

SPECIFICATION FOR PERMANENT SOIL NAILED SLOPE

1.0 DESCRIPTION

- 1.1 This work shall consist of furnishing the nails, corrosion protection details, materials, field tests and the construction of a nailed slope by internally reinforcing the soil mass with grouted reinforcing elements (nails) in close conformity with the lines, grades, dimensions and design parameters on the drawings or as established by the Engineer.
- 1.2 The nailed slope shall be constructed from the top down as the soil in front of the designed slope profile is removed in stages and the nails are installed and grouted at each level after completion of slope cutting at respective stages. Upon completion of each stage of slope cutting, the exposed soil face shall be protected with a steel mesh and reinforced shotcrete facing. Drainage systems when required shall be installed prior to applying shotcrete/gunite.

2.0 GENERAL

- 2.1 The Contractor shall submit method statement on the nail installation method and can increase the drilled hole diameter or length to develop the required design loads upon Engineer's approval.

3.0 MATERIALS

- 3.1 Steel Nail Reinforcement: shall comply with BS 4449 or equivalent. Thread details shall be as approved or as specified. Only nails greater than 12m in length can be spliced at staggering arrangement using an approved mechanical splicer by the Engineer. The test results of the splicer must be submitted together with the sample of splicer for approval.
- 3.2 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 1.0mm.
- 3.3 Finished internal and external surfaces of the sheathing shall be smooth, clean and free from flaws, pin holes, bubbles, cracks and other defects. Sheathing and all associated components shall be used in accordance with the manufacturer's instructions. Sheathing and other plastic protective components shall:
- not contain any substances that will promote corrosion
 - be covered to prevent exposure to ultra-violet light from direct and indirect sunlight
 - be resistant to slip
 - be capable of withstanding the applied handling stresses, the hydrostatic and grouting pressures.
- 3.4 Centralizers shall be provided on the steel bar and the sheathing at suitable intervals to meet the following requirements:
- the steel bar shall be positioned in the sheathing so that a minimum grout cover to bar of 25mm is maintained
 - minimum clearance of 15mm between the sheathing and the sides of the drill holes or casing.
- 3.5 Corrugated sheathing shall be embedded at least 50mm into soil nail head.

- 3.6 Corrosion Protection: Where required, corrosion protection shall consist of one of the following or combination of:
- Epoxy Coating: The minimum thickness of resin-bonded epoxy coating applied electrostatically to the nail shall be 0.3mm.
 - Encapsulation: The encapsulation shall be fabricated from high density corrugated polyethylene (PE) tubing conforming to the requirements of BS 8081 or equivalent with a minimum wall thickness of 1.0mm. The annulus between the nail and the encapsulating tube shall be a minimum of 25mm and be grouted with grout conforming to Clause 3.10(c) of this specification.
 - Galvanizing: The galvanizing shall be in accordance with BS 729 or BS EN ISO 1461:1999 and shall be hot dipped with minimum coat thickness of 85 μ m.
- 3.7 Steel Welded Wire Fabric : shall comply to BS 4483 or equivalent.
- 3.8 Cast-in-Place or Precast Concrete : Provide concrete for structural concrete facing where required and shown on the drawing. Details of connection, drainage and backfilling procedures shall be construed as shown on the Drawings.
- 3.9 Permanent Structural Shotcrete Facing
- Materials:

Cement – Shall be ordinary Portland Cement complying with BS 12 or MS 522 and Portland Pulverized Fuel Ash Cement complying with MS 1227.

Aggregate – Aggregate shall comply with BS 882.

Accelerating additives shall be compatible with the cement used, be non-corrosive to steel and shall not promote other detrimental effects such as cracking and excessive shrinkage, and shall not contain calcium chloride. They are to be used in accordance with manufacturer's recommendations. Silica fume, if used, shall not exceed 10 percent of the cement weight and shall be an admixture with a minimum of 90 percent SiO₂ with a proven record of performance for use in shotcrete.

Water used in the shotcrete mix shall be potable, clean and free from substances which may be injurious to concrete and steel. Water used shall comply with BS 5328 or MS 28. Testing of water in accordance to BS 3148:1990 or BS EN 1008:2002 is compulsory.

Premixed and prepacked concrete product specifically manufactured as a shotcrete product may be provided for on-site mixed shotcrete if approved by the Engineer. The packages shall contain cement and aggregates conforming to the material portion of this specification.
 - Shotcrete Quality: Shall be produced by either wet mix process or dry mix process achieving a minimum compressive strength of 18 MPa in 7 days and 30 MPa in 28 days. The shotcrete shall have a minimum cement content of 350kg/m³.
- Shotcrete will be accepted based on 28-days strength. The contractor may submit a proposal for expediting the work. The contractor's proposal shall detail methods to ensure that the minimum required 28-days strength is attained.
- Mixture Proportions: Submit for acceptance of the recommended mix proportion, strength results, water-cement ratio and source of materials. Select mix proportion on the basis of compressive strength tests of specimens continuously moist cured until tested at 28 days in accordance with BS 1881 or equivalent. For mixture acceptance purposes, average core compressive strength must be equal to 1.2 times the required

compressive strength specified in (b) above. Water cement ratio shall be 0.35 – 0.50 (by weight), air content $6.5\% \pm 1.5\%$ (by volume) and slump 38mm to 76mm.

- (d) **Batching and Mixing:** Aggregate and cement shall be batched by weight or by equivalent volume. Provide mixing equipment capable of thoroughly mixing the materials in sufficient quantity to maintain placing continuity.
- (e) **Delivery Equipment:** Provide equipment capable of delivering the premixed material accurately, uniformly, and continuously through the delivery hose. Follow recommendations of the equipment manufacturer on the type and size of nozzle to be used, and on cleaning, inspection and maintenance of the equipment. Ready mixed shotcrete shall be delivered in transit mixers.

Provide a supply of clean, dry air adequate for maintaining sufficient air delivery and for simultaneous operation of a suitable blow pipe for clearing away rebound. The compressor shall be capable of providing a minimum of $9\text{m}^3/\text{min}$ (315cfm) per operating nozzle.

- (f) **Pre-construction Testing:** Test panels with the designed slope angle shall be made by each application crew to proof competency of the crew using the equipment, materials, mixture proportions and procedures proposed for the job prior to the commencement of the work.

A test panel at least 1200mm by 1200mm shall be made for each mixture being considered and for each shooting position to be encountered on the job. The test panels shall be fabricated to the same thickness as the structure, but not less than 100mm. Take at least six 76mm diameter cores from each panel for testing in accordance with BS 1881. Samples for testing shall be obtained by the Contractor in the presence of the Engineer.

- (g) **Safety requirements:** Special attention shall be given to eye and dust protection hazards when shotcrete is to be applied. Cement and other admixtures are caustic and can cause skin and respiratory irritation unless sufficient safety measures are taken in addition to the required ventilation. During the application of shotcrete, provide nozzlemen and helpers with gloves, face shields, and adequate protective clothing.
- (h) **Finish:** Provide undisturbed gun finish of shotcrete as applied from nozzle without hand finishing unless otherwise specified. A clean area at base of each lift is required to ensure good bonding interface between lifts.
- (i) **Curing:** Immediately after completion, keep shotcrete continuously moist for at least 24 hours. Use one of the following materials or methods.
 - (1) Continuous sprinkling.
 - (2) Absorptive mat or fabric, sand, or other covering kept continuously wet.
 - (3) Curing compounds. On natural gun or flash finishes, use the application rate of 4 liter per 10m^2 . Do not use curing compounds on any surfaces against which additional shotcrete or other cementitious finishing materials are to be bonded unless positive measures such as sandblasting are taken to completely remove curing compounds prior to the application of such additional materials.

Provide additional final curing immediately after the initial curing and before the shotcrete has dried. Use one of the following materials or methods:

- (1) Continue the method used in initial curing.
- (2) Application of impervious sheet material.

Continue curing for the first 7 days after shotcreting or until the required 7 days strength is obtained. During the curing period, maintain shotcrete in a moist condition as specified.

- (j) Construction Testing: Cut core samples from the structure and test in accordance with BS 1881. A minimum of six cores shall be taken from each 100m² of completed facing.

Alternatively, make one test panel with minimum dimensions of 1200mm by 1200mm by 200mm gunned in the same position as the work represented for each 100m² of completed facing. Panels shall be gunned during the course of the work by the contractor's regular nozzleman. Field cured panels in the same manner as the work, except that the test specimens shall be soaked in water for a minimum of 40 hours prior to testing. The contractor shall collect a minimum of three cores from each panel for testing in accordance with BS 1881.

The average compressive strength of each set of three cores must equal or exceed 85 percent of the compressive strength specified in Clause 3.9(b) of this specification.

- 3.10 Temporary Shotcrete Facing: The contractor shall submit for approval to the engineer, materials, methods and control procedures for this work.
- 3.11 Grout for Nails: Provide a non-shrink neat cement or a non-shrink sand cement grout to be used in soil nail anchorage consisting of a pumpable mixture capable of reaching a minimum cube strength of 30 MPa in accordance with BS 1881. Chemical additives which control, bleed or retard set in the grout are to be used only when approved in writing by the Engineer. Non-shrink additive shall be used in accordance to the manufacturer's specification. Water cement ratio of the grout shall not exceed 0.45.
- 3.12 Fasteners and Attachment Devices: Provide high strength nuts of Grade 4 steel conforming to BS 5950 and BS 4190:2001 or equivalent. Bearing plates shall be of Grade 43A steel plate and comply with BS 4449, BS 5950 and BS 4360. Permanent casings (if required) shall comply with BS 4019. Holes in steel plates for soil nail 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 2mm from the centroid of the plate. The clearance between the steel bar and the hole of the steel plate shall not be more than 2mm. All steel components for soil nails shall be hot-dip galvanized to BS 729 or BS EN ISO 1461:1999.
- 3.13 Soil nails shall have non-corrodible centralizers capable of ensuring an even annulus of grout around the steel bar. Centralizers must also be provided inside and outside of encapsulate nail assemblies and shall be spaced no further than 2m apart. The nominal diameter of the centralizers shall not differ from the specified diameter of the drill hole by more than 10mm.
- 3.14 Horizontal Drains: Provide as required and shown on the drawings, slotted or perforated uPVC pipe. The contractor shall make provisions to ensure that the hole does not collapse prior to the insertion of the slotted or perforated drain.

4 CONSTRUCTION

- 4.1 Submittals : Provide shop drawings, details, test nail procedures, material and mill test certificates, mix designs, qualifications, construction procedures and detailed construction sequencing plans including excavation sequence, at least one week prior to the commencement of the work. The Engineer shall reply to the Contractor's submission within 1 week after receipt of the submission.

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, corrugated sheathing, coupling sleeves, nuts, washers, plates, connectors, centralizers, grout pipes, etc.
- b) details of galvanizer to be employed for galvanizing the steel components and method of making good any damaged hot-dip galvanized coating
- c) details of corrosion protection for the threaded portion of the steel bar at soil nail head
- d) details of working platform
- e) details of temporary support to drill holes
- f) details of permanent casing (if required)
- g) method of storing materials
- h) method of drilling and details of drilling equipment
- i) method of assembling soil nail bars
- j) method of installing soil nail bars into drill holes
- k) method of grouting and details of grouting equipment
- l) details of testing assembly including details of datum for deformation measurement and bearing pad
- m) method of constructing soil nail heads
- n) details of testing assembly including details of datum for deformation measurement and bearing pad

Submit for approval on calibration data of each test jack, pressure gauge, load cell and master pressure gauge used.

Calibration tests shall be performed by an independent testing laboratory within 90 calendar days of the date submitted. Approval or rejection of the calibration data shall be given within 5 working days of submittal.

- 4.2 Qualification: Submit proof of at least two projects similar in size and scope on which Contractor has installed permanent soil nails or ground anchors in the past 2 years.

Drilling operators and foreman shall have a minimum of 2 years experience installing soil nails or permanent ground anchors with the contractor's organization. List of project personnel having appropriate qualifications shall be submitted for the Engineer's approval at least 7 working days prior to any physical works at site. Inadequate proof of personnel qualifications shall be cause for withholding construction approval. Changes to previously approved personnel must be applied and approved in writing.

Provide shotcreting nozzle operators with at least 1 year experience in the application of shotcrete on projects of comparable nature or work under the immediate supervision of foreman or instructor with at least 2 years of such experience.

The Engineer shall approve the contractor's qualification and site personnel within 7 working days after the receipt of the submission. Work shall not start nor any materials ordered until the contractor's qualifications have been approved. The Engineer may suspend the work if the contractor substitutes unqualified personnel for approved personnel during construction. If work is suspended due to the substitution of unqualified personnel, the Contractor shall be fully liable for additional costs resulting from the suspension of the work. Adjustments in contract time resulting from the suspension under such circumstances will not be allowed.

- 4.3 Excavation : Excavation shall proceed in stages, exposing the minimum amount of soil or rock face which will allow the practical and expeditious application of the initial layer of shotcrete and the installation of soil nails, while assuring stability of the excavated face and minimizing ground movements. Rock-blasting below completed portions of the soil nailed slope shall be made using controlled blasting techniques or approved alternative. The Contractor shall be entirely responsible for the temporary stability of the excavation and shall obtain all necessary approvals or permissions from relevant authorities for the excavation works.

- 4.4 Shotcreting : After each stage of cut, in anticipation of shotcreting, clean surfaces of all loose material, mud, rebound from previously placed shotcrete and other foreign matter that will

prevent bonding of shotcrete from the cut surface and dampen surface before shotcreting. Permanent drainage shall be installed as specified in the drawings with temporary protection to prevent the hole from being plugged by shotcrete. Drainage system shall be provided at the bottom of the soil nailed slope in such a manner as to carry the water away from the toe. During placement of shotcrete, the horizontal drains shall be protected against contamination to ensure proper functioning.

Shotcrete shall be applied with the same equipment and the same technique as used to construct the approved test panels. Nozzle operators constructing the test panels are to be the same operators used in placing shotcrete in the work. Thickness measuring pins shall be installed at 1.5m centres in each direction. The pins shall be non-corrosive. Other methods to establish if the required minimum thickness of shotcrete is being applied, may be approved if the contractor can satisfactorily demonstrate the reliability of these other methods.

When a layer of shotcrete is to be covered, it shall first be allowed to develop its initial set. Then, all laitance, loose material, and rebound must be removed by blooming or scraping. Remove all laitance which has been allowed to take final set by sandblasting and thoroughly clean the surfaces.

Firmly position the wire fabric together with thickness measuring pins to prevent vibration while the shotcrete is being applied. Lap mesh two squares in both directions. Tie wires shall be bent flat in the plane of the mesh and not form large knots. A minimum cover of 25mm of shotcrete shall be required.

Thickness, method of support, air pressure and water content of shotcrete shall be controlled in such a manner as to preclude sagging or sloughing off.

The shotcrete shall be applied from the bottom up to prevent accumulation of rebound shotcrete deposited on the surface yet to be covered. Shotcrete shall emerge from the nozzle in a steady uninterrupted flow.

Checking for hollowness underneath the completed shotcrete shall be carried out by sounding with hammer blows. Rectification on the deficient areas shall be carried out by approved method. Shotcreting shall be discontinued and suitable means shall be provided to screen the nozzle stream if wind or air currents cause separation of the stream during placement. Deficient areas shall be rectified at the Contractor's expense and time.

Horizontal and vertical corners shall be filled first and also in areas where rebound cannot escape or be blown free.

Nozzle shall be positioned at such distance and angle to place material behind reinforcement before material is allowed to accumulate on its face. Shotcrete shall not be placed through more than one layer of reinforcing steel rods or mesh in one application unless demonstrated by preconstruction tests that steel can be properly encased.

Construction joints shall be tapered to a thin edge, and the surface of such joint shall be thoroughly wetted before any adjacent section is placed.

Surface defects shall be repaired as soon as possible after initial placement of the shotcrete. All shotcrete which lacks uniformity, exhibits segregation, honeycombing, or lamination, or which contains any dry patches, slugs, voids, or sand pockets shall be removed and replaced with fresh shotcrete.

Do not repair core holes with shotcrete. Fill solid with patching mortar, after cleaning and thoroughly dampening.

Use the following precautions during shotcreting :-

- (a) Do not use rebound or previously expended material in the shotcrete mix.

- (b) The area to which shotcrete is to be applied shall be clean and free of rebound or overspray.
- (c) Discontinue shotcrete if rain or in the presence of runoff and underground seepage.

After the shotcrete surface has attained its initial set, finish as specified in Clause 3.9(h), cure in accordance with Clause 3.9(i) of this specification.

- 4.5 Nail Installation : Drill holes for soil nails at the locations shown in the drawings. Provide nail length and nail diameter necessary to develop load capacity to satisfy testing acceptance criteria for the design load required but not less than lengths or diameters shown on the drawings. Core drilling, rotary drilling, percussion drilling, auger drilling or driven casing can be used. It shall be the contractor's responsibility to choose drilling methods that will maintain stable open drill holes and do not promote mining and loosening of the soil at the perimeter of the drill hole or fracture soils with weak stratification planes by use of high flush volumes and pressure. The Contractor shall provide temporary support to drill holes to prevent collapse of drill holes until completion of grouting, including but not limited to the use of temporary casing. Drill holes shall be cleared of all debris and standing water immediately before installation of soil nails. Before soil nails are installed, the Contractor shall furnish the Engineer with all necessary equipment and assistance to check the inclination, diameter, bearing, cleanliness and length of all drill holes. Subsidence or physical damage by such operations shall result in immediate cessation of operations and repair at contractor's expense.

The set up of drilling plant and ancillary equipment shall be in such a manner that water, spillage of grout, dust, fume and noise generated in the course of drilling operation shall be sufficiently diverted, controlled, suppressed and muffled.

At the ground surface the drill hole shall be located within 150mm of the location shown. At the point of entry the nail angle shall be within plus or minus 3 degrees of that shown on the approved drawings. The diameter of drill holes shall be the minimum diameter as specified. The grout cover to the lower end of steel bar shall be at least 50mm.

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 groundwater and depth of zone of no air return etc. shall be submitted to the Engineer within 2 working days after completion of drilling in a format agreed by the Engineer.

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

Within 12 hours of the completion of grouting, no drilling shall be carried out at a place within 10m radius of any freshly grouted soil nails including soil nails for pull out tests.

Soil nails shall be installed and grouted as soon as possible after drilling. In any case, each drill hole shall not be left unsupported for more than one day. All drill holes shall be checked for cleanliness prior to installation of soil nails. During the whole process of installation, no jacking or hammering of the soil nail bars shall be carried out.

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

Place centralizers at 2m intervals in the total length with the last centralizer 300mm from the end of each nail and ensure that no less than 25mm of grout cover is achieved along the nail.

The grout pipe shall terminate at a point within 150mm 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 150mm 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 spacing of not more than 2m. Grout pipes shall not be removed from the drill holes after insertion and the part protruding from drill holes after grouting shall be trimmed down to the base of soil nail head.

After insertion of steel bar into the drill hole, the top end of the drill hole 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. 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 drill hole during grouting. The Contractor shall propose the arrangement of outlet pipe and sealing plug and carry out site trial to demonstrate that the set up performs satisfactorily. The Contractor shall endeavour to re-use the outlet pipes as much as practicable.

Soil nails shall be grouted over their whole length of steel bar in one single operation. Grout shall be injected into drill hole through the grout pipe to the lower end of drill hole such that air and water are displaced from the drill hole as grouting proceed. When the consistency of the grout flowing out of the outlet pipe is the same as the injection grout, the grouting operation shall stop and the inlet grout pipe is sealed. A pressure head of at least 300mm of grout measured from the top of drill hole 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.

The Contractor shall state the calculated gross volume of the drill holes, discounting the volume of all cast in components of each of the soil nails to be grouted in the request forms for inspection of soil nail installation for the Engineer's agreement. The Contractor shall record the volume of grout used for grouting each drill hole and the volume used for refilling each drill hole after grout settlement. A copy of the records shall be submitted to the Engineer within 2 days after each grouting operation.

In case of excessive grout loss, the Contractor shall report to the Engineer immediately. If a drill hole cannot be fully filled with grout after injecting a volume of grout equal to 10 times the calculated gross volume of the drill hole, discounting the volume of all cast-in components, the Contractor shall immediately cease the grouting operation for that drill hole unless otherwise agreed by the Engineer. The Contractor shall report to the Engineer the grouted length of the drill hole and submit proposal for completing the grouting for that drill hole to the Engineer for approval as soon as possible.

Unless otherwise agreed by the Engineer, for soil nails with double corrosion protection the annular space between the wall of drill hole 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.

Mortar packing and secondary grouting to the wall face shall be accomplished as soon as practical after nail installation.

4.6 Nail Testing

(a) Apparatus

The Contractor shall submit the details of the testing arrangement including the set-up and support for the testing apparatus to the Engineer for approval. The apparatus for measuring loads and deformations shall have an accuracy of 5 kN and 0.01 mm respectively. The apparatus for measuring deformation shall be capable of measuring a displacement of up to 50mm. 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 after drilling.

Dial gauges capable of measuring to the accuracy of 0.01 mm shall be used to measure movement of the nail and measurement error due to rotation of the measuring point during testing shall be avoided. A calibrated hydraulic jack and gauge unit with the calibrated electronic load cell (preferably vibrating wire type) shall be used to apply the test load. The pressure gauge shall be graduated in 500 kPa increments or less and use load cell to measure the applied load. The test loads shall be applied incrementally as per the requirement of BS8081 or unless otherwise specified by the Engineer.

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. Reaction frames should not bear on the shotcrete face within a 1m radius of the centre of the drilled hole and shall be free from any possible movement due to any construction activities, weather conditions or the testing itself. Monitoring instruments should be carefully positioned and independently supported to pick up the extension of the soil nail steel bar and any movement of the steel bearing plate.

(b) Pullout Testing

Install a preliminary test nail, which shall be a non-service nail, and load test to pull-out failure prior to the construction of working nails. Pull-out failure is defined as movement in excess of 1mm between the 1 minute and 10 minute readings or 2mm per log cycle of time over a minimum load holding period of 60 minutes.

The soil nail shall be grouted over the length as specified in the drawings or as directed by the Engineer. The test length of nail shall be chosen such as to cause pullout failure prior to yielding of steel, but it shall not be less than 2.5m. 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. A minimum free length / ungrouted zone of 1m in length to the face shall be provided. Subject to the Engineer's approval, alternative means to form the required bond length may be adopted by the Contractor. 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 method of installation and size of drill hole shall be the same as for construction nails. The test nail shall be grouted in place as part of a regular production grouting process. After grouting, the nail shall not be loaded until the primary grout has attained a crushing strength of at least 30 N/mm^2 , as verified from tests on 150 mm cubes.

The preliminary and routine pullout test shall be made by incrementally loading the nail. The nail movement shall be measured and recorded to the nearest 0.01mm with respect to an independent fixed reference point at each increment of load. The test load shall be monitored with a load cell and pressure gauge as a primary and secondary device respectively. The load holding period shall start as soon as the test load is applied. Movement shall be recorded at 0, 1, 2, 3, 4, 5, 6 and 10 minutes. If the load holding is extended, the nail movement shall be recorded at 15, 20, 30, 40, 50 and 60 minutes. Where required the measurements shall be taken longer as directed by the Engineer. Each increment of load shall be no greater than 25 percent of the design load of the nail tested. The loading shall be terminated at failure or earlier at the option of the Contractor if at least 3 times the design unit bond stress is demonstrated for the preliminary pullout test or at least 2 times the designed nail load for the routine pullout

test. For safety reasons, all nails shall not be stressed beyond 0.8 times the characteristic strength of the nail reinforcement.

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.

Where required, the whole soil nail shall be pulled out from the drill hole 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 drill hole grouted.

(c) Acceptance Criteria

The preliminary test nail is deemed acceptable if the unit bond stress at a failure load or test termination is equal to or greater than twice the design unit bond stress. Unacceptable test results shall result in modifications to design and/or construction procedures. The verification testing procedure shall be repeated.

4.7 Soil Nail Head

Soil nail heads shall be constructed in accordance with the details as shown on relevant Drawings as specified by the Engineer. The Contractor shall submit for the Engineer's agreement a method statement for the construction of soil nail heads.

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

Steel reinforcement for soil nail heads shall be of Grade 460 steel and comply with BS4449. Concrete for soil nail heads shall be Grade 30 or 30 MPa sprayed concrete.

Concreting of soil nail heads shall be carried out in a manner 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. In the method statement, the Contractor shall propose for the Engineer's agreement, the construction sequence of 2-stage sprayed concrete soil nail heads. The Contractor shall also conduct trial runs to demonstrate to the Engineer that the proposed method statement will produce satisfactory results and the rebound of sprayed concrete material is minimal.

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

Where instructed by the Engineer, the Contractor shall uncover a maximum of 3 concreted soil nail heads 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, and the Contractor shall break up all the remaining soil nail heads cast on the same day at that site for the Engineer's examination. The soil nail heads shall be recast and re-examined to the satisfaction of the Engineer.

4.8 Construction Sequencing

The Contractor shall submit the method statement and work program as per the duration of work stipulated in the Contract for the Engineer to review. Follow closely the construction sequence on the approved method statement.

5.0 FINAL EXAMINATION AND ACCEPTANCE

- 5.1 The work will be jointly examined by the Contractor and the Engineer as soon as practicable after the completion of the work. The contractor will be required to carry out survey and prepare final “as-built” drawings of all elements of the work. The drawings shall indicate all dimensions, elevations, inclinations and cross sections of the nailed slope.



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