed by the Engineer shall be installed to enable the Engineer to examine slope treatment works. The scaffolding shall allow access to within 0.8 m of the slope face. Hand and foot holds for climbing shall be provided by bamboo or metal members at centres not exceeding 0.5 m vertically and 0.8 m horizontally.

(2) A system of safety ropes shall be installed on the scaffolding. Safety ropes shall be 12 mm diameter and shall have a breaking force of at least 18 kN. The system of safety ropes shall consist of:

(a) Vertical ropes at not more than 3 m centres horizontally securely anchored to the crest of the slope, and

(b) Horizontal ropes at not more than 3 m centres vertically.
The system of safety ropes shall be constructed in such a manner that the ropes are tied at not more than 3 m spacings in both directions to form a net.

(3) The scaffolding shall be provided for the purpose of carrying out inspection to the slope by the Engineer and shall not be used for carrying out site operations without the permission of the Engineer.

(4) Where rock slope works are included in the Contract, sufficient time shall be allowed in the programme for the Engineer to inspect the rock slope, check the stability, design slope treatment works and determine the extent of the works required, taking into account of any specified time stated in the Contract that the Engineer may require for the inspection and design of slope treatment works.

Protection fences and barriers

7.108

(1) Protection fences and barriers for slope treatment works shall be constructed as stated in the Contract before slope treatment work starts.

(2) Damage to protection fences and barriers shall be repaired immediately. The permission of the Engineer shall be obtained before protection fences and barriers are dismantled.

Preparation for slope treatment works

7.109

(1) Vegetation shall be cleared and existing impermeable surfaces and topsoil shall be removed from existing soil slopes before slope treatment works start.

(2) Surface of slopes shall be trimmed and scarified before slope treatment works start. On completion of trimming and scarifying, any loose materials shall be removed from the surface of slopes by means of water jet coupled to compressed air for rock slopes or other hard surfaces and air jet for soil slopes unless otherwise directed by the Engineer.

(3) Rock faces and joints, and the surface and joints of retaining walls shall be cleaned of moss, vegetation and loose material, immediately before slope treatment works start, and surplus water shall be removed by an air jet. Water flowing from or across the rock face shall be diverted by relief drains or by other methods agreed by the Engineer before the application of impermeable surfaces.

(4) Any slope surface that has been stripped for inspection by the Engineer without any further slope work shall be reinstated to its original condition.

Scaling and trimming of rock slopes

7.110

ROCK SLOPE TREATMENT WORKS

Rock scaling shall only be carried out on areas as directed by the Engineer. Rock scaling shall include the removal of all loose blocks of any size using hand tools, or boulders not exceeding 0.2 m³ in volume using powered mechanical equipment. Scaling and trimming of rock slopes shall be carried out in such a manner that soil and rock is removed from the slope face without affecting the stability and integrity of the slope. Measures shall be taken to prevent uncontrolled falls of debris arising from scaling and trimming works. Scaling and trimming of rock slopes shall be carried out using hand-held tools. All material removed or excavated by scaling and trimming and loose fragments of soil and rock shall be
removed from the slope. Rock faces shall be cleaned using a water jet coupled to compressed air after scaling and trimming is complete.

**Rock splitting** 7.111

Rock splitting shall be carried out using percussive hammers, drills, hydraulic splitters, chemical expanding agents, hand-tools or other methods agreed by the Engineer.

**Removal of boulders** 7.112

Boulders that are to be removed from slopes shall be broken down by means of line drilling, expansive grouts, rock breakers or other methods agreed by the Engineer. For the purpose of this Clause, a boulder to be removed on rock slopes shall qualify as “boulder” only if it exceeds 0.2 m³ in volume before excavation and it cannot be removed without the use of powered mechanical equipment.

**Sealing and infilling of rock joints** 7.113

Joints in rock faces shall be sealed with Grade 20/20 concrete, cement mortar or masonry as stated in the Contract. Rock for masonry infilling shall be bedded in cement mortar. Relief drains instructed by the Engineer shall be installed before rock joints are sealed or infilled.

**Concrete buttresses** 7.114

1. Concrete for buttresses shall be Grade 20/20 unless otherwise stated in the Contract.

2. Drainage which is required behind buttresses shall consist of relief drains connected to 50 mm diameter uPVC outlet pipes laid at a gradient of at least 1 in 50. The uPVC pipes shall be securely fixed to the formwork before concreting starts.

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**SOIL-CEMENT FILL**

**Mixing soil-cement** 7.115

Soil-cement shall be thoroughly mixed in a concrete mixer. Small quantities of soil-cement shall not be hand mixed unless permitted by the Engineer. The method of mixing soil-cement shall be agreed by the Engineer.

**Deposition and compaction of soil-cement fill** 7.116

1. Soil-cement fill shall be deposited in its final position and compacted no more than 30 minutes after the cement has been added to the mix.

2. Soil-cement fill shall be compacted to specification as stated in Section 6 to obtain a relative compaction of at least 95% throughout. Soil-cement fill shall be at optimum moisture content during compaction. The tolerance on the optimum moisture content percentage shall be ±3.

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**SPRAYED CONCRETE**

**Trial panel** 7.117

A trial panel at least 50 mm thick and at least 3 m x 3 m shall be constructed for sprayed concrete on the surface to be treated. The average percentage rebound shall be estimated for each trial panel and shall be used in the calculations of the cement content of the applied concrete. Where required by the Engineer, trial panels shall be constructed for different types of spraying equipment or different shotcretors. Test panels to establish the suitability of sprayed concrete mix, spraying equipment and shotcretors shall be made and tested as stated in Clauses 7.143 to 7.147.
**Preparation of slope surfaces**

7.118  
(1) Weak material along joints or seams in slope surfaces to which sprayed concrete will be applied shall be removed to a depth equal to the width of the weak zone.

(2) If the soil surface temperature exceeds 25°C or the moisture content is less than 10%, the surface to be sprayed shall be watered using sprays unless otherwise instructed by the Engineer. Hoses without sprays shall not be used. Spraying of water onto the slope surface shall be carried out not more than 1 hour before spraying of concrete starts.

(3) Before sprayed concrete is applied, all tree trunks, railings, channels, utilities, pipes, structures, street furniture or other facilities adjacent to or within the sprayed concrete area shall be protected with approved means from being contaminated by sprayed concrete or rebound particles. All contaminated surfaces shall be cleaned and made good to the satisfaction of the Engineer.

**Fixing reinforcement**

7.119  
Fabric reinforcement for sprayed concrete shall be fixed securely to the slope by steel nails or rawl bolts and shall be laid without sharp bends or creases. The cover to the reinforcement shall be at least 20 mm and laps between adjacent sheets shall be at least 150 mm. The fabric reinforcement shall be placed centrally in the sprayed concrete and be supported clear of the ground and away from all surface irregularities with adequate number of cover blocks.

Weepholes and joints in sprayed concrete

7.120  
(1) 50 mm diameter weepholes shall be constructed:

(a) On soil surfaces at 1.5 m staggered centres in each direction, and

(b) On rock faces, on rock joints and at locations/spacings as directed by the Engineer.

(2) All weepholes shall extend through the full thickness of the sprayed concrete and shall be laid with an outward inclination of 1 in 10.

(3) On soil slopes, expansion joints shall be constructed in sprayed concrete in line with the expansion joints of the adjacent channels, berm slabs and concrete structures etc. or at 15m intervals maximum in case there is no channels, berm slabs or concrete structures.

(4) Construction joints in sprayed concrete shall comply with the requirements specified in Section 16.

**Equipment for spraying concrete**

7.121  
(1) Sprayed concrete shall be applied using the dry process in which water and admixtures shall be added at the nozzle. Alternatively, sprayed concrete shall be applied using the wet process in which wet ready-mixed concrete shall be supplied to the nozzle.

(2) Equipment for the dry-mix process shall be capable of projecting a mixture of cement, fine and coarse aggregate and water at high velocity on to the surface of the slope to produce a dense homogenous cover. The equipment shall be fitted with weight-batching facilities.

(3) Equipment for the wet-mix process shall be capable of projecting a mixture of wet ready-mixed concrete at high velocity on to the surface of the slope to produce a dense homogenous cover.
Only skilled operators experienced in the use of sprayed concrete and approved by the Engineer shall be employed as shotcretors.

**Spraying concrete** 7.122

1. The surface temperature and moisture content of the soil shall be measured, and the results submitted to the Engineer, immediately before sprayed concrete is applied.

2. For the dry-mix process, the aggregate and sand for sprayed concrete shall be kept dry before mixing. The water shall be added at the nozzle at the instant of application. The air and water supply, the rate of application and all other factors affecting the quality of the work shall be adjusted to produce dense concrete with no sloughing. For the wet-mix process, the ready-mixed concrete shall comply with Section 16 of GS unless otherwise approved by the Engineer. For both the dry-mix process and the wet-mix process, rebound material shall not be reused and shall be removed within 8 hours of spraying.

3. Sprayed concrete shall be applied in layers not exceeding 50 mm thick to the total thickness stated in the Contract. The maximum panel dimension shall not exceed 15 m².

4. Sprayed concrete shall be applied perpendicularly to the surface to be sprayed and the nozzle shall not be positioned farther than 1.5 metres from the surface during spraying.

5. Colour pigment approved by the Engineer shall be mixed thoroughly with the sprayed concrete mix. A layer of 25 mm thick of the coloured sprayed concrete shall be applied to form the total thickness of sprayed concrete stated in the Contract.

6. Details of the colour pigments (e.g. specification and colour samples etc.) and the method statement shall be submitted for the Engineer’s approval prior to application. The pigment shall comply with ASTM C979 and shall have the characterization of light fast, lime proof, weather resistance and durable like concrete. Colour to be employed shall be directed by the Engineer.

**Curing sprayed concrete** 7.123

Sprayed concrete shall be cured for at least 4 days after application by either Method 1, Method 2 or Method 3 as stated in Section 16.

**Inspection of sprayed concrete** 7.124

Completed areas of sprayed concrete shall be sounded using a wooden mallet. Cores of 75 mm diameter shall be taken from the completed sprayed concrete area at the rate of 1 no. per every 150 m² of sprayed surface or part thereof at locations determined by the Engineer, for checking the quality and thickness of the sprayed concrete as well as cover to reinforcement. Whenever any defect is found, further investigation shall be carried out to locate the extent of the defect. Areas which in the opinion of the Engineer are substandard or hollow shall be removed and re-sprayed. Core holes shall be reinstated with cement mortar of colour matching the adjacent surfaces.
Records of sprayed concrete

Records of sprayed concrete operations shall be kept by the Contractor on the Site and shall be submitted daily to the Engineer. The records shall contain details of the quantities of all materials used at each location. The records could be either a hard copy or soft copy as agreed by the Engineer. The hard-copy report shall use recycled papers. The soft copy shall be in read-only format and the hard copy shall be double side printed as agreed by the Engineer.

PROTECTIVE MESH FOR SLOPES

Fixing protective mesh for slopes

Unless otherwise stated in the Contract, protective mesh for slope shall be orientated, laced and suspended down and fixed onto the slope face with dowels or steel hooks at intervals not exceeding 3 m. The diameter of the drillholes for dowels or steel hooks shall be at least 20 mm larger than the diameter of the dowels or steel hooks. The method of drilling and cleaning of drillholes shall be as stated in Clause 7.128(1) and (2). The last column or row of dowels or steel hooks fixing the edges and base of the protective mesh shall be positioned not more than 300 mm from the respective edges/base of the mesh. Laps in mesh sheets in vertical direction shall be avoided as far as possible, however where necessary, the laps shall be at least 300 mm minimum wide and the lapping sheets shall be laced with 2.2mm nominal diameter galvanized and PVC-coated binding wire at the centre of the lap in the same way as adjacent vertical sheets.

ROCK BOLTS

Trials for rock bolts

The design bond length of rock bolts with bonded anchorages shall be determined for each rock type by a pull-out trial. The proof load of a pull-out trial shall be twice the working load. Pull-out trials shall be carried out on two bolts for each combination of rock bolt and rock type. Unless otherwise permitted by the Engineer the bolts used in trials shall be discarded and shall not form part of the permanent works, and the hole shall be sealed by grouting.

Drilling, preparing and testing rock bolt holes

(1) Holes for rock bolts shall be drilled at the locations instructed by the Engineer. The diameter of the hole shall be at least 20 mm larger than the diameter of the rock bolt or the outer diameter of the connectors, if used, whichever is larger. The method of drilling shall be rotary or rotary percussive with water flush or air flush accompanied by the operation of an effective dust extraction and filtering device. Holes shall be drilled to provide 50 mm cover to the end of bolts for which cement grout is used to form the bond length.

(2) Holes for rock bolt shall be flushed with clean water before rock bolt installation starts until the return water runs clear. Standing water shall be blown out from the hole using compressed air after flushing.

(3) Holes for rock bolts shall be tested by the Packer test as stated in Clauses 7.148, 7.149 and 7.150 and the results of the tests shall be submitted to the Engineer for approval, before installation of rock bolts starts.
Fixing rock bolts

7.129 (1) The permission of the Engineer shall be obtained before installation of rock bolts starts.

(2) Rock bolts shall be installed in accordance with the manufacturer's recommendations.

(3) Rock bolts shall be fully grouted after stressing. Heat-shrinkable plastic sleeves of an approved type shall be provided to the free length of rock bolts.

(4) Installation of rock bolts, including grouting of the free length and installation of head protection, shall be completed as soon as practicable and not more than 14 days after completion of the drillhole.

(5) Rock bolts with a grouted anchorage shall not be stressed until the grout crushing strength has attained a value of 21 MPa when tested in accordance with Clauses 7.180, 7.181 and 7.182.

Grouting rock bolts

7.130 (1) Grouting for rock bolts shall be in accordance with Section 7, Part 4, except as stated in the followings:-

(a) Grout shall be introduced at the lower end of drillholes with downward inclinations and shall displace all air and water through the top of the drillhole.

(b) Packers and return ducts which maintain a head on the grout until the grout has set shall be used for drillholes with upward inclinations or with inadequate downward inclinations. The packers and ducts shall be such that separate grouting of the anchorage zone and free-length zone of the drillhole can be carried out. The head to be maintained on the grout shall be as approved by the Engineer.

Proving rock bolts

7.131 Each installed rock bolt shall be proved as stated in Clauses 7.151 to 7.153. Rock bolts shall be locked off at 1.1 times the working load after proving. The complete bolt head assembly shall be encased by a concrete block after locking off.

Records of rock bolts

7.132 Records of installation of rock bolts shall be kept by the Contractor on the Site and a copy shall be submitted to the Engineer not more than 7 days after each installation operation. The records could be either a hard copy or soft copy to be determined by the Engineer. The hard-copy report shall use recycled papers. The soft copy shall be in read-only format and the hard copy shall be double side printed as agreed by the Engineer. Records shall contain the following:

(a) Rock bolt identification number,

(b) Drilling details, including:
   - Date and time drilling started and finished
   - Machine and operator identification
   - Location, level, inclination, bearing, length and diameter of drillhole
   - Rate of penetration at 0.5 m intervals,
(c) Water tightness of drillhole, including:
   - Date and time water test started and finished
   - Details of any pre-grouting and redrilling
   - Length of test zone
   - Water pressure applied
   - Duration of test
   - Measured water absorption rate,

(d) Details of steel bolts, including:
   - Type and diameter
   - Bond length
   - Overall length
   - Number and type of centralising spacers
   - Stressing record and lock-off load, and

(e) Details of grouting, including:
   - Date and time grouting started and finished
   - Details of any packers used and length of grouted zones
   - Head maintained on grout during setting
   - Volume of grout accepted
   - Identification marks of grout cubes.

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**ROCK DOWELS**

**Drilling and preparation of rock dowel holes**

7.133 The drilling and preparation of holes for rock dowels shall be as stated in Clause 7.128(1) and (2).

**Grouting rock dowels**

7.134 (1) Grouting for rock dowels shall be in accordance with Section 7, Part 4, except as stated in Clause 7.134 (2).

(2) Rock dowels shall be grouted over the complete length of the drillhole in which the dowel is installed. Centralisers as stated in the Contract shall be fitted to rock dowels before grouting to ensure an even annulus of grout. No jacking or hammering of the dowels shall be carried out during the whole process of insertion of dowels into drillholes. Grout shall be introduced at the lower end of drillholes with downward inclinations and shall displace all air and water through the top of the drillhole.

**Records of rock dowels**

7.135 Records of installation of rock dowels shall be kept by the Contractor and a copy shall be submitted to the Engineer not more than 7 days after each installation operation. The records could be either a hard copy or soft copy, as agreed by the Engineer. The hard-copy report shall use recycled papers. The soft copy shall be in read-only format and the hard copy shall be double side printed as agreed by the Engineer. The records shall contain details of the location, length, inclination and level of each rock dowel installed.
**SOIL NAILS**

### Drilling for Soil Nails

7.136

1. Drilling for soil nails shall comply with Clauses 7.164(4) and (5) and the following sub-clauses of this Clause. The set up of drilling plant and ancillary equipment shall be in such a manner that water, dust, fumes and noise generated during of drilling operation shall be sufficiently diverted, controlled, suppressed and muffled.

2. Drilling for soil nails shall be carried out using rotary or percussive type drills with air as the flushing medium unless otherwise agreed by the Engineer. Temporary support shall be provided to drillholes to prevent the collapse of drillholes until after the completion of grouting, including but not limited to the use of temporary casing. Drillholes shall be cleared of all debris and standing water immediately before installation of soil nails. All necessary equipment and assistance shall be provided to the Engineer to check the inclination, diameter, bearing, cleanliness and length of all drillholes.

3. Where instructed by the Engineer, drilling records including reference numbers of soil nails, date and time of drilling, penetration rate, description of strata of materials penetrated and any special observations during drilling such as underground voids encountered, collapse of hole, groundwater encountered, appropriate depth to ground water and depth of zone of no air return etc. shall be submitted to the Engineer not more than 2 working days after completion of drilling in a format agreed by the Engineer.

4. Where required in the Contract or ordered by the Engineer, permanent steel casing of appropriate internal diameter and of 6.3 mm minimum thick shall be installed and left in place with soil nails. Unless otherwise specified by the Engineer, the bottom 2 m length of drillhole shall be left unsupported by permanent casing.

5. The dimensions of soil nail heads and the orientation of soil nails shall be constructed in accordance with the Drawings or instructions given by the Engineer.

6. The permitted deviation of drillholes shall be ±2° to the specified vertical and horizontal alignments. The diameter of drillholes shall be the minimum diameter as specified. The grout cover to the lower end of steel bar shall be at least 50 mm.

7. No drilling shall be carried out within 10 metres radius of any freshly grouted soil nails, including soil nails for pull out tests, grouted less than 12 hours previously.

### Installation and Grouting for Soil Nails

7.137

1. Soil nails shall be installed and grouted as soon as possible after drilling. In any case, each drillhole shall not be left unsupported for more than 3 days. All drillholes shall be checked for cleanliness prior to installation of soil nails. For soil nail bars with threaded type connectors, each length of the steel bars shall be tightened by means of an appropriately sized wrench. During the whole process of installation, no jacking or hammering of the soil nail bars shall be carried out. Grouting for soil nails shall comply with Clauses 7.154 to 7.160, 7.162, 7.163, 7.166, 7.167(1) to 7.167(6), 7.168, 7.170, 7.172(1), 7.173 to 7.182 and the following sub-clauses of this Clause.
(2) The gross volume of the drillholes, discounting the volume of all cast in components of each of the soil nails to be grouted shall be calculated and recorded on the request forms for inspection of soil nail installation.

(3) The grout pipe shall terminate at a point within 150 mm above the lower end of the steel bar and no side cut hole shall be made on the grout pipe except that the cut is made within 150 mm above the lower end. Grout pipe shall be fixed onto the steel bar or corrugated sheathing (in case of double corrosion protection soil nails) by non-corrodible ties at spacings of not more than 2 m. Grout pipes shall not be removed from drillholes after insertion and the part protruding from drillholes after grouting shall be trimmed down to the base of soil nail head.

(4) Where heat-shrinkable sleeve is used, the heat-shrinkable sleeve shall be heat-shrunk by means of an apparatus approved by the Engineer, and it shall be used in accordance with the manufacturer’s instructions. The sleeve shall have sufficient length and shall be positioned such that a minimum 100 mm length of reinforcement bar beyond the connector is protected by the sleeve after completion of heat-shrinking. No lapping of the sleeve shall be allowed. The sleeve thickness shall not be less than 1.0 mm after heat-shrinking. Finished surface of the sleeve shall be smooth, free of trapped air pockets, flaws, holes, cracks, burn marks and other defects. Any defects or damages found on the sleeve shall be made good to the satisfaction of the Engineer.

(5) Soil nails shall be grouted on the day when the steel bars are inserted into drillholes. Soil nails which are not grouted after insertion and are left in drillhole overnight shall be withdrawn from the drillhole and the drillhole shall be checked for cleanliness and obstructions prior to re-insertion.

(6) After insertion of steel bar into the drillhole, the top end of the drillhole shall be sealed with an appropriate plug capable of withstanding a grout pressure head, which is maintained during the first hour after completion of grouting as described in sub-clause (8) of this Clause. An outlet pipe extending above the slope surface shall be installed through the plug to allow discharge of air, water and grout from the upper end of the drillhole during grouting. The arrangement of outlet pipe and sealing plug shall be submitted for the agreement of the Engineer and a site trial shall be carried to demonstrate that the set up performs satisfactorily.

(7) Soil nails shall be grouted over their entire length of steel bar in one single operation. Grout shall be injected into drillhole through the grout pipe to the lower end of drillhole such that air and water are displaced from the drillhole as grouting proceeds. When the consistency of the grout flowing out of the outlet pipe is the same as the injecting grout, the grouting operation shall stop and the inlet grout pipe sealed. A pressure head of at least 300mm of grout measured from the top of drillhole shall be maintained in the outlet pipe during the first hour after completion of grout. Any settlement of the grout level inside the outlet pipe observed shall be replenished with fresh grout immediately.

(8) The set up of grouting plant and ancillary equipment shall be in such a manner that water, spillage of grout, dust, fumes and noise generated during the grouting operation shall be sufficiently diverted, controlled, suppressed and muffled.
(9) The volume of grout used for grouting each drillhole and the volume used for refilling each drillhole after grout settlement shall be recorded. A copy of the records shall be submitted to the Engineer not more than 3 days after each grouting operation. The records shall include all details as required in Clause 7.172(1)(a) to 7.172(1)(f) and the following:

(a) volume of grout spilled from the drillhole,

(b) volume of grout added to the outlet pipe after grout settlement.

(10) Any excessive grout loss shall be reported to the Engineer immediately. If a drillhole cannot be fully filled with grout after injecting a volume of grout equal to 10 times the calculated gross volume of the drillhole, discounting the volume of all cast-in components, the grouting operation shall immediately cease for that drillhole unless otherwise agreed by the Engineer. The grouted length of the drillhole shall be reported to the Engineer and proposals for completing the grouting for that drillhole shall be submitted to the Engineer for approval as soon as possible.

(11) Unless otherwise agreed by the Engineer, for soil nails with double corrosion protection the annular space between the wall of drillhole and corrugated sheathing shall be grouted first in a continuous operation. The annular space between corrugated sheathing and steel bars shall be grouted immediately afterwards in a continuous operation.

Pull-out tests for soil nails

7.138 Soil nails for pull-out tests shall be installed and tested prior to the installation of permanent soil nails. The number of pull-out tests shall be as shown on the Drawings or as instructed by the Engineer. Soil nails subjected to pull-out tests shall not form part of the permanent works. The details of the testing arrangement including the set-up and support for the testing apparatus shall be submitted for the Engineer’s approval. The apparatus for measuring loads and deformations shall have an accuracy of 5 kN and 0.05 mm respectively. The apparatus for measuring deformation shall be capable of measuring a displacement of up to 50 mm. The apparatus shall be tested and calibrated by approved laboratories not more than 6 months prior to the date of carrying out the tests. Test and calibration certificates shall be submitted to the Engineer at least one week before the test. Drilling records of holes selected for pull-out tests shall be provided to the Engineer within 24 hours of drilling. The following procedure shall be adopted:

(a) The loading apparatus shall be set up in such a way that no loading, other than the pull-out load, acts on the steel bar at the nail head. The reaction of the pull-out load from the loading apparatus shall act on a sufficiently sized rigid bearing plate placed against a temporary cut face at normal to the alignment of the steel bar to ensure adequate load spreading and to avoid eccentric loading. Monitoring instruments shall be carefully positioned and independently supported to record the extension of the soil nail steel bar and any movement of the steel bearing plate.

(b) The soil nail shall be grouted over the length as specified in the Drawings or as directed by the Engineer. The length to be grouted shall be isolated by means of a packer that can prevent grout from leaking through to the free-length
section during grouting and that can ensure that the proposed bonded section is effectively grouted to the required length as shown in the Drawings. The entire free length of the steel bar shall be properly debonded or capped to ensure that the test load can be directly transferred to the bonded zone in case of grout leak through the packer. The pull-out test shall not be carried out until the grout has reached a cube strength of 21 MPa.

(c) The maximum test load shall be either 90% of the yield load of the steel bar of the test nail \( (T_p) \) or the ultimate soil/grout bond load \( (T_{ult}) \).

(d) The test nail shall be loaded in stages: from the initial load \( (T_a) \) via two intermediate test loads \( (T_{DL1} \text{ and } T_{DL2}) \) to the maximum test load. \( T_{DL1} \text{ and } T_{DL2} \) are the loads that result in the bonded zone tested to the design working bond strength and 2 times the working bond strength respectively. \( T_a \) shall not be greater than \( T_{DL1} \) or 5% of \( T_p \). All loadings including \( T_a, T_{DL1}, T_{DL2} \text{ and } T_p \) shall be specified in the Drawings or as directed by the Engineer.

(e) During the first two loading cycles, the intermediate loads, \( T_{DL1} \text{ and } T_{DL2} \) shall be maintained for 60 minutes for deformation measurement. After the measurement has been completed, the load shall be reduced to \( T_a \) and the residual deformation shall be recorded. In the last cycle, the test load shall be increased gradually from \( T_a \) straight to maximum test load and then maintained for deformation measurement. The measurement at each of the cycles shall be taken at time intervals of 1, 3, 6, 10, 20, 30, 40, 50 and 60 minutes. The test nail is considered to be able to sustain the test load if the difference of nail movements at 6 and 60 minutes does not exceed 2mm or 0.1% of the grouted length of the test nail. In this case, the test shall proceed to the next loading cycle or be terminated if the test nail is subject to \( T_p \).

(f) If the nail fails to sustain the test load \( T_{DL1}, T_{DL2} \text{ or } T_p \), the test shall be terminated and the nail movement against residual load with time shall be recorded. The measurements shall be taken at time intervals of 1, 3, 6, 10 and every 10 minutes thereafter over a period for at least two hours. Where required the measurements shall be continued and at intervals as directed by the Engineer.

(g) Throughout the test, the soil nail movement versus the applied load shall be measured, plotted on a graph and recorded along with all other relevant information. All the results shall be submitted to the Engineer within 3 days of completion of the test.

(h) Where required, the whole soil nail shall be pulled out from the drillhole for the Engineer’s inspection. Where the steel bar remains in-situ after the pull-out test, the bar shall be cut-off flush with the finished ground and the remaining part of the drillhole grouted.
Soil-nail head

(1) Soil-nail heads shall be constructed in accordance with the details as specified in the Contract. A method statement for the construction of soil nail heads shall be submitted for the Engineer’s agreement.

(2) The threads at the top end of soil nail bars shall be thoroughly cleaned, properly treated with galvanized coating or protected with approved zinc-rich paint prior to construction of soil nail heads.

(3) Steel reinforcement for soil nail heads shall be of grade 460 steel and comply with CS2 requirements. Concrete for soil nail heads shall be Grade 30/20 concrete or 30 MPa sprayed concrete and comply with GS Section 16 requirements.

(4) Concreting of soil-nail heads shall be carried out in a manner which ensures that the placed concrete is adequately compacted. Unless agreed otherwise by the Engineer, concreting of soil-nail heads using sprayed concrete shall be applied in two stages, allowing the bearing plate to be positioned firmly against the first stage concrete. The method statement as referred to in sub-clause (1) of this Clause shall include proposal for the construction sequence of 2-stage sprayed concrete soil nail heads. Trial runs shall also be conducted to demonstrate to the Engineer that the proposed method statement will produce satisfactory results and the rebound of sprayed concrete material is minimal.

(5) Any temporary excavation for constructing soil nail heads, including overbreaks shall be backfilled with Grade 30/20 concrete, 30 MPa sprayed concrete or other material as agreed by the Engineer.

(6) Where instructed by the Engineer, a maximum of 3 concreted soil-nail heads shall be uncovered from the batch of soil nail heads cast on any one day at any site for examination of the quality of soil-nail heads. If defective workmanship is identified in any one of the uncovered soil-nail heads, the whole batch of soil nail heads cast on the same day at that site shall be deemed to be defective. All the remaining soil nail heads cast on the same day at that site shall be broken up for the Engineer’s examination. The soil-nail heads shall be recast and re-examined to the satisfaction of the Engineer.

Preparation of surfaces

Areas to be applied with mats shall be cleared of all rubbish, debris and loose soils. All local irregular spots and areas shall be either trimmed or filled with compacted fill material or compacted soil cement to provide smooth surfaces unless otherwise specified by the Engineer. The finished slope surfaces shall be inspected by the Engineer prior to installation of mats.

Laying and fixing of mats for erosion control

Mats for erosion control shall be laid and fixed onto sloping ground in accordance with the manufacturers recommended procedures and in compliance with the following requirements:
(a) the mats shall be anchored along the slope crest and each berm level with at least 200 mm length embedded into the ground or underneath the concrete berm slabs. The mats shall also be embedded at least 200 mm into any adjacent structures to be constructed. The mats shall be rolled out from top down the slope surfaces. Sufficient hot-dip galvanized anchorage pins at a maximum spacing of 1 m centre to centre shall be provided to ensure the mats are in complete and total contact with the ground at every place. In areas of irregularities due to exposed rocks or existing structures, additional anchorage pins shall be provided to prevent any gap or void forming underneath the mats. Lapping between mats shall be at least 150 mm and shall be formed with the upslope mat over the downslope mat. No lapping shall be formed within 1 m of any intersection of two slope surfaces which have a sharp difference in slope gradient or strike direction.

(b) where recommended by the manufacturer of the mats for erosion control, on completion of laying and anchoring of the mats, soft soil shall be placed and tamped into the mats and all voids within the mats shall be completely filled to form an integral composite structure,

(c) the sequence of hydroseeding and laying of mats shall be in accordance with the manufacturer’s recommended sequence. The protective materials for hydroseeding shall be laid on top of the erosion control mat, if specified.

**TESTING: OPTIMUM MOISTURE CONTENT AND MAXIMUM DRY DENSITY OF SOIL-CEMENT FILL**

The maximum dry density and optimum moisture content of soil-cement fill shall be as stated in Section 6 except that the method of testing shall be the Vibrating Hammer Test Method in accordance with BS 1924.

**TESTING: CONCRETE CORES FROM SPRAYED CONCRETE**

(1) The strength of sprayed concrete shall be determined from concrete cores cut from a test panel constructed at the same time as sprayed concrete is applied.

(2) One test panel shall be constructed for each application in a day or as directed by the Engineer.

(3) The test panel shall be 250 mm thick and shall be at least 1 m x 1 m. The panel shall be constructed by spraying concrete into the mould at the same time as the concrete to be tested is applied. The test panel shall be cured by the same method as the sprayed concrete.
**Samples: concrete cores from sprayed concrete**

7.144

(1) Three concrete cores shall be provided from each test panel. Cores shall not be taken within 125 mm from the edges of the panel.

(2) Concrete cores shall be 100 mm diameter and shall be the full depth of the test panel.

(3) The method of taking concrete cores shall be in accordance with CS1.

**Testing: concrete cores from sprayed concrete**

7.145

(1) Each concrete core shall be tested to determine the compressive strength and density.

(2) The method of preparing and testing the cores to determine the compressive strength shall be in accordance with CS1. The method of testing the cores to determine the density shall be in accordance with CS1. Three concrete cores shall be tested at 28 days.

**Compliance criteria: concrete cores from sprayed concrete**

7.146

The results of tests for compressive strength of concrete cores shall be interpreted in accordance with BS 6089. Adjustments to the measured strength in respect of the age of the core when tested shall not be made unless permitted by the Engineer. The minimum compressive strength of concrete cores, converted to the estimated in-situ cube strength in accordance with BS 6089, shall be the specified grade strength at 28 days.

**Non-compliance: concrete cores from sprayed concrete**

7.147

If the result of any test for compressive strength or density of concrete cores from sprayed concrete does not comply with the specified requirements for the property, particulars of proposed changes to the materials, mix design, methods of production or methods of construction shall be submitted to the Engineer. Further trial mixes shall be made and further trial panels shall be constructed unless otherwise permitted by the Engineer.

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**TESTING: Packer tests on drillholes for rock bolts**

**Testing: Packer test**

7.148

(1) The water loss from drillholes for rock bolts shall be determined by the Packer test. The number of drillholes to be tested shall be instructed by the Engineer.

(2) The Packer test shall be carried out on the bond length of the drillhole at a test pressure of 100 kPa. The method of testing shall be as stated in Clause 7.183.

**Compliance criteria: Packer test**

7.149

The water loss determined by the Packer test in the grouted hole shall not exceed 5 Lugeons when measured over a 10 minute period.

**Non-compliance: Packer test**

7.150

If the result of any Packer test on drillholes for rock bolts does not comply with the specified requirements for the test, the drillhole shall be grouted, re-drilled and retested. Grouting, re-drilling and retesting shall be continued until the result of the Packer test complies with the specified requirements for the test.
## TESTING: ROCK BOLTS

<table>
<thead>
<tr>
<th><strong>Testing: rock bolts</strong></th>
<th>7.151</th>
<th>Each installed rock bolt shall be tested to determine the loss in stress by applying a test load of 1.5 times the working load for 5 minutes.</th>
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<tbody>
<tr>
<td><strong>Compliance criteria: rock bolts</strong></td>
<td>7.152</td>
<td>The loss in stress in installed rock bolts shall not exceed 5% of the test load in 5 minutes.</td>
</tr>
</tbody>
</table>
| **Non-compliance: rock bolts** | 7.153 | (1) If the result of any test for loss in stress of installed rock bolts does not comply with the specified requirements for the test, an additional test for loss of stress shall be carried out on the rock bolt.  
(2) If the result of any additional test for loss of stress of installed rock bolts does not comply with the specified requirements for the test, the rock bolt shall be replaced. |
PART 4: GROUTING FOR GEOTECHNICAL WORKS

GLOSSARY OF TERMS

**Ground** 7.154 Ground, for the purpose of grouting for geotechnical works, is fill material, soil and rock and the interfaces between fill material, soil and rock and any structures.

**Grout** 7.155 Grout, for the purpose of grouting for geotechnical works, is cement grout, cement-sand grout, cement-bentonite grout and proprietary grout approved by the Engineer.

**Grouting** 7.156 Grouting, for the purpose of grouting for geotechnical works, is the mixing and injection of grout through predrilled or preformed holes.

**Grouting stage** 7.157 Grouting stage, for the purpose of grouting for geotechnical works, is the discrete length of drillhole into which grout is to be injected in a continuous operation.

**Lugeon** 7.158 Lugeon is a water loss of 1 litre per minute per metre length of hole tested at an effective pressure of 1 MPa.

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MATERIALS

**Materials for grout** 7.159 Materials for grout shall comply with Section 16 except as stated in this Section.

**Grout for geotechnical works** 7.160 (1) Cement grout for geotechnical works consists of PC, PFA, sand and water. Admixtures shall not be used unless permitted by the Engineer. The use of PFA in cement grout shall follow the same requirements of PFA in concrete as specified in Section 16.

(2) Sand for grout shall be clean dry sand complying with BS 1200 and shall have a particle size distribution such that 100% passes a 2 mm BS test sieve and not more than 30% passes a 0.2 mm BS test sieve.

(3) Water for grout shall be clean fresh water having a temperature not exceeding 30°C or less than 5°C.

(4) Cement grout shall have a minimum crushing strength of 30 MPa at 28 days.

(5) The amount of bleeding of grout shall not exceed 0.5% by volume 3 hours after mixing or 1.0% maximum when measured at 23±1.7°C in a covered glass or metal cylinder of 100 mm internal diameter and with a grout depth of approximately 100mm. In addition, the water shall be reabsorbed by the grout within 24 hours.

(6) The flow cone efflux time of grout shall not be less than 15 seconds.
Standpipes

7.161 Unless otherwise approved by the Engineer standpipes for grouting shall be standard black metal pipe complying with BS 1387. With the permission of the Engineer, non-metallic grout pipe may be used for grouting rock dowels, rock bolts and soil nails. Where metal standpipes are used for grouting rock dowels, rock bolts and soil nails, they shall be extracted from drillholes as grouting proceeds.

Particulars of grouting for geotechnical works

7.162 (1) The following particulars of the proposed materials and methods of construction for grouting for geotechnical works shall be submitted to the Engineer:

(a) Details of drilling, grouting and testing equipment,

(b) Details of grout mix, including admixtures,

(c) Methods of storing, mixing and injecting grout,

(d) Methods of drilling, cleaning, capping and sealing grout holes,

(e) Methods of grouting, including grouting stages, order of working and regrouting methods,

(f) Methods of controlling surface water, groundwater, grout leakage and ground movement, including methods of containing overflowing grout, grout spill, monitoring and instrumentation, and

(g) Safety and hazard risk control measures, including bursting of high pressure grout pipes.

(2) The particulars shall be submitted to the Engineer for approval at least 28 days before grouting starts.

Trials for grouting

7.163 Unless otherwise permitted by the Engineer a grouting trial shall be carried out. The extent and depth of holes for grouting trials and the tests to be carried out shall be as stated in the Contract.

DRILLING FOR GROUTING FOR GEOTECHNICAL WORKS

Drilling for grouting for geotechnical works

7.164 (1) Holes in rock for grouting for geotechnical works shall be drilled using rotary or percussion type drills. The tolerance for the holes shall be as stated in Clause 7.45(1) and (2) except that for drillholes of soil nails shall be as stated in Clause 7.136(6). Grease and other lubricants shall not be used in the flushing medium or on the rods, except around the threads at the ends of the rods. Drilling methods that result in drill cuttings causing blockages such that grouting cannot be performed satisfactorily shall not be used.

(2) The set-up of drilling plant and ancillary equipment shall be in such a manner that water, dust, fumes and noise generated in the course of drilling and grouting operation shall be sufficiently diverted, controlled, suppressed and muffled. The flushing medium for drilling shall be clean water or air as agreed by the Engineer.
(3) The minimum size of hole for grouting in rock shall be 40 mm.

(4) Holes in soil for grouting for geotechnical works shall be drilled by a method which is suitable to the ground conditions and which is approved by the Engineer.

(5) The location of all underground obstructions and utilities shall be determined by the Contractor before drilling starts and the drilling pattern shall take account of the location of obstructions and utilities.

(6) Casings required to prevent the collapse of grout holes shall be as stated in Clause 7.44. Casings shall be removed immediately before or simultaneously with the grouting or sleeve grouting operation in such a manner that the grout hole will not collapse and the injection of grout will not be hindered.

(7) Grout holes shall be flushed clean with water or compressed air introduced at the bottom of the hole after drilling is complete. The holes shall be protected with capping pipes or standpipes to prevent subsequent collapse or clogging after flushing.

(8) Grout holes that have been drilled more than one day before grouting of the hole starts shall be reflushed with water or compressed air immediately before grouting is commenced and excess flushing water shall be removed by air jet. Holes drilled in soft ground or in ground other than rock and in which sleeve grouts are proposed as part of the grouting operation shall be sleeve grouted as soon as practicable after drilling.

Standpipes and capping pipes 7.165

(1) Unless otherwise permitted by the Engineer, grout holes shall be capped after drilling and before grouting. Capping shall be by a suitably sealed grout connection, standpipe, packer or other methods agreed by the Engineer. The cap shall seal the hole to prevent contamination or clogging of the hole until grouting operations start.

(2) Standpipes, if stated in the Contract, shall be installed in holes after drilling. The pipe shall be sealed into the hole using cement grout consisting of PC and water in the proportions 1:1 by volume.

GROUTING FOR GEOTECHNICAL WORKS

Monitoring of grouting operations 7.166

(1) Instrumentation shall be installed to monitor heave, bulging, settlement, lateral movement, deformation or fracturing of the ground or structures due to grouting operations. Records of monitoring shall be kept by the Contractor on the Site and a copy provided for the Engineer. Arrangements for installing instruments and taking measurements inside and outside the Site shall be made by the Contractor.

(2) The accuracy of the instruments shall be checked before grouting starts and at regular intervals agreed by the Engineer.

Grouting equipment 7.167

(1) Grouting equipment for geotechnical works shall be a type, quantity and size suitable for the grouting required. The equipment shall be kept clean and in good working order.
(2) Standby grouting equipment shall be available at all times and shall be capable of being brought into operation immediately in the event of breakdowns during grouting operations.

(3) Grout mixers shall be high-speed colloidal mixers having a rotor speed of at least 1000 r/min and capable of producing a colloidal grout mix. Mixers shall be fitted with a water volume-measuring device for batching purposes.

(4) Holding tanks shall be fitted with an agitator to provide continuous agitation of the grout at 100 r/min. The tank shall be fitted with a dipstick to allow continuous measurement of the volume of grout in the tank. A 2.36mm removable screen shall be provided between the tank and the pump or grout lines.

(5) Grout pumps shall be a positive displacement type. Pumps shall be fitted with bypass valves to allow a standby pump to be brought into operation.

(6) Working pressure gauges shall be accurate to within 3% and shall be calibrated against a test gauge before grouting starts and at weekly intervals. A test gauge with accompanying calibration certificates shall be kept on the Site for the purpose of calibrating working gauges. Working gauges shall be numbered and a record shall be kept of gauge number, shifts worked, calibration dates and repairs undertaken. Records shall be kept on the Site and shall be available for inspection by the Engineer at all times.

(7) Packers shall be such that they seal holes in rock at the specified level and shall be capable of withstanding the maximum grout or water pressure to be used at that level without leakage. Packers may be of the mechanical or inflatable rubber type. A sufficient number of packers of a size to suit the holes shall be available on the Site.

**Mixing grout 7.168**

(1) Grout for geotechnical works shall be mixed by volume or batched by weight as agreed by the Engineer. The mix proportions may be adjusted if approved by the Engineer depending on the results of the trial grouting, water tests in the hole or the results of previously grouted holes.

(2) Grout shall be mixed by adding approximately two-thirds of the cement to the water adding any admixture and adding the remaining one-third of cement. Other mixing procedures shall not be used unless permitted by the Engineer.

(3) The time for which grout shall be mixed in high speed mixers shall be suitable for the type of mixer used. Grout shall be continuously agitated in a holding tank after mixing and shall be screened before being circulated in the grout lines. Mixed grout shall be continuously circulated in such a manner that grout which is not taken in a hole can be returned to the holding tank.

(4) Grout to which a retarding agent has not been added, and which is not used within 30 minutes of mixing, shall not be used for grouting.

**Pressure grouting 7.169**

(1) Holes in rock shall be grouted in grouting stages not exceeding 3 m. Grouting may be carried out in either an upstage or a downstage sequence.
(2) Ground other than rock shall be grouted in such a manner that grout can be injected at various points along the grout hole in a multi-stage operation. The grouting method shall employ perforated pipes with rubber sleeve valves unless otherwise permitted by the Engineer.

(3) Grouting pressures shall initially be 100 kPa per 4-metre depth of hole and shall not exceed the overburden pressure unless permitted by the Engineer.

(4) Holes shall be grouted in a continuous operation at the grouting stages and pressures stated in the Contract. Unless otherwise permitted by the Engineer grouting shall be carried out by injecting the grout under pressure into each grouting stage of the hole until the grouting stage refuses to take further grout.

(5) If in the opinion of the Engineer grouting of any hole or grouting stage has not been completed due to excessive grout takes, low pressures, excessive leakage or other causes, the hole shall be redrilled or flushed out with water and re-injected with grout.

Loss or leakage of grout

7.170 (1) If during the grouting of any hole, grout is found to flow from adjacent grout holes in quantities, which in the opinion of the Engineer are sufficient to interfere seriously with the grouting operation or to cause appreciable loss of grout, the holes shall be temporarily capped. If in the opinion of the Engineer capping is not essential, ungrouted holes shall be left open to allow air and water to escape.

(2) If during the grouting of any hole grout is found to flow from joints in the geological formation at the Site or any other location, the leaks shall be plugged or caulked in a manner agreed by the Engineer.

(3) If during the grouting of any hole the grout-take increases suddenly by a significant amount, the Engineer shall be informed immediately.

Making good holes

7.171 (1) Grout holes through concrete shall be made good using concrete agreed by the Engineer. The concrete shall be firmly compacted and shall be finished to match the adjacent surface.

(2) Uncapped holes in rock shall be topped up after grouting using cement grout consisting of PC and water in the proportions 1:1 by volume, or 1:3 cement sand mortar.

Records of grouting for geotechnical works

7.172 (1) Records of grouting for geotechnical works shall be kept by the Contractor on the Site and shall be available for inspection by the Engineer at all times. Records shall include the following details:

(a) Hole location and reference number,

(b) Depth of hole,

(c) Type of grout and grout mix proportions,

(d) Volume of grout injected,

(e) Grouting pressures, and

(f) Times and details of any interruptions, leakages and equipment malfunctions.
A record of grouting for each hole shall be submitted to the Engineer within 24 hours of completion of grouting of the hole. The record shall contain the following details:

(a) Hole location and reference number,
(b) Grouting stage numbers and lengths,
(c) Collar level and hole inclination,
(d) Details of grout injections including the information stated in Clause 7.172(1), and
(e) Details of the grouting procedure, including any stoppages, leaks to other holes, surface leaks and ground movement.

A record of the testing for each hole, including test results, shall be submitted to the Engineer within 24 hours of completion of testing of a hole. Records of Packer tests shall contain the following details:

(a) Hole location and reference number,
(b) Depth of packer in the hole,
(c) Date and time of test,
(d) Type of gauge or meter and identifying reference number,
(e) Test readings for each 5 minute period,
(f) Calculated test results in Lugeons, and
(g) Details of any equipment malfunctions, sudden water losses or blockages, surface leakage or other variations in test procedure.

A report of grouting for each part of the Works as stated in the Contract, including record drawings and logs of holes, shall be submitted to the Engineer within one week of completion and testing of grouting for that part of the Works. The form of records, logs and record drawings shall be as agreed by the Engineer.

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**TESTING: GROUT - GENERAL REQUIREMENTS**

**Batch:** grout for geotechnical works

A batch of grout for geotechnical works is any quantity of grout used for grouting geotechnical works in one continuous operation in one day.

**Samples:** bleeding of grout

(1) One sample of grout shall be provided from each batch of grout for geotechnical works to determine the amount of bleeding of the grout.
(2) Samples shall be provided not more than 30 minutes after the grout has been mixed and shall be protected from moisture content changes before the tests for amount of bleeding are carried out.

Testing: bleeding of grout 7.175

(1) Each sample of grout taken as stated in Clause 7.174 shall be divided into three specimens. Each specimen shall be tested to determine the amount of bleeding.

(2) Grout for geotechnical works shall be tested for bleeding in accordance with ASTM C940-98a. Bleeding tests shall be completed immediately prior to each application in a day or as directed by the Engineer.

Non-compliance: bleeding of grout 7.176

If the result of any test for amount of bleeding of grout for geotechnical works does not comply with the specified requirements for amount of bleeding, particulars of proposed changes to the materials, grout mix or methods of production shall be submitted to the Engineer. Further grouting trials shall be carried out unless otherwise permitted by the Engineer.

TESTING: GROUT - FLOW CONE EFFLUX TIME

Samples: flow cone efflux time of grout 7.177

One sample of grout shall be provided from each batch of grout for geotechnical works to determine the flow cone efflux time of the grout.

Testing: flow cone efflux time of grout 7.178

Each sample of grout taken as stated in Clause 7.177 shall be tested to determine the flow cone efflux time. The method of testing shall be in accordance with ASTM C939.

Non-compliance: flow cone efflux time of grout 7.179

If the result of any test for flow cone efflux time of grout does not comply with the specified requirements for flow cone efflux time, particulars of proposed changes to the materials, grout mix or methods of production shall be submitted to the Engineer. Further grouting trials shall be carried out unless otherwise permitted by the Engineer.

TESTING: GROUT - CRUSHING STRENGTH

Samples: crushing strength of grout 7.180

(1) One sample of grout shall be provided from each batch of grout for geotechnical works to determine the crushing strength of the grout.

(2) Samples shall be provided not more than one hour after the grout has been mixed and shall be protected from moisture content changes before test cubes are made.

Testing: crushing strength of grout 7.181

(1) Nine 100 mm test cubes shall be made from each sample of grout taken as stated in Clause 7.180. Three test cubes shall be tested to determine the crushing strength at 3 days, three test cubes shall be tested to determine the crushing strength at 7 days and three test cubes shall be tested to determine the crushing strength at 28 days. For permanent soil nails and rock dowels, the test cubes for determining the crushing strength at 3 days and 7 days can be omitted.
(2) The method of making, curing and testing the test cubes shall be to specification as stated in Section 16.

Non-compliance: crushing strength of grout 7.182 If the result of any test for crushing strength of grout for geotechnical works does not comply with the specified requirements for grout, particulars of proposed changes to the materials, grout mix or method of production shall be submitted to the Engineer. Further trial mixes shall be made and further grouting trials shall be carried out unless otherwise permitted by the Engineer.

TESTING: PACKER TESTS ON DRILLHOLES FOR GROUTING AND GROUTED DRILLHOLES

Testing: Packer tests 7.183 (1) The water loss from drillholes for grouting and from grouted and regrounded drillholes shall be determined by the Packer test.

(2) The number of drillholes for grouting to be tested to determine the water loss shall be as instructed by the Engineer.

(3) Every grouted drillhole and every regrounded drillhole shall be tested to determine the water loss.

(4) Packer tests shall be carried out in accordance with BS 5930, Chapter 21.5 and Clause 7.183(5) to (8)

(5) Tests shall be carried out using clean water, in grouting stages not exceeding 3 m in length. The rate of flow of water in the test shall be determined to an accuracy of 10% for flows exceeding 1 L/min.

(6) The test pressure shall be equal to the overburden pressure and shall not exceed the specified maximum grouting pressure for the grouting stage being tested.

(7) The test shall be carried out between a packer and the base of the hole for grouting stages at the base of a hole and shall be carried out between two packers in other cases.

(8) The test shall be carried out by pumping water at the specified pressure into the grouting stage being tested and measuring with a volume meter the water loss over three consecutive 10 minute periods. The result shall be calculated in Lugeons for each 10 minute period.

Compliance criteria: Packer tests 7.184 The water loss determined by the Packer test in the grouted hole shall not exceed 5 Lugeons when measured over a 10-minute period.

Non-compliance: Packer test on drillholes for grouting 7.185 If the result of any Packer test on drillholes for grouting does not comply with the specified requirements for the test, the drillhole shall be grouted, re-drilled and retested. Grouting, re-drilling and retesting shall continue until the result of the Packer test complies with the specified requirements for the test.
If the result of any Packer test on grouted drillholes or regrounded drillholes does not comply with the specified requirements for the test, the grout shall be removed and the drillhole shall be regrounded and retested. Removal of grout, regrouting and retesting shall continue until the result of the Packer test complies with the specified requirements for the test.
### GLOSSARY OF TERMS

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<th>Term</th>
<th>Number</th>
<th>Definition</th>
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<td>Caisson drain</td>
<td>7.187</td>
<td>Caisson drain is an excavated vertical shaft, with or without raking drains, to provide drainage by intercepting and lowering the groundwater level in the vicinity.</td>
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<tr>
<td>Geotextile filter</td>
<td>7.188</td>
<td>Geotextile filter is a permeable sheet of synthetic material used like a granular filter for filtration and in-plane drainage.</td>
</tr>
<tr>
<td>Filter pipe</td>
<td>7.189</td>
<td>Filter pipe is a perforated or non-perforated pipe used for draining groundwater.</td>
</tr>
<tr>
<td>Granular filter</td>
<td>7.190</td>
<td>Granular filter is a graded sand or gravel placed against a soil to prevent the migration of fine particles out of the soil caused by water flow, and graded such that free discharge of water flowing into the filter is allowed.</td>
</tr>
<tr>
<td>Prefabricated band drain</td>
<td>7.191</td>
<td>Prefabricated band drain is a synthetic drain which, when installed in a soil strata, acts as a drainage medium for dissipation of pore water pressure.</td>
</tr>
<tr>
<td>Raking drain</td>
<td>7.192</td>
<td>Raking drain is a drillhole, with or without perforated filter pipes and geotextile filter sheath, installed generally at an upward inclination for groundwater lowering by gravity flow.</td>
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<tr>
<td>Relief drain</td>
<td>7.193</td>
<td>Relief drain is a synthetic drain installed on slope surfaces or in excavations to divert water seepage before applying sprayed concrete, masonry dentition or other construction.</td>
</tr>
<tr>
<td>Trench drain</td>
<td>7.194</td>
<td>Trench drain is a trench wholly or partly filled with granular material or clean crushed rock, with or without filter pipes and geotextile filter.</td>
</tr>
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### MATERIALS

<table>
<thead>
<tr>
<th>Term</th>
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</table>
| Granular filter material    | 7.195  | (1) Granular filter material for granular filter, trench drains and caisson drains shall consist of durable, inert, natural material free of clay, organic material and other impurities.  

(2) Granular filter material shall have the particle size distribution stated in the Contract. |
| Geotextile filter           | 7.196  | Geotextile filter shall be a proprietary type approved by the Engineer and shall have the properties stated in the Contract.                  |
Filter pipes 7.197

(1) Filter pipes shall comply with the following:

- Precast concrete pipes: BS 5911
- Vitrified clay pipes: BS 65
- DI pipes: BS 4772
- Steel pipes: BS 534
- Porous concrete pipes: BS 1194
- Perforated concrete pipes: BS 5911
- Pitch fibre pipes: BS 2760
- uPVC pipes: BS 4660 or BS 3506
- Corrugated polyethylene tubing: AASHTO Designation M252

(2) Class O UPVC pipes shall not be used.

(3) The perforations in perforated pipes shall be cleanly cut and shall be uniformly spaced along the length and circumference of the pipe.

(4) UPVC plastic pipes shall be jointed by couplers.

Raking drains 7.198

(1) Type O raking drains shall be unlined raking drains. Drain holes shall be at least 40 mm diameter.

(2) Type 1 raking drains shall be single pipe raking drains consisting of a single perforated pipe with a non-perforated invert.

(3) Type 2 raking drains shall be single pipe raking drains consisting of a single perforated pipe with a non-perforated invert and enclosed within a geotextile filter sheath.

(4) Type 3 raking drains shall be double pipe raking drains consisting of an outer permanent pipe and an inner removable pipe enclosed within a geotextile filter sheath. The outer and inner pipes shall be perforated pipes with a non-perforated invert.

(5) Pipes for raking drains shall be perforated pipes with non-perforated invert as approved by the Engineer. The portion of openings in the perforated pipe shall cover between approximately two-thirds 50% and 70% of the circumference of the pipe. The percentage of opening areas to overall surface area of the pipe shall not be less than 14% for 40 mm diameter pipe, nor less than 8% for 65 mm or above diameter pipe. The pipe material shall have the following physical properties or having equivalent functions:

- Material: non-metallic
- Minimum tensile strength: 21,300 kN/m²
- Minimum compressive strength: 22,000 kN/m²
(d) Minimum flexural strength: 6,800 kN/m²

(6) Couplers for filter pipes shall also have non-perforated invert and shall be of similar strength and durability of the pipe materials. The lapped length of coupler and each end of the filter pipes shall be at least 100 mm. The elongation at the pipe connection shall be less than 5 mm under a 45 kg pulling force.

(7) Geotextile filter sheaths for raking drains shall be formed of non-woven geotextile filter robust enough to prevent tearing and shall have the following physical properties or materials having equivalent functions or performance as approved by the Engineer:

(a) Material: non-metallic
(b) Minimum tensile strength: 17 kN/m
(c) Apparent opening size: 140 µm
(d) Coefficient of permeability under 2 kN/m²: 5 x 10⁻³ m/s
(e) Flow rate at 100 mm head under 2 kN/m²: 195 L/m²/s

(8) Tying wires for jointing pipes and stitching filter sheath shall be non-metallic wires of minimum breaking load 400 N or equivalent as approved by the Engineer.

Relief drains

7.199 Relief drains shall be drain mats with multi-layer porous fabric wrapped in filter fabric and covered with an impermeable fabric or products having equivalent functions or performance as approved by the Engineer. PVC flanges for connecting relief drains to outlet pipes shall be directed by the Engineer.

Fill material for trench drains

7.200 (1) Fill material to be used with geotextile filter in trench drains shall be clean crushed rock. Type A and Type B fill material shall have the particle size distributions stated in Table 7.2.

(2) Fill material passing a 425µm BS test sieve shall be non-plastic.

(3) The D15 particle size of Type A fill material for use with perforated pipes shall be at least 15% larger than twice the maximum dimension of the perforations, where D15 is the equivalent sieve size in millimetres, interpolated from the particle size distribution curve, through which 15% of the fill material would pass.

<table>
<thead>
<tr>
<th>Type of fill material</th>
<th>Percentage by mass passing BS test sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>63 mm</td>
</tr>
<tr>
<td>Type A</td>
<td>-</td>
</tr>
<tr>
<td>Type B</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 7.2: Particle size distribution of fill material for trench drains
| **Caisson liners** | 7.201 | Caisson liners shall be concrete tapered rings at least 100 mm thick and not exceeding 1 m deep. The liners shall be constructed with well-compacted concrete of Grade 20/20 or greater. |
| **Prefabricated band drains** | 7.202 | (1) Prefabricated band drains shall consist of a core and a filter. The drains may be manufactured as a single unit or the filter may be wrapped around the core, and overlapped and sealed to contain the core. The drains shall be made from chemically treated paper, polyethylene, polyester, polyolefine or other synthetic material or combination of such materials.  
(2) Prefabricated band drains shall be provided with an outer casing or mandrel of rhomboidal or rectangular cross section for use during installation. The drains shall also be provided with an anchor to ensure embedment of the drain during extraction of the mandrel.  
(3) The strength of the materials in prefabricated band drains shall be such that the drains will withstand all forces resulting from handling and installation.  
(4) The filter jacket for prefabricated band drains shall be a type which:  
(a) Has been previously proved effective under similar soil and pressure conditions,  
(b) Is in all cases able to prevent excessive migration of soil particles into the core, and  
(c) Has a permeability not less than that of the surrounding soil.  
(5) Prefabricated band drains shall be able to conform to soil deformation without buckling or crimping of the core. |

| **Particulars of granular filters** | 7.203 | (1) The following particulars of the proposed materials and methods of construction for granular filters shall be submitted to the Engineer:  
(a) Whether granular filter material is to be supplied ready mixed or is to be mixed on the Site,  
(b) Source of supply, including name of supplier of ready mixed material,  
(c) Quantity of each constituent if the material is to be mixed on the Site,  
(d) Construction Plant and methods of mixing for material mixed on the Site,  
(e) Method of storage and location of storage areas on the Site,  
(f) Methods of deposition and compaction of material, and |
(g) Results of three tests for particle size distribution of the fill material against which the granular filter is to be placed.

(h) Details of filter design including calculations and grading envelopes.

(2) The particulars shall be submitted to the Engineer for approval at least 14 days before deposition of granular filter material starts.

**Particulars of geotextile filter** 7.204

(1) The following particulars of the proposed materials and methods of construction for geotextile filter shall be submitted to the Engineer:

(a) Manufacturer’s name and source of supply,

(b) Details of geotextile filter including manufacturer's literature,

(c) A certificate for the geotextile filter showing the manufacturer's name, the date and place of manufacture and showing that the geotextile filter complies with the requirements stated in the Contract, and including results of tests stated in the Contract,

(d) Calculations showing that the geotextile filter complies with the filtration characteristics stated in the Contract,

(e) Details of previous uses of the geotextile filter.

(f) Details of quantities to be supplied in each delivery,

(g) Method of storage,

(h) Methods of cutting and jointing geotextile filter,

(i) Method of repairing small batches, and

(j) Methods of laying and holding in position.

(2) The particulars, including certificates, shall be submitted to the Engineer for approval at least 28 days before the first delivery of the geotextile filter to the Site. Certificates shall be submitted for each batch of geotextile filter delivered to the Site.

**Particulars of trench drains** 7.205

(1) The following particulars of the proposed materials and methods of construction for trench drains shall be submitted to the Engineer:

(a) Method of excavation of trench and installation of geotextile filter,

(b) Details of granular fill material as stated in Clause 7.200, and

(c) Details of geotextile filter as stated in Clause 7.204.

(2) The particulars shall be submitted to the Engineer for approval at least 14 days before installation of trench drains starts.
| **Particulars of raking drains** | 7.206 | (1) The following particulars of the proposed materials and methods of construction for raking drains shall be submitted to the Engineer:  
(a) Method of connecting adjacent sections of pipes,  
(b) Proportions of sealant mix, and  
(c) Details of geotextile filter sheath.  
(2) The particulars shall be submitted to the Engineer for approval at least 14 days before installation of raking drains starts.  

| **Particulars of relief drains** | 7.207 | (1) The following particulars of the proposed materials and methods of construction for relief drains shall be submitted to the Engineer:  
(a) Details of relief drains and outlets, and  
(b) Method of fixing relief drains to the slope face.  
(2) The particulars shall be submitted to the Engineer for approval at least 14 days before fixing of relief drains starts.  

| **Particulars of caisson drains** | 7.208 | (1) The following particulars of the proposed materials and methods of construction for caisson drains shall be submitted to the Engineer:  
(a) Methods of excavation and installation and removal of caisson liners,  
(b) Method of compaction of fill material,  
(c) Details of granular filter material as stated in Clause 7.203, and  
(d) Details of geotextile filter as stated in Clause 7.204.  
(2) The particulars shall be submitted to the Engineer for approval at least 14 days before construction of caisson drains starts.  

| **Particulars of prefabricated band drains** | 7.209 | (1) The following particulars of the proposed materials and methods of construction for prefabricated band drains shall be submitted to the Engineer:  
(a) Details of type of drain, including manufacturer's literature,  
(b) A certificate showing the manufacturer's name, the date and place of manufacture and showing that the drains comply with the requirements stated in the Contract,  
(c) Details of previous installations by the Contractor using similar drains,  
(d) Method of installation, and  
(e) Details of installation mandrel, drain anchor, method of penetration and method of recording depth of installation.  

7.70
Particulars of filter pipes 7.210

(1) The following particulars of the proposed materials and methods of construction for filter pipes shall be submitted to the Engineer:

(a) Details of type of pipes, including manufacturer's literature,

(b) A certificate showing the manufacturer's name, the date and place of manufacture and showing that the pipes comply with the requirements stated in the Contract,

(c) Details of previous installations by the Contractor using similar pipes, and

(d) Method of installation.

(2) The particulars shall be submitted to the Engineer for approval at least 28 days before installation of the filter pipes starts.

Particulars of groundwater control, drawdown and monitoring 7.211

(1) The following particulars of the proposed materials and methods of construction for groundwater control, drawdown and monitoring shall be submitted to the Engineer:

(a) Construction Plant and materials for dewatering,

(b) Timing and sequence of dewatering operations,

(c) Details of silt traps,

(d) Methods of monitoring flow rates and volumes of silt, including monitoring intervals, and

(e) Methods and locations for discharging groundwater.

(2) The particulars shall be submitted to the Engineer for information at least 14 days before the relevant work starts.

Samples of materials 7.212

Samples of the following proposed materials shall be submitted to the Engineer for approval of the source and type of each material at the same time as particulars of the material are submitted:

(a) Granular filter material,

(b) Geotextile filter and two pieces of geotextile filter joined in accordance with the manufacturer's recommendations for each type of joint, and

(c) Relief drains.
## HANDLING, DELIVERY AND STORAGE OF MATERIALS

### Handling and storage of granular filter material

**7.213**

1. Granular filter material shall not be handled or stored in a manner which will result in mixing of the different types and sizes or in segregation, contamination, deterioration or erosion of the material.

2. Stockpiles of granular filter material shall be placed on well-drained, prepared areas and shall be separated by dividing walls of sufficient height to keep the different materials separate.

### Delivery and storage of geotextile filter

**7.214**

1. Geotextile filter shall be delivered in secure wrappings to ensure that the geotextile filter is dry and protected from damage, contamination and exposure to conditions that may adversely affect it.

2. Geotextile filter shall be stored on a level surface and shall be kept in a secure and dry condition, which will not result in damage to the fabric or in contamination of the fabric.

### Storage of filter pipes

**7.215**

- Coils of plastic tubing for filter pipes shall be stored flat.

### Delivery and storage of prefabricated band drains

**7.216**

1. Prefabricated band drains shall be supplied in rolls, securely packed in lightproof wrappings.

2. Prefabricated band drains shall be stored in a clean, dry environment.

## GRANULAR FILTERS

### Mixing granular filter material

**7.217**

- Granular filter material shall be thoroughly mixed by the method approved by the Engineer. Material that has been stockpiled shall be remixed before deposition.

### Deposition and compaction of granular filter material

**7.218**

1. Granular filter material shall be deposited and compacted as stated in Section 6.

2. Granular filter material shall be deposited in a manner which will not result in segregation or contamination of the material.

3. Granular filter material shall be deposited in such a manner that a continuous free draining zone is formed. The surface of each layer shall be cleaned and scarified before the next layer is deposited unless otherwise permitted by the Engineer.

## GEOTEXTILE FILTER

### Damage to geotextile filter

**7.219**

1. The total period for which geotextile filter is exposed to daylight or other sources of ultra-violet radiation during handling, delivery, storage and installation shall not exceed 7 days.
(2) Geotextile filter that has been damaged or exposed to daylight or other sources of ultra-violet radiation for longer than the period stated in Clause 7.219(1) shall not be used in the permanent work unless permitted by the Engineer.

(3) Repairs to geotextile filter that has been torn or damaged during installation shall be carried out using a patch of the same material extending at least 300 mm beyond the edge of the damaged area. Repairs shall not be carried out on geotextile filter that has been damaged during storage or storage before installation.

**Laying geotextile filter** 7.220

(1) Geotextile filter shall be installed in such a manner that the individual yarns, webs or layers of the fabric retain their intended orientation and relative positions with respect to each other.

(2) Geotextile filter shall be installed, cut and jointed in accordance with the manufacturer's recommendations.

(3) Laps in sheets of fabric reinforcement that are not stated in the Contract to be jointed shall be at least 300 mm.

**Protection of geotextile filter** 7.221

Construction plant and other vehicles shall not operate on installed geotextile filter unless in the opinion of the Engineer it is adequately protected by a cover of fill material or other means agreed by the Engineer.

**Records of geotextile filter** 7.222

Records of installation of geotextile filter shall be kept by the Contractor on the Site and a copy shall be submitted to the Engineer each day. Records shall contain the following details:

(a) Identification of structures and sections of work where geotextile filter is installed,

(b) Type of geotextile filter, including identification of batch,

(c) Date of first exposure of geotextile filter to ultra-violet radiation before installation,

(d) Type of joint, amount of overlap, method of holding in place and any repairs to geotextile filter carried out during installation,

(e) Date of installation of geotextile filter, and

(f) Date of final covering of geotextile filter.

**RAKING DRAINS**

**Installation of raking drains** 7.223

(1) The length of raking drains assembled before installation shall not exceed 12.5 m. Connections between adjacent pipes shall be secured in such a manner that the cumulative longitudinal extension of a 12.5 m assembled length of pipe does not exceed 5 mm when pulled by hand.

(2) Pipes for Type 2 and Type 3 raking drains are to be wrapped in geotextile filter sheath in the following manner prior to installation in order to ensure that the overlap and stitching shall be at the
non-perforated invert of the pipe. The pipe shall be placed onto and along the centre of a strip of geotextile filter with the non-perforated invert at the top. The strip of geotextile filter shall be of sufficient width to allow an overlap of at least 50 mm, and shall be drawn around the pipe and stitched together tightly with non-metallic wires. The stitching shall be tied off onto the pipe and the fabric at every 300 mm to prevent dislocation during installation. The filter sheath shall be marked to ensure that the non-perforated invert is correctly positioned during installation.

(3) During delivery and installation of raking drains, care must be taken to ensure that the pipe and geotextile filter sheath are not damaged. The method of installing the raking drains shall be submitted to the Engineer for approval prior to installation.

(4) Before installation of drain pipes, the drillholes shall be checked for cleanliness. Whenever any obstruction is encountered inside a drillhole during pipe insertion, the pipe shall be withdrawn and the obstruction shall be cleared before re-insertion. No jacking or hammering of pipes shall be carried out during the whole process of pipe insertion.

Drilling for raking drains 7.224

(1) Drilling lubricants other than clean air or fresh water shall not be used for drilling holes for raking drains. Casings shall be used to prevent collapse of the hole and to permit unobstructed insertion of the pipes and geotextile filter sheath.

(2) The drillhole entry point shall be positioned within a tolerance of ±75 mm. Deviation in alignment shall not exceed 1 in 20. Deviation from straight shall not exceed 20 mm in any 3 m length of drillhole. A positive gradient shall be maintained throughout the complete length of the hole. The inclination of holes shall be measured by a method agreed by the Engineer.

(3) Drilling and sampling for undisturbed soil samples and rock cores instructed by the Engineer to be recovered from drillholes shall be as stated in Clauses 7.43 to 7.67.

(4) Drillholes shall be temporarily plugged or otherwise protected to prevent entry of deleterious material after drilling.

Records of drillholes for raking drains 7.225

Records of drillholes for raking drains shall be kept by the Contractor on the Site and a drillhole log for each drillhole shall be submitted to the Engineer before installation of the raking drain starts. The borehole log shall contain the following details:

(a) Drain reference number,

(b) Location, inclination, bearings, diameter and length of hole,

(c) Details of drilling progress,

(d) Details of water seepage related to drilling progress, and

(e) Details of samples taken.
TRENCH DRAINS

**Excavation for trench drains** 7.226
The width of trench drains shall be at least 450 mm. The width of trench drains with filter pipes not exceeding 150 mm diameter shall be at least four times the nominal diameter of the pipe. The width of trench drains for pipes exceeding 150 mm diameter shall be at least the same as the external diameter of the pipe plus 450 mm.

**Geotextile filter surround for trench drains** 7.227
Geotextile filter surround for trench drains shall be installed as stated in Clause 7.220.

**Bed for trench drains** 7.228
(1) Concrete bed for filter pipes in trench drains shall be at least 75 mm thick and shall be Grade 20/20 concrete.

(2) Granular bed for filter pipes for trench drains shall have a thickness at least the same as the diameter of the pipe or 150 mm, whichever is greater.

**Deposition and compaction of fill material for trench drains** 7.229
(1) The material for granular bed for trench drains shall be deposited in the trench in layers not exceeding 150 mm thick and for the complete width of the trench. Each layer shall be compacted with six passes of a plate vibrator or by other methods agreed by the Engineer.

(2) Fill material around filter pipes in trench drains shall be deposited and compacted as stated in Section 6. The permission of the Engineer shall be obtained before fill material is deposited around filter pipes.

RELIEF DRAINS

**Trials for relief drains** 7.230
A trial length of relief drains of at least 2 m shall be constructed.

**Fixing relief drains** 7.231
Relief drains shall be fixed in position before surface protection or remedial measures are applied. Fixing shall be carried out in a manner that will not affect the serviceability of the relief drains or outlets. Water collected in relief drains shall be discharged to outlets agreed by the Engineer.

CAISSON DRAINS

**Construction of caisson drains** 7.232
(1) Excavation for caisson drains shall be carried out by manual methods in stages not exceeding 1.0 m depth unless otherwise permitted by the Engineer. Dewatering shall be carried out for excavation below the groundwater level so that work may be carried out, as near as may be practicable in the circumstances, in dry conditions. Dewatering shall be carried out as stated in Clauses 7.236 and 7.237.

(2) Unless otherwise permitted by the Engineer, the caisson drain shaft shall be supported at all times during construction using concrete liners. Voids between liners and excavated faces shall be filled with no fines concrete. Caisson liners for each 1.0 m stage shall be installed on the same day as that stage is excavated.
(3) Softened and loose material shall be removed from the base of the caisson drain immediately before granular filter material is deposited in the caisson drain.

(4) Part or all of the concrete liner adjacent to the granular filter layer shall be removed before granular filter material or fill material is deposited. Debris from the concrete liner shall be removed from the caisson drain.

(5) Granular filter material shall be deposited in layers not exceeding 500 mm and shall be compacted by methods approved by the Engineer.

**Discharge of water from caisson drains**

| 7.233 | Water collected in caisson drains shall be discharged to the outlets stated in the Contract.

**Records of caisson drains**

| 7.234 | (1) Records of caisson drains shall be kept by the Contractor on the Site and a copy shall be submitted to the Engineer not more than 14 days after completion of construction of caisson drains. The records shall contain the following details:

   a) Record of work carried out each day, and
   
   b) Drawings showing the exact locations of caisson drains and the final depths relative to PD.

(2) Detailed face logs of caisson drains shall be kept by the Contractor on the Site and shall be available for inspection by the Engineer at all times. The logs shall contain the following information and the format shall be as shown in Figure 10 of ‘Geoguide 2: Guide to Site Investigation’, Hong Kong Government 1987.

   a) Details of depths and rate of groundwater seepage,
   
   b) Details of water levels, including dates and details of fluctuation,
   
   c) Four colour prints and one negative each of photographs or composite photographs taken during excavation. Each excavation stage shall be photographed using a reference board with maximum dimensions of 300 mm (width) by 450 mm (length). The photographs shall cover all the excavated face before the placing of caisson liners. Where more than one photograph is required to cover the full excavated depth or length of a face, the overlap between adjacent photographs shall be between 10% and 20%. Each photograph shall identify the face of the excavation and shall contain a natural scale and a colour comparison chart placed alongside the excavated face. The minimum size of colour prints shall be 125 mm by 175 mm.

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**PREFABRICATED BAND DRAINS**

| Installation of prefabricated band drains | 7.235 | (1) The installed location of prefabricated band drains shall be within 300 mm of the specified location in plan on the ground surface and the drain shall be within 2% of the installed length to the vertical.
Each prefabricated band drain shall be installed in one continuous length without joints.

The depth of penetration of prefabricated band drains shall be as stated in the Contract and modified as instructed by the Engineer during installation based on the resistance of the soil to penetration. The Engineer shall be notified immediately of any sudden change in the penetration resistance to the mandrel.

**GROUNDWATER CONTROL AND DRAWDOWN**

<table>
<thead>
<tr>
<th>Drawdown of groundwater table</th>
<th>7.236</th>
</tr>
</thead>
<tbody>
<tr>
<td>The groundwater table shall not be drawn down to more than 2 m below the earthworks final surface to specification in Section 6 for excavation.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dewatering</th>
<th>7.237</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Dewatering shall be carried out in such a manner that no loss of fines from the ground occurs.</td>
<td></td>
</tr>
<tr>
<td>(2) Silt traps shall be provided and shall be regularly maintained. All dewatering pumps shall discharge into silt traps.</td>
<td></td>
</tr>
<tr>
<td>(3) Pumped groundwater shall not be discharged onto roads, footpaths, kerb channels or adjacent land. All arrangements shall be made with and the necessary approvals shall be obtained from the relevant authorities for discharging water to drainage systems, watercourses or the sea. Dewatering shall not start until the approved arrangements for disposal of the water have been implemented. Water entering the Site shall not be discharged into the same silt traps as are used for dewatering.</td>
<td></td>
</tr>
<tr>
<td>(4) The total capacity of pumps available on the Site for dewatering shall be at least equal to twice the rate of flow measured through the silt traps at any time when the groundwater table is maintained at maximum drawdown.</td>
<td></td>
</tr>
<tr>
<td>(5) Half of the total pump capacity shall be equipped with a secondary motive power source in addition to the primary motive power. The secondary motive power source shall commence operation automatically in the event of failure of the primary motive power source or an effective alarm system shall be set up which will warn of failure of the primary motive power source. The maximum allowable delay between failure of the primary motive power source and full operation of the secondary motive power source shall not exceed 15 minutes.</td>
<td></td>
</tr>
<tr>
<td>(6) A full-time attendant shall be available on the Site at all times to execute the changeover if manual operation of equipment is required to bring the secondary motive power into operation.</td>
<td></td>
</tr>
<tr>
<td>(7) The operation of the changeover of motive power equipment shall be demonstrated before the relevant work starts unless otherwise permitted by the Engineer.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Groundwater recharge</th>
<th>7.238</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) If groundwater recharge is to be carried out to maintain the specified groundwater levels at any location, the groundwater recharge system shall have the means to regulate and measure the rate of recharge and to provide an adequate continuous supply of water for recharge. Only clean water shall be used.</td>
<td></td>
</tr>
</tbody>
</table>
(2) The capacity of pumps and the power sources which are to be used for groundwater recharge shall be as stated in Clause 7.237(4) except that the rate of flow shall refer to the maximum rate of groundwater recharge required.

(3) The groundwater table at any location shall not be raised above the background groundwater table measured before the relevant work starts.

**Monitoring of groundwater control and drawdown**

7.239

(1) Monitoring of groundwater levels shall be carried out at locations stated in the Contract or instructed by the Engineer at all times when groundwater control and drawdown is carried out. Arrangements for installing instruments and taking measurements both inside and outside the Site shall be made by the Contractor.

(2) The survey marks for monitoring shall be located in position and level to the Hong Kong standard survey grid and to PD to within 10 mm in every direction.

(3) Monitoring stations and monitoring shall be as stated in Clauses 7.248 to 7.265.

(4) Groundwater levels shall be measured to an accuracy of 20 mm. Settlements shall be measured to an accuracy of 3 mm.

(5) The Engineer shall be notified immediately if any incremental settlement reading exceeds 5 mm or if the accumulated settlement exceeds the maximum allowable settlement stated in the Contract.

**Records of settlement, groundwater control and drawdown**

7.240

Records of monitoring of settlement, groundwater control and drawdown shall be kept by the Contractor on the Site and a copy shall be submitted to the Engineer within 24 hours of taking readings.

**TESTING: GRANULAR FILTER MATERIAL**

**Batch: granular filter material**

7.241

A batch of granular filter material is any quantity of granular filter material of the same type and grading delivered to the Site at any one time.

**Samples: granular filter material**

7.242

(1) One sample of granular filter material shall be provided from each 500 m³ or part thereof of the material delivered to the Site.

(2) Unless otherwise permitted by the Engineer, one sample of granular material shall be provided from each 500 m³ or part thereof of granular filter material that has been deposited and compacted.

(3) The size of each sample taken as stated in Clause 7.242(1) shall be 10 kg. The method of sampling shall be in accordance with BS 812: Part 102.

(4) Samples taken as stated in Clause 7.242(2), shall consist of material excavated from the compacted layer to form a flat bottomed, steep sided hole of approximately 0.13 m² to the complete depth of the compacted layer. A template shall be used to fix the edges of the hole if necessary. The sides and bottom of the hole shall be at least 50 mm from other types of fill material.
**Testing: granular filter material**

7.243 (1) Each sample of granular filter material shall be tested to determine the particle size distribution.

(2) The method of testing shall be in accordance with the wet sieving method stated in Geospec 3, Test Method 8.2

**Non-compliance: granular filter material**

7.244 (1) If the result of any test for particle size distribution on a sample of granular filter material taken as stated in Clause 7.242(1) does not comply with the specified requirements for particle size distribution, additional samples shall be provided from the same batch and additional tests for particle size distribution shall be carried out.

(2) The batch shall be considered as not complying with the specified requirements for particle size distribution if the result of any additional test for particle size distribution does not comply with the specified requirements for particle size distribution.

(3) If the result of any test for particle size distribution on a sample of granular filter material taken as stated in Clause 7.242(2) does not comply with the specified requirements for particle size distribution, additional samples shall be provided from the same batch and additional tests for particle size distribution shall be carried out.

(4) The batch shall be considered as not complying with the specified requirements for particle size distribution if the result of any additional test for particle size distribution does not comply with the specified requirements for particle size distribution.

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**TESTING: FILL MATERIAL FOR TRENCH DRAINS**

**Batch: fill material for trench drains**

7.245 A batch of fill material for trench drains is any quantity of fill material for trench drains of the same type delivered to the Site at any one time.

**Samples: fill material for trench drains**

7.246 (1) Unless otherwise permitted by the Engineer, one sample of fill material for trench drains shall be provided from each batch of fill material for trench drains delivered to the Site.

(2) The size of each sample and the method of sampling shall be in accordance with Clause 7.242(3).

**Testing: fill material for trench drains**

7.247 (1) Each sample of fill material for trench drains shall be tested to determine the particle size distribution. Fill material passing a 425 µm BS test sieve shall also be tested to determine the plasticity index.

(2) The method of testing to determine the particle size distribution shall be in accordance with Geospec 3, Test Method 8.2. The method of testing to determine the plasticity index shall be in accordance with Geospec 3, Test Method 6.1.
PART 6: GEOTECHNICAL INSTRUMENTATION

GLOSSARY OF TERMS

Datum station 7.248 Datum station is a mark for which horizontal or vertical values, or both, have been fixed, and which is used as a datum for monitoring or control surveys.

Geotechnical instrumentation 7.249 Geotechnical instrumentation is the installation and monitoring of instruments in the ground or structures to provide information on soil and rock parameters, and to monitor specific variations in the condition of the ground or structures for the purposes of geotechnical design, construction control and performance monitoring.

Monitoring mark 7.250 Monitoring mark is a mark, fixed or installed, on a structure to be monitored.

Reference point 7.251 Reference point is a mark placed close to another important survey mark to aid recovery or replacement.

Survey station 7.252 Survey station is a mark on a stone, concrete, metal or wooden block, pipe, peg or other item defining a surveyed position.

SUBMISSIONS

Particulars of geotechnical instrumentation 7.253 (1) The following particulars of the proposed geotechnical instrumentation shall be submitted to the Engineer:

(a) Details of instruments and any alternative instruments proposed by the Contractor,

(b) Manufacturer’s specifications,

(c) Test and calibration certificates,

(d) Method of installation,

(e) Method of acceptance testing,

(f) Details of ancillary measuring equipment,

(g) Schedule for installing instrumentation in relation to other work,

(h) Documents showing that the instruments are capable of measuring within the ranges and accuracies stated in the Contract,

(i) Name and experience of persons responsible for installation, testing and monitoring of instruments,
(j) Details of standpipe piezometer tips, including manufacturer's specification, and

(k) Details of the form of records.

(2) The particulars shall be submitted to the Engineer for approval at least 28 days before installation of instrumentation starts.

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**GENERAL GEOTECHNICAL INSTRUMENTATION REQUIREMENTS**

**Instruments for geotechnical instrumentation**

7.254

(1) Instruments for geotechnical instrumentation and their accessories shall be provided complete with all appropriate tubing, connections, monitoring equipment, read-out units and any other tools necessary for the installation calibration, setting to work and maintenance of the instruments.

(2) Instruments shall be manufactured by companies with proven experience and only instruments which are well proven and have been in successful use shall be used, unless otherwise agreed by the Engineer.

(3) Installed instruments shall become the property of the Employer. Detachable tubing, connections, monitoring equipment and read-out units shall become the property of the Contractor upon the expiry of the Maintenance Period.

(4) Instruments shall be handled, stored, installed and used in accordance with the manufacturer's recommendations and in such a manner that the performance of the instruments will not be impaired.

(5) Instruments shall be protected from damage and measures shall be taken to ensure that the instruments suffer the minimum practicable amount of disturbance.

(6) Instruments shall be calibrated by a laboratory approved by the Engineer. Instruments shall be calibrated at intervals recommended by the manufacturer and at other intervals instructed by the Engineer. Calibration certificates shall be provided to the Engineer within 24 hours of calibration.

(7) Installation, testing and monitoring of the instruments shall be carried out under the supervision of a suitably qualified technician. Particulars of the technician, including qualifications and experience, shall be submitted to the Engineer at least 7 days before commencement of work relating to geotechnical instrumentation.

**Location and arrangement of instruments**

7.255

(1) The locations and arrangement of instruments for geotechnical instrumentation shall be as stated in the Contract or as agreed with the Engineer before installation.

(2) The positions and alignments of instruments shall be recorded after installation and surveys shall be carried out at times and frequencies agreed by the Engineer to detect any displacement of the instruments.

(3) At least two reference points shall be established for each survey station or monitoring mark.
(4) The survey station that has the least chance of being disturbed shall be selected as datum station. The datum station shall be stainless steel and shall be protected from damage. At least three reference points shall be established for each datum station.

(5) The survey network shall be related to the territorial control points provided by the Engineer.

**Installation of instruments**

7.256

(1) The Engineer shall be informed 24 hours, or such shorter period agreed by the Engineer, before the installation of each instrument for geotechnical instrumentation starts.

(2) Instruments shall be installed, fixed and protected in a manner which will ensure that the instruments will function satisfactorily. Tests shall be carried out after installation to demonstrate that the instruments have been correctly installed and are functioning correctly. Instruments that are not correctly installed or are not functioning correctly shall be reinstalled or replaced as instructed by the Engineer.

(3) All installed instruments, tubes and wires shall be clearly marked with a unique and conspicuous identification number.

**Tubes and cables for instruments**

7.257

(1) Tubes and cables attached to instruments for geotechnical instrumentation for remote reading shall be impervious to air and water, and shall have sufficient strength and stiffness to withstand the internal and external pressures. Tubes and cables shall be protected from mechanical damage and from the harmful effects of direct sunlight, heat and ultra violet radiation at all times.

(2) Tubes and cables shall be free of defects and shall be marked with identification colours and numbers at 5 m intervals. The tubes and cables shall be wound onto reels in such a manner that kinks are not formed and strain is not induced. Open ends of tubes and cables shall be blocked with stop ends at all times.

(3) Tubes and cables shall be buried at least 0.5 m below ground level.

(4) Tubes and cables shall be laid with sufficient slack, loops and bends to allow for settlement and other ground movements. The routing of tubes and cables shall be as agreed by the Engineer and shall be in straight lines unless otherwise permitted by the Engineer. The radius of bends shall be at least 300 mm. Each tube or cable shall be laid from the measuring instrument to the terminal duct in one continuous length without joints.

**Maintenance of instruments**

7.258

(1) Instruments for geotechnical instrumentation shall be maintained in good working order until the expiry of Maintenance Period. Instruments, survey marks and stations shall be protected by suitable barricades, notices, signs, marker-buoys or by other methods agreed by the Engineer. Construction shall be carried out in a manner that will avoid damage to the instruments.

(2) The Engineer shall be informed immediately of any instruments found damaged or instruments found not to be in working order. Replacements shall be installed for read-out units that are faulty or under repair.
Records of geotechnical instrumentation

1. Records of activities relating to installation of geotechnical instrumentation shall be kept by the Contractor on the Site and a copy shall be submitted to the Engineer within 24 hours of installation of the instrument is complete.

2. A drawing showing the locations and identification of installed instruments shall be prepared by the Contractor and submitted to the Engineer within 24 hours of installation of the instrument is complete.

3. A drawing showing the locations and details of survey stations, monitoring marks and reference points shall be prepared by the Contractor and submitted to the Engineer not more than 3 days after the survey network has been established.

MONITORING AND RECORDING

Recording readings

1. Instrument readings and processed data for geotechnical instrumentation shall be recorded by the Contractor on agreed record sheets, and shall be submitted to the Engineer within 24 hours of recording. The form of record sheets shall be as agreed by the Engineer. Unless otherwise agreed by the Engineer, readings shall be taken in the presence of the Engineer.

2. Initial readings shall be taken immediately after the instruments have been installed and after the effects of installation have subsided. The initial readings shall be submitted to the Engineer and shall form the basis of comparison of subsequent readings. The instruments and the initial readings shall be replaced if the initial readings are not repeatable.

3. The frequencies for reading instruments shall be as agreed with the Engineer. The Engineer shall be informed immediately of sudden or significant changes in the readings.

4. All installed instruments shall be left in correctly functioning condition after final readings have been taken or at the end of the Maintenance Period. Keys for locks shall be tagged to identify the instrument number and shall be handed over to the Engineer.

SETTLEMENT PLATES

Installation of settlement plates

1. Settlement plates for geotechnical instrumentation shall be securely founded on level ground free of obstructions and shall be immediately surveyed for level and position and plotted on a plan.

2. Settlement plates shall be protected from damage and shall be kept in position by a 600 mm thick layer of granular fill material or bags of sand which shall be placed by manual methods and shall extend 600 mm beyond the edges of the plate. The initial survey of levels and positions shall be taken immediately after the fill material or bags of sand have been placed.
(3) The metal rod fixed to the centre of the plate shall be in an upright position, and protected by a tubular sleeve. The sleeve and the metal rod shall be extended as fill material is placed such that at any time the sleeve and rod are at least 500 mm above the level of the surrounding fill material or high water mark, and the metal rod is within 2% of the embedded length to the vertical.

(4) The level of the top of the metal rod shall be recorded immediately before and immediately after each extension piece is added. Marker-buoys shall be fixed to the tops of tubular sleeves installed in water, unless otherwise permitted by the Engineer.

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**TILTMETER SYSTEM**

*Installation of tiltmeter system* 7.262

(1) Tilt-plates for geotechnical instrumentation shall be orientated to correspond with the specified direction of measurement and fixed in place on the rock or structure. The installed direction shall be recorded to an accuracy of \( \pm 3^\circ \).

(2) A protective cap or cover shall be fitted to protect the tilt-plates from damage.

(3) Tilt-plates and the tiltmeter shall be cleaned and inspected for damage before readings are taken. The tiltmeter shall be accurately located on the tilt-plate and a reading taken. The tiltmeter shall then be removed and the contact surface re-cleaned. The procedure shall be repeated until consistent readings are obtained. The tiltmeter shall then be rotated through \( 180^\circ \) and the procedures repeated.

(4) The accuracy of the tiltmeter and its readout system shall be checked both before and after the readings taken each day. Instrument errors shall be investigated and immediately corrected. A record of calibrations and adjustments shall be submitted to the Engineer together with the monitoring data.

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**TELLTALES**

*Installation of telltales* 7.263

Unless otherwise approved by the Engineer telltales for geotechnical instrumentation shall be as shown in Figure 10.5 of ‘The Geotechnical Manual for Slopes’, Hong Kong Government, 1984. Telltales shall be rigidly fixed across cracks to enable any movement across the cracks to be determined. Telltales shall be labelled and marked with the date of installation.

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**STANDPIPE PIEZOMETERS**

*Standpipe piezometers* 7.264

Standpipe piezometer tips for geotechnical instrumentation shall be porous ceramic or plastic material at least 200 mm long and with a bore of at least 19 mm. The permeability shall be at least \( 10^{-4} \) m/s. The piezometer tip shall be connected to rigid PVC standpipes with a bore of at least 19 mm.
Installation of standpipe piezometers

7.265 (1) Standpipe piezometers for geotechnical instrumentation shall be installed in drillholes at the depths instructed by the Engineer.

(2) The sand filter surrounding the piezometer tip shall be between 1000 mm and 1500 mm long and shall consist of sand between the sizes of 200 μm and 1210 μm. Measurements shall be made to determine the actual location of the sand filter column.

(3) A seal shall be formed above the sand filter by placing 500 mm of bentonite pellets of between 10 mm and 15 mm in size. The pellets shall be placed in the hole and tamped with a suitably shaped tamper to form a homogeneous plug to the hole.

(4) If the depth of the completed hole is greater than the depth at which the piezometer tip and sand filter are to be placed, the bottom of the drillhole shall be grouted with grout consisting of cement and bentonite in the proportions 1:1 by mass together with sufficient water to achieve the required workability. The drillhole above the plug shall be grouted with the same type of material.

(5) The water level in the piezometer shall be measured after the standpipe piezometer has been installed and the standpipe shall be topped up with clean water. The rate of drop of water level or pressure head shall be recorded at times of 0, 1/4, 1/2, 1, 2, 4, 8, 15, 30 minutes or until the water has returned to its initial level.

(6) The water level shall be measured by an electrical type water level probe agreed by the Engineer. The water shall be salted if necessary for response to the probe.

(7) Measurements of the depth of piezometer tip and sand filter and the readings taken as stated in Clause 7.265(6) shall be submitted to the Engineer for approval within 24 hours of completion of installation of the piezometer standpipe.
PART 7: SLOPE AND RETAINING WALL RECORD SURVEY

GENERAL

Scope 7.266 A survey of all slopes and retaining walls formed, modified or partially modified under the Contract shall be conducted and completed upon their completion or at any other time as appropriate during the construction period. Such survey shall be completed upon the substantial completion of the Works as certified by the Engineer.

SUBMISSIONS

Particulars of slope and retaining wall record survey 7.267 (1) The following particulars of the slope and retaining wall record survey shall be submitted to the Engineer:

(a) All necessary details of the subject slopes and retaining walls as required by the Engineer, including details of the extent of new fill body of a fill slope as appropriate, recorded on a plan of 1:1000 scale showing the locations with graphical boundaries appropriately highlighted and referenced to the HK1980 Grid, and

(b) A soft copy of the plan as stated in Clause 7.267(1)(a) prepared in a format as specified in the Contract.

(2) The particulars shall be submitted to the Engineer not more than 28 days, or such other time stated in the Contract, after completion of the slope and retaining wall record survey as agreed by the Engineer.
PART 8: PAINTING TO CONCRETE / SPRAYED CONCRETE SURFACES

MATERIALS

Paint for concrete/sprayed concrete surfaces 7.268 Paint for concrete/sprayed concrete surfaces shall be water-based paint for external use. The components of paint shall not be toxic or hazardous to health.

SUBMISSION

Particulars of paint 7.269 Details of paint products (e.g. specification and colour samples etc.) and method statement shall be submitted for the Engineer’s approval prior to painting. The colour of paint shall be “Antique” to BS 5252F: 2004 colour code 10B25 or other colour as directed by the Engineer.

PAINTING TO CONCRETE / SPRAYED CONCRETE SURFACES

Painting to concrete/sprayed concrete surfaces 7.270 (1) The surface of concrete/sprayed concrete shall be prepared prior to applying the paint. The surface to be painted shall be clean, free of contaminants such as oils, grease, release agents, mortar splashes etc. All debris and loose materials shall be removed from the surface. Painting shall not be carried out in direct strong sunlight, hot windy conditions or in an environment with excessive dust.

(2) Paint shall be stored in accordance with Section 24 and shall be mixed in accordance with the manufacturer’s instruction prior to application. Two coats of paint shall be applied to the surface. Each coat of paint shall be applied using an airless spray at 12 m²/litre or equivalent to obtain a uniform finish or as recommended by the manufacturer. Sufficient time gap shall be allowed between the applications of first and second coating as recommended by the manufacturer. Each coating shall be protected from rain for the first 24 hours after application.
APPENDIX 7.1

DYNAMIC PROBE TEST

Scope

7.1.1 This method covers the determination of the penetration resistance of soil using the dynamic probe.

Apparatus

7.1.2 The following apparatus is required:

(a) Dynamic Probe as shown in Figure 36 of `Geoguide 2: Guide to Site Investigation,' Hong Kong Government 1987. The anvils shall be rigidly fixed to the guide rod; the lower anvil shall also be rigidly fixed to the extension rods. The mass of the lower anvil shall be 1.5 kg to 1.8 kg. The combined mass of the anvils and guide rod shall not exceed 5.0 kg.

(b) Extension rods with a length of 1000 mm ±10 mm. The rods shall be attached to bear against each other by means of external couplers.

Procedure

7.1.3 The procedure shall be as follows:

(a) The lower end of the probe shall be rested against the ground at the test location, with the first extension rod and guide rod in a vertical position.

(b) The hammer shall be raised to bear against the upper anvil, and shall be allowed to fall freely. It shall not be connected to objects which may influence its acceleration and deceleration, and shall be stationary when released in the upper position. The fall shall be 300 mm ± 5 mm.

(c) The hammer shall be used to drive the probe into the ground, with a rate of driving between 20 and 60 blows per minute.

(d) Additional extension rods shall be added as necessary. The rods shall be rotated clockwise one full turn each time a rod is added to ensure that screw joints are tight.

(e) The blow count for every 100 mm of penetration shall be recorded, or at refusal the penetration distance for 50 blows of the hammer. Interruptions exceeding 5 minutes shall be recorded.

(f) If any obstruction to the probe is encountered which cannot be penetrated over 100 mm by 100 blows of the driving hammer, then that probe shall be considered to have reached refusal and the test shall be terminated.

Reporting of results

7.1.4 The following shall be reported:

(a) Blow count for every 100 mm penetration or at refusal the penetration distance for 50 blows of the hammer.

(b) Interruptions exceeding 5 minutes.

(c) Dynamic probe record (Figure 37 of Geoguide 2).

(d) That the test was carried out in accordance with this Specification.