SECTION 683 ‑ SOIL NAIL WALLS‑

##This section cross-references Sections 175, 610 and 611.

If any of the above sections are relevant, they should be included in the specification.

If any of the above sections are not included in the specification, all references to those sections should be struck out, ensuring that the remaining text is still coherent:

683.01 GENERAL

This section specifies the requirements for the supply of materials, testing and construction of soil nail walls.

**Soil nailing and/or a soil nail wall shall not be used as soil reinforcements or as a soil retaining structure to support any existing bridge spill-through abutment where the existing spill-through abutment fill is to be removed to make way for an increase of clearance either vertically or horizontally beneath the bridge superstructure. Dispensation for this requirement may be granted if all the following conditions are satisfied:**

(a) the abutment is supported on bored piles with a minimum pile diameter greater than 900 mm

(b) the bored piles have adequate structural and geotechnical strength to support any lateral pressure induced by soil movements due to the construction of a soil nail wall

(c) the superstructure, its bearings and its expansion joints can accommodate the additional lateral displacement of the piles without any detrimental effect to the serviceability of the structure during its design life

(d) a monitoring program for ground movement and structure displacement is submitted to the Superintendent for review 4 weeks before the construction of any soil nail walls.

683.02 DEFINITIONS

For the purpose of this section the following definitions shall apply:

**Soil Nail** A component of a soil strengthening system consisting of steel or fibre reinforced polymer (FRP) reinforcement bar(s) inserted centrally into a pre‑drilled hole and grouted in place. A soil nail does not require post-tensioning.

**Soil Nail Wall** A soil strengthening system consisting of soil nails installed at appropriate intervals in both horizontal and vertical directions to provide permanent support to the material retained by the wall.

**Bonded Length** The length of a soil nail along which passive resistance is developed.

683.03 STANDARDS

|  |  |  |
| --- | --- | --- |
| **Table 683.031 Standards** | | |
| **Design Standards** | | **Required for** |
| AS 5100.3 | Bridge Design  Foundations and soil supporting structures | Design and construction of soil nail walls where the walls are associated with bridge structures such as batter slope stability reinforcement adjacent to a bridge structure, directly beneath a bridge abutment and/or bridge approach embankments |
| AS/NZS 4678 and Amdts 1 and 2 | Earth retaining structures | Design and construction of a soil nail wall designed to function as an earth retaining structure not associated with a bridge structure |
| Where the design requirements differ between the two Australian Standards, the requirements of AS 5100 shall take precedence over those of AS/NZS 4678. | | |

Table 683.031 continued next page

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|  |  |
| --- | --- |
| **Table 683.031 Standards** (continued) | |
| **Material and Testing Standards** | |
| American Concrete Institute ACI 440.6M-08 | Specification for Carbon and Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement |
| ASTM D7205/D7205M-06 | Standard Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars |
| ASTM A1059–08 | Standard Specification for Zinc Alloy Thermo-Diffusion Coatings (TDC) on Steel Fasteners, Hardware, and Other Products |
| ASTM C940 | Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory |
| ASTM D7337 | Tensile Creep Rupture |
| ASTM D7205/D7205M‑06 | Tensile properties of the FRP bar |
| ACI 440.3R-04 | Test Method B.8, “Test Method for Creep Rupture of FRP Bars”, or  Test method B.6, “Accelerated test method for alkali resistance of FRP bars”  CSA-S806-02, Annex O, “Test method of alkali resistance of FRP rods” |
| CAN/CSA-S806-12 | Annex H, “Test Methods for Creep of FRP Rods” |
| **Design Standards** | **Required for** |
| CSA-S806-02 | Annex O, “Test method of alkali resistance of FRP rods” |
| AS 1478.2 | Chemical admixtures for concrete, mortar and grout  Part 2: Methods of sampling and testing admixtures for concrete, mortar and grout |
| AS 2193 | Calibration and classification of force-measuring systems |
| AS/NZS 2312 | Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings |
| AS 3972 | General purpose and blended cements |
| AS/NZS 4130 and Amdt 1 | Polyethylene (PE) pipes for pressure applications |
| AS/NZS 4671 | Steel reinforcing materials |
| AS/NZS 4680 | Hot-dip galvanized (zinc) coatings on fabricated ferrous articles |
| BS 8006 | Part 1 Code of practice for strengthened/reinforced soils and other fills, and  Part 2 Code of practice for strengthened/reinforced soils. Soil nail design |
| BS EN 14490:2010 | Execution of special geotechnical works. Soil nailing |
| FHWA-NHI-14-007 | American Federal Highway document |
| Standards are referenced in an abbreviated form (e.g. AS/NZS 4678) | |

Section 175 details the relevant references to these documents.

683.04 SOIL NAIL DESIGN

The geotechnical and structural capacity of a soil nail design shall be in accordance with AS 5100.3 and the appropriate Material and Testing Standards listed in Table 683.031. Notwithstanding the requirements of this standard, a soil nail shall have a minimum of 3 m bonded length. The length of a soil nail within 1 m (minimum) behind the shotcrete facing shall not be included in development of soil nail capacity. The spacing of soil nails shall be not greater than 1.8 m in both horizontal and vertical directions.

A soil nail shall be designed in accordance with AS 5100.03.

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(i) Geotechnical design for soil nails (Rd,g)

Rd,g = gRu,g >=Ed

(ii) Structural strength design for soil nails (Rd,s)

Rd,s = sRu,s >=Ed

Where: Rd,g = Geotechnical soil nail design Load (kN)

g = Geotechnical strength reduction factor

Ru,g = Ultimate geotechnical strength of soil nail (kN)

Rd,s = Structural strength soil nail design Load (kN)

s = Structural strength reduction factor

Ru,s = Ultimate structural strength of soil nail (kN)

Ed = Design action effect (kN)

**HP The Contractor shall submit construction drawings for review by the Superintendent a minimum of four weeks prior to commencement of soil nail installation.**

At each layer of soil nailing the construction drawings shall include the following information:

(a) The Contractor's Nominated Geotechnical Representative who is registered with VicRoads prequalification system in the category of GT‑PRE.

(b) The procedure for inspection of the excavated soil face and verification of consistency with design assumptions including the sampling method and frequency, the methodology and parameters for classification of soils and field estimation of rock strength; and the records that will be retained for quality assurance.

(c) The proposed construction procedure for drilling, installing and grouting the soil nails including details of the drilling equipment and grouting equipment. A permanent Polytetrafluoroethylene (PTFE) or Polyvinyl Chloride (PVC) grout collar shall be installed in each drilled hole before installation of the soil nail to prevent collapse of soil in the drilled hole.

(d) A drawing(s) showing -

(i) full description of expected material types and groundwater levels

(ii) soil nail diameter, hole diameter, grout mix

(iii) the ultimate geotechnical strength of soil nail (Ru,g) between grout and soils assumed in the soil nail design

(iv) the geotechnical strength reduction factor adopted in the design (g)

(v) the ultimate structural strength of soil nail (Ru,s) between soil nail bar and grout assumed in the soil nail design

(vi) the material strength reduction factor adopted in the design (s)

(vii) bond length of the soil nail along which capacity of the nail is developed

(viii) design load of individual soil nails (Rd,g)

(ix) horizontal inclination of soil nails

(x) nail assembly including the soil nail, type and spacing of centralisers, the grout tubes, grout collar and grouting bung

(xi) the encapsulation, anchor head and any materials required for electrical isolation or corrosion protection.

If the Contractor proposes to install the soil nails before applying sprayed concrete to the face of the soil the details to be submitted in accordance with clause 683.04 shall include measures that will be taken to preserve the integrity of the excavated face until sprayed concrete is applied.

Design and construction of soil nail walls shall comply with the requirements of the Australian Standard for Bridge design - Foundations and soil supporting structures as listed in Table 683.031. A soil nail wall designed to function as an earth retaining structure shall meet the requirements of the Australian Standard for Earth retaining structures as listed in Table 683.031. Where the design requirements differ between the two Australian Standards, the requirements of the Australian Standard for Bridge design – Foundations and soil supporting structures shall take precedence over those of the requirements of earth retaining structures.

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683.05 CONSTRUCTION SEQUENCE

The construction of the soil nail walls shall be carried out in the following sequential order unless otherwise approved by the Superintendent:

(a) Soil shall be excavated in layers as specified on the drawings.

(b) The excavated soil face shall be inspected by a suitably qualified geotechnical engineer to confirm consistency with the design assumptions. The Contractor shall ensure that the geotechnical engineer’s inspection records and findings are retained as quality assurance records.

(c) The exposed soil surface shall be prepared, reinforcement placed and one layer of sprayed concrete applied to the face of the soil. Minimum clearance between the reinforcement and the soil surface shall comply with the requirements of the Australian Standard for Bridge design - Foundations and soil supporting structures as listed in Section 175. Sprayed concrete shall comply with the requirements of Section 684.

(d) When the sprayed concrete has attained the specified strength, holes for the soil nails shall be drilled, and soil nails installed and grouted.

(e) Load tests will be carried out to confirm soil nail capacity before excavation of the next layer.

(f) Drains shall be constructed at the time the layers of wall incorporating the drains are constructed.

**HP If the geotechnical engineer’s inspection reveals that the soil profile differs from that assumed in the design, the matter shall be referred back to the designers and soil nails shall not be installed until the design has been verified or amended to the satisfaction of the Superintendent.**

683.06 SOIL NAILS

(a) Steel Reinforcement

(i) Soil nails shall consist of Grade 500N deformed high strength steel reinforcing bars complying with the requirements of AS/NZS 4671 and the requirements of Section 611, including the supply to the Superintendent of a current certificate of approval, issued by the Australian Certification Authority for Reinforcing Steel (ACRS).

The bars shall be detailed as shown on the drawings or as specified.

(ii) Where a soil nail consists of two or more steel reinforcing bars joined by a coupler between bars, the couplers shall be of the same strength grade or higher grade than the bars.

(b) Carbon and Glass Fiber-Reinforced Polymer (FRP) Reinforcement

Where the Contractor proposes to use Carbon or Glass Fiber-Reinforced Polymer Bar Materials for soil nails, approval may be granted by the Superintendent provided that the Contractor demonstrates the adequacy of the proposed FRP system to meet the design requirements of this specification to the Superintendent’s satisfaction.

In addition, the following conditions shall be satisfied:

(i) FRP (bar, nut, washer and bearing plate) shall satisfy all aspects of ACI 440.6.

(ii) The FRP are tested for Tensile Creep Rupture in accordance with ASTM D7337 standard

a. ACI 440.3R-04, Test Method B.8 “Test Method for Creep Rupture of FRP Bars”, or

b. CAN/CSA-S806-12, Annex H “Test Methods for Creep of FRP Rods”.

(iii) FRP bars are tested and show test reports in accordance with ACI 440.3R‑04 Test method B.6 “Accelerated test method for alkali resistance of FRP bars” and CSA‑S806‑02 Annex O “Test method of alkali resistance of FRP rods”.

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(iv) Tensile properties of the FRP bar shall comply with the property requirements of ASTM D7205/D7205M‑06.

(v) The FRP bar used in a soil nail shall be of continuous length with no coupler(s) and contain no joints. Size of FRP bar batches, batch sizes and sampling shall comply with ACI 440.6.

(vi) For certification and quality control, batch testing shall be undertaken in Australia to ASTM D7205/D7205M‑06. Test certificates, both directly related and traceable to each batch, and including a test method statement, shall be endorsed in accordance with the AS ISO/IEC 17025 accreditation for the testing laboratory. Test certificates for each batch of bar shall be provided to the Superintendent prior to FRP bar being used.

(vii) Where nuts and bearing plates are required, the FRP shall be a continuously threaded solid bar with continuously reinforced thread cross section. Bars that have cut or moulded threads applied as a secondary production process shall not be used.

(viii) The design ultimate tensile strength shall be limited to 40% of the minimum tensile strength of that published in the technical data sheet of the manufacturer of the FRP.

(ix) FRP soil nails shall be tested in accordance with clauses 683.10 and 683.11 for verification of construction quality.

(x) The nail head, nuts and the associated anchor plates shall be protected from fire in fire prone areas, such as bush fire.

**HP FRP bar shall not be installed until the AS ISO/IEC 17025 accreditation-endorsed test certificates for each batch of bar have been submitted for review by the Superintendent and written approval to use FRP bar has been given by the Superintendent.**

683.07 CORROSION PROTECTION

(a) Where FRP bars and materials are approved for use as soil nails by the Superintendent, further corrosion protection is not required.

(b) All steel soil nails, including bars, nuts, washers, bearing plates and couplers, shall be either ‑

(i) galvanized in accordance with AS/NZS 4680; or

(ii) thermo-diffusion coated to ASTM A1059, to achieve at least Coating Class 80, or a minimum thickness of zinc of 80 microns; or

(iii) coated with a zinc-rich (>80% zinc by weight in the dry film) coating product that achieves a minimum thickness of zinc of 100 microns.

Nuts shall be suitably treated, after application of corrosion protection, to run freely on the bar thread.

(c) Centralisers shall be provided at 1 m intervals minimum along a soil nail to ensure that a minimum grout cover of 40 mm is maintained over the entire length of the soil nail. Centralisers shall be manufactured from a corrosion resistant material and shall be shaped to ensure achievement of the specified minimum cover during insertion of the nails, minimise disturbance of the hole during insertion, and minimise obstruction to the grouting.

(d) Prior to grouting, all soil nails shall be insulated from contact with grout/shotcrete at the interface between the ground and the underside of the shotcrete facing. The Contractor shall apply corrosion protection over the entire length of the soil nail to be embedded in the shotcrete facing. The protection shall be extended to a minimum of 300 mm behind the underside of the shotcrete facing. Very heavy duty and robust wrapping tapes complying with the requirements of AS/NZS 2312 shall be used for the protection work and these tapes shall be installed in accordance with the manufacturer’s instructions.

(e) All steel soil nails shall be encapsulated in a corrugated sheath sealed at the buried end.  The Superintendent will not consider the use of nails without encapsulation unless the Contractor can:

(i) verify by exhumation of sacrificial nails that the soil nail installation procedure will achieve a minimum cover of 40 mm of dense cement grout for the full length of the nail

(ii) verify during installation of production nails, that the alignment of each hole is at least as straight as the holes drilled for the sacrificial test nails

(iii) demonstrate that the nails will be installed with the lowest part of the nail a minimum of one metre above the maximum known groundwater table.

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(f) Each encapsulation sheath shall:

(i) be manufactured from high density polyethylene complying with AS 4130 with a minimum wall thickness of 2 mm

(ii) have corrugations with a pitch between 12 mm and 24 mm and depth not less than 6 mm

(iii) be securely sealed at the buried end of the nail and at any joints

(iv) extend to the top of the grout collar

(v) withstand a water head of 5 m without leaking or deformation

(vi) be fitted with internal centralisers at each end of the nail and between the ends at a spacing that will ensure satisfactory grout flow and shall achieve a minimum gap of 20 mm between the nail and the sheath

(vii) be fitted with external centralisers at a maximum spacing of 2 m to achieve a gap between the encapsulation sheath and the drilled hole of at least 25 mm.

683.08 CASINGS

A permanent PTFE or PVC grout collar shall be installed in each drilled hole before installation of the soil nail to prevent collapse of soil inside the drilled hole.

Unless the Contractor can demonstrate to the satisfaction of the Superintendent that all of the drilled holes for the soil nails will not collapse in any form or shape at any stage during the entire soil nail installation process, temporary casings shall be placed for the full depth of the bored holes to support and prevent collapse of the drilled holes until supported by the soil nail system itself. The casing shall be withdrawn progressively during grouting of the hole.

The thickness of the casings shall be determined by the Contractor who shall be responsible for its structural adequacy and the effects of any distortion which is likely to occur to the casings.

683.09 GROUT TUBING

Grout and bleed tubing of a minimum internal diameter of 12 mm shall be provided. Tubing shall be made from high density polyethylene Type PN 10 (nominal working pressure of 1 MPa) complying with the requirements of AS/NZS 4130. Tubing shall have a wall thickness of at least 2.0 mm. Tubing shall be of adequate strength to resist damage both during installation and grouting.

The grout collar shall be inserted at least 600 mm into the drilled hole and may project up to 50 mm into the sprayed concrete face.

683.10 SOIL NAIL INSTALLATION

**HP Installation of production nails shall not commence until the soil nail design and the installation procedure as stipulated in clause 683.12(a) and (b) have been validated to the satisfaction of the Superintendent.**

(a) General

Soil nails shall be installed as soon as practicable after completion of excavating each layer. The soil nail shall be inserted and grouted on the same day as the completion of drilling the hole.

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(b) Drilling

Drilling of holes for soil nails shall be in accordance with the drawings or as specified. Deviation in alignment shall not exceed 1 in 20. Deviation from straight shall not exceed 20 mm in any 3 metres. The holes shall be located within 100 mm radius of the design nail position.

Where no protective sheathing is provided for permanent soil nails, the drill hole diameter shall be such that the steel bar shall have a minimum grout cover of 40 mm. For FRP, the drill hole diameter shall be such that it will not restrict the flow of grout to provide a uniform cover to the FRP.

Water or any other liquid shall not be used as drilling fluid or for flushing the holes.

(c) Insertion of Soil Nails

**HP** **All soil nail holes shall be inspected prior to inserting the soil nail. All drilling records shall be available for inspection by the Superintendent prior to inserting the soil nail.**

The soil nail shall be installed in one continuous operation to avoid damage to the nail and the drill hole and shall be positioned and secured to prevent movement.

(d) Bearing Plates and Anchor Heads

Soil nail bearing plates shall have the minimum dimensions in accordance with the drawings, and shall have corrosion protection as specified in clause 683.07. The plates shall be fixed to the nail head through use of a cupped washer and nut to accommodate variation in plate angle. The plates shall be bedded firmly onto the shotcrete face with non-shrink mortar/grout.

If soil nails are anchored within the spayed concrete face the anchor head shall be designed to ensure full penetration of the sprayed concrete. The sprayed concrete at the anchor head shall be adequately reinforced and designed in accordance with Section 610 to resist punching shear and pull out force of the soil nail.

(e) Grouting Equipment

The Contractor shall include full details of the grout proportions and additives, mixing and pumping equipment, and methods which they propose to use in the soil nail installation procedures.

683.11 GROUTING

(a) Grout

(i) Grout Mix Design

Grout for filling soil nail holes shall be composed of cement, water and an admixture to reduce shrinkage and bleeding. Cement shall conform to the requirements for Type GP general purpose cement in accordance with AS 3972 and shall be free from calcium chloride. Admixtures shall not contain chlorides, nitrates or similar electrolytic conducting materials and shall only be used where they will increase workability or reduce shrinkage and bleeding. The water/cement (W/C) ratio shall be as low as possible, consistent with adequate workability and shall be between 0.38 and 0.45.

All batching shall be by mass with an approved measuring device and to an accuracy of **±** 1%.

The Contractor shall state the maximum water/cement (W/C) ratio for the proposed mix design and provide test results including the 7 day compressive strength, bleeding properties and flow cone value.

**The grout mix design shall be strictly adhered to by the Contractor. In the event of changes to the agreed grout mix design, the Contractor shall submit a new grout mix design to the Superintendent for review or approval as appropriate.**

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(ii) Soluble Salts

**Chloride‑ion Content**

The maximum acid‑soluble chloride‑ion content of the grout as placed, expressed as the percentage of the total mass of cement in the grout mix shall not be greater than 0.07%.

**Sulphate Content**

The sulphate content of grout as placed, expressed as the percentage by mass of acid‑soluble SO3 to the total cement in the grout mix shall not be greater than 5%.

Sulphate and chloride‑ion content shall be determined by testing of hardened concrete in accordance with AS 1012.20.

(iii) Testing of Grout

The following tests shall be carried out both on trial batches of grout for mix design purposes and on production batches at the frequency specified:

1. Compressive strength - Test cubes shall be made, cured and tested in accordance with the requirements of AS 1478.2.

The minimum compressive strength for the grout shall be 32 MPa at 7 days.

The cube side dimension shall be in the range 40 to 75 mm.

At least one pair of cubes shall be taken from each five cubic metres or part thereof of grout.

1. Bleeding - At least one bleed test shall be carried out for each five cubic metres or part thereof of grout in accordance with the requirements of ASTM C 940.

The bleeding of the grout shall not exceed 2% of the volume three hours after mixing and shall not exceed 4% of the volume at any time.

All separated water shall be absorbed within 24 hours.

1. Workability - Flow cone value – Testing using a flow cone to determine grout flow time (time to first break in continuous flow of grout) shall be in accordance with AS 1478.2. The flow time of the grout shall be in the range of 10 to 30 seconds.

**At least one determination of flow time shall be made from each five cubic metres or part thereof of grout.**

(b) Grout Mixing and Pumping Equipment

**Details of the mixing and pumping equipment shall be included in the soil nail installation procedure specified in clause 683.10.**

Grout shall be mixed in a high speed mechanical mixer, for at least two minutes, until a uniform colloidal consistency is produced. Mixing by hand, or by a tumbling action, will not be permitted.

Water shall be added to the mixer first, then the cement shall be added gradually, and the grout stirred continuously until pumped into the soil nail hole. Grout shall be stirred for a minimum period of two minutes prior to being pumped into the soil nail hole. Admixtures shall be added to the mix in accordance with the manufacturer's recommendations. The hoppers to the pumps shall be fitted with 2.36 mm sieve strainers. Grout shall not be used later than 1.5 hours after the addition of cement to the mix.

Pumps shall be capable of continuous operation with little pressure variation, and shall have a system for recirculating the grout whilst actual grouting is not in progress. Pumps shall be fitted with a pressure gauge and shall be capable of delivery at pressures up to 1 MPa. The use of compressed air will not be permitted.

All piping to the grout pump shall have a minimum of bends, valves and changes in diameter.  All pipes and fittings shall have a minimum internal diameter of 25 mm.

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All equipment, especially piping, shall be thoroughly washed with clean water after each series of operations and more frequently if necessary.

(c) Grouting Operations

Grouting shall not be carried out while the air temperature is below 5°C, or while the shade temperature exceeds 35°C.

Just prior to grouting, the Contractor shall ensure that all loose soil in a soil nail hole is removed. The soil nail bar shall then be placed centrally in the drill hole. Where a soil nail hole is supported by a temporary casing, the casing shall be withdrawn gradually. A minimum of 0.5 m of the bottom end of the casing shall be filled with grout before the casing is fully withdrawn.

Grout shall then be injected into each sheathing at a speed of between 0.3 m and 0.6 m per second.

The Contractor's grouting procedure shall ensure that there are no air or water inclusions left in the grouted zone.

The volume of grout for each hole shall be recorded. The Contractor shall cease the grouting operation if the volume of grout injected is greater than ten times of the calculated volume to complete the grouting of the soil nail. The Contractor shall report this to the Superintendent immediately and no further grouting shall be continued until the condition is reviewed by the Superintendent.

Where seepage of grout in a soil nail hole has occurred subsequent to grouting, the Contractor shall top up the soil nail hole with grout to the satisfaction of the Superintendent.

683.12 SOIL NAIL TESTING

1. Types of Soil Nail Testing
   1. Design Verification
   2. Sacrificial and Exhumation
   3. Production

The Contractor shall carry out three types of soil nail testing in clause 683.12(a) at appropriate stages of soil nail design and installation to validate the soil nail design and to demonstrate that the proposed procedure will achieve the specified soil nail durability and load capacity.

The tests shall be carried out for each change of soil profiles at the location where soil nails are to be installed.

All test nails shall have a free length a minimum of 1.0 m or longer as specified by the designers to allow for transfer of load to the bonded section of the test nail. The bond length shall be sufficiently long to allow for testing of bond strength between the bar and the grout and between the grout and the soil nail hole. As a minimum, the bonded length shall be a minimum of 2.0 m or equate to one half of the average bonded length of the production soil nails at each row of installation whichever gives the longest bond length.

The tests shall be carried out in the presence of the Superintendent.

Types I and II testing shall be undertaken with the test load cycles in accordance with Table 683.161. Type III testing shall be undertaken with the test load cycles in accordance with Table 683.162.

Any Type I or Type III test that fails to meet the acceptance criteria in Table 683.163, the Superintendent may nominate additional testing until such time where the design assumptions have been verified and the construction methodologies have been amended to the satisfaction of the Superintendent. All cost associated with additional testing shall be borne by the Contractor.

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1. Soil Nail Installation Procedure

**HP The Contractor shall submit a procedure for soil nail installation and grouting to the Superintendent for review a minimum of 2 weeks prior to commencement of Types I and II testing.**

As a minimum and not limited to, the Contractor shall provide the following information to the Superintendent for review:

(i) installation procedure for design verification and sacrificial nails including details of the plant and equipment to be used and the certificate(s) of equipment calibration endorsed in accordance with the AS ISO/IEC 17025 accreditation for the calibration laboratory

(ii) the method of drilling and the proposed hole diameter

(iii) the method, equipment and materials to be used for grouting

(iv) details of loading frame on the face of excavation upon which the test load is applied

(v) details of nail head displacement monitoring device and procedures

(vi) field log sheet showing procedures in recording load cycles as per Table 683.161 and Table 683.162

(vii) plots of nail head displacement as per Table 683.163

(viii) estimated maximum test load to be applied to the nail head

(ix) all details to be recorded on the soil nail lot register

(x) proposed detailed construction procedure.

(c) Calibration of Measuring Equipment

The measuring equipment shall permit elongation to be measured with a maximum uncertainty of 2%. The force measuring system shall comply with the Grade B requirements of AS/NZS 2193.

The tensioning force determined by applying all relevant corrections to the gauge reading from the calibration certificate, and the tensioning force calculated from the elongation shall not differ by more than 4%.

All testing shall be carried out by personnel experienced in this testing and with equipment calibrated by a NATA accredited laboratory. The currency of the Calibration certificates shall be issued no greater than one year from the date of the testing and shall be made available upon request by the Superintendent.

(d) Records

Results of the Types I, II and III soil nail testing shall be documented by the Contractor and a copy of the results forwarded to the Superintendent within 24 hours of completing the test.

683.13 TYPE I - DESIGN VERIFICATION TEST

(a) Test Loads

The test load shall be a minimum of equating to the lowest value of Ru,g (683.04.i) or Ru,s (683.04.ii) based on the bonded length of the test nail.

(b) Pull-Out Test

A batch of at least three Type I tests shall be performed for each type of soil profile encountered. The soil nail configuration and length and the drilling, installation and grouting procedure shall be the same as proposed for the production nails.

The test load cycles shall be undertaken in accordance with Table 683.161.

The test results shall be within the limit of the acceptance criteria in Table 683.163

**HP If any of the verification test results has failed to meet the acceptance criteria in Table 683.162, the Contractor shall not proceed with TYPE II testing until the design assumptions have been modified by the Contractor to the satisfaction of the Superintendent.**

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683.14 TYPE II – SACRIFICIAL AND EXHUMATION

The test results shall demonstrate to the satisfaction of the Superintendent that the proposed procedure will achieve the specified soil nail durability and load capacity. The Contractor may seek dispensation for Type II testing if the following information is provided to the satisfaction of the Superintendent.

* evidence that steel soil nails with encapsulation sheath are to be used as a rock dowel
* evidence that Type I tests in the same rock profile have been undertaken to the satisfaction of the Superintendent.

Where dispensation is granted, such dispensation is site specific and shall not be applied across the remainder of the project or on other projects.

No dispensation for Type II testing shall be considered by the Superintendent if the soil nails are installed in fill, soils, residual soils, or extremely weathered to moderately weathered rocks or the average defect spacing of the rock within the bonded length of the soil nail is less than 100 mm or the Rock Quality Designator (RQD) is less than 50.

(a) Test Load

The Contractor shall assess the load required to exhume the soil nail in order that the soil nail reinforcement as defined in 683.06 will not fail prematurely under the test load and that the entire length of the soil nail can be exhumed from its drill hole.

A batch of at least three Type II tests shall be performed for each type of soil profile encountered. The soil nail configuration and length and the drilling, installation and grouting procedure shall be the same as proposed for the production nails.

(b) Exhumation Test on Sacrificial Nails

The batch of soil nails used for the Type II sacrificial nails shall be exhumed to verify the adequacy of the grout cover. Precautions shall be taken to avoid damage during exhumation to the grout column. The exhumed nails shall be cut into 500 mm lengths and the minimum grout cover at each section shall be photographed, measured and recorded.

If any section on any nail in the batch has a grout cover less than the specified minimum cover the Contractor shall amend the installation procedure and conduct further exhumation tests until the specified minimum cover is achieved at each section of each batch of 3 sacrificial test nails.

The Superintendent shall be notified at least 24 hours in advance of each load test and each exhumation test.

(c) Exhumation Tests on Production Nails without Encapsulation (steel soil nails only)

If the Contractor proposes to install production nails without encapsulation the soil nail installation procedure shall be validated in each type of soil profile encountered by installing and exhuming each batch of three fully grouted production nails. The exhumed nails shall not be reused as production nails.

If any section on any nail in the batch has less than 40 mm of dense grout the production nails shall be encapsulated.

683.15 TYPE III - SOIL NAIL PRODUCTION LOAD TESTS

**HP No production nails are to be installed without completion of Type I and II testing and the results are provided to the Superintendent for review a minimum of 7 days prior to installation of production nails. The Contractor shall submit a pull‑out test procedure and the locations of test nails to the Superintendent for review at least 14 days prior to commencement of soil nail installation.**

The Contractor shall carry out Type III tests per each layer of excavation. The minimum number of Type III testing per each row of soil nails within each layer of excavation is the greatest number of soil nails calculated based on the following criteria:

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(a) 5% of the total number of soil nails

(b) 2 number soil nails

(c) 2 number soil nails per each soil type

(d) 2 number soil nails per installation method.

The locations of the soil nails to be tested along each row of soil nails shall be approximately evenly spaced in accordance with the drawings or as nominated by the Superintendent. The Superintendent shall review the appropriateness of test nail locations. The Type III soil nails production tests shall be supplied, installed and tested by the Contractor in accordance with the requirements of this section.

The tests shall be carried out in the presence of the Superintendent.

(a) Test Nails

A test nail shall be constructed in accordance with clause 683.12 or as nominated by the Superintendent.

A test nail shall not form part of the production nails unless otherwise approved by the Superintendent.

All test nails which do not form part of the production nails shall be trimmed to a minimum of 100 mm below the cut batter face, and shall be fully grouted on completion of the pull‑out test.

(b) Test Load

The test load shall be a minimum of 1.5 times the geotechnical design load (Rd,g) in accordance with clause 683.04(i), or as nominated by the Superintendent.

(c) Pull-Out Test

The test shall be undertaken in accordance with Table 683.162.

The test results shall be within the limit of the acceptance criteria in accordance with Table 683.163.

**HP Any test nails that fail the pull-out test shall be reported to the Superintendent immediately. The reasons for the failure shall be ascertained by the geotechnical consultant nominated by the Contractor and forwarded to the Superintendent for review. The Contractor shall cease installation of the remaining soil nails until such time where the revised design ultimate geotechnical strength (Ru,g****) between ground-grout** **has been addressed to the satisfaction of the Superintendent. The Contractor shall carryout two additional soil nail tests on either side of the soil nail failing to meet the acceptance criteria. The Contractor shall provide mitigation measures at this location to the satisfaction of the Superintendent and pay for all costs associated with this work at no extra cost to the Superintendent.**

683.16 TEST LOAD CYCLES AND ACCEPTANCE CRITERIA

The Test Load shall be calculated relevant to the types of testing. Type I verification test and Type II sacrificial test shall have loading cycles in accordance with Table 683.161 and Type III production nail test shall have loading cycles in accordance with Table 683.162. The test is deemed to have failed if the movement of the nail head does not meet all of the criteria in Table 683.163.

(a) Test Load Cycles

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**Table 683.161 Load Testing for Type I and Type II Testing (Verification and Sacrificial)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Load Cycle** | **% of Load** | **Time held for each load increment**  **(minutes)** | **Accumulative time**  **(minutes)** |
| 1 | 25 | 10 | 10 |
| 50 | 10 | 20 |
| 75 | 10 | 30 |
| 100 | 10 | 40 |
| 2 | 100 | 0, 0.5, 1, 3, 5, and thereafter every 10 minutes to 180 minutes | 220 |
| 3 | 75 | 5 | 225 |
| 50 | 5 | 230 |
| 25 | 5 | 235 |
| 0 | 5 | 240 |
| Notes:   1. The test load shall be maintained constant throughout the entire duration of the testing. At each time interval, the actual movements of the nail head independent of the base plate shall be recorded. 2. Results of the soil nail tests shall be documented by the Contractor in accordance with the format submitted by the Contractor as per clause 683.12(b). The Contractor shall provide a copy of the results to the Superintendent within 24 hours of completing the any individual test. | | | |

**Table 683.162 Load Testing for Type III testing (Production Soil Nails)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Load Cycle** | **% of Load** | **Time held for each load increment (minutes)** | **Accumulative time (minutes)** |
| 1 | 25 | 10 | 10 |
| 50 | 10 | 20 |
| 75 | 10 | 30 |
| 100 | 10 | 40 |
| 2 | 100 | 0, 0.5, 1, 3, 5, and thereafter every 10 minutes to 60 minutes | 100 |
| 3 | 75 | 5 | 105 |
| 50 | 5 | 110 |
| 25 | 5 | 115 |
| 0 | 5 | 120 |
| Notes:   1. The test load shall be maintained constant throughout the entire duration of the testing. At each time interval, the actual movements of the nail head independent of the base plate shall be recorded. 2. Results of the soil nail tests shall be documented by the Contractor in accordance with the format submitted by the Contractor as per clause 683.12(b). The Contractor shall provide a copy of the results to the Superintendent within 24 hours of completing the any individual test. | | | |

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(b) Acceptance Criteria

**Table 683.163**

|  |  |
| --- | --- |
| **Acceptance Criteria** | |
| 1 | The plot of nail head displacement with log time shall be linear and display a decreasing rate of creep, and the creep rate shall be less than 2 mm per log cycle of time at the end of Load Cycle 2. |
| 2 | At any stage during Load Cycle 2, the differential movement of the nail head under the test load shall be less than 0.2% of the bonded soil nail length. |

Notwithstanding of requirements of Type III Production Nail Testing, if any test result fails to meet the acceptance criteria, the Contractor shall undertake the following actions to the satisfaction of the Superintendent. In addition, the Superintendent may nominate additional testing at no additional cost to the Superintendent:

(i) review the soil nail designs and installation procedures

(ii) undertake further testing to verify revised soil nail designs and installation procedures

(iii) submit the revised soil nail designs and testing results to the Superintendent for review.

683.17 SUB SURFACE DRAINAGE

Geocomposite strip drains shall be securely fixed to the excavated soil face prior to construction of the sprayed concrete wall and shall be masked to prevent concrete adhering to the filter face.

The low point of each strip drain shall be connected to a collector pipe with outlets to a spoon drain in front of the wall or as specified on the drawings. The collector pipe shall be fitted with a flush-out riser connected to an inspection opening at the top of the wall as shown on the drawing.

Preformed PVC fittings shall be used for all connections between strip drains and the collector pipe and all connections shall be sealed and protected to prevent ingress of concrete during concrete spraying.

The collector pipe shall be flushed within 4 hours of the completion of the sprayed concrete surrounding it.

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