

# Structures

## Master Specification

### ST-RE-C2 Soil Nailing

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## ST-RE-C2 Soil Nailing

### 1 General

- 1.1 This Part specifies the requirements for the supply of materials and the construction of Soil Nail Structures. These consist of galvanized steel bars that are installed in drilled holes, grouted, fitted with galvanized plates and nuts and covered in a concrete facing. The requirements for sprayed facings and precast facings are specified in ST-SC-C4 "Sprayed Concrete Work" and ST-SC-S3 "Precast Concrete Units" respectively.
- 1.2 The Contractor must comply with the requirements of this Part and the Soil Nail Structure Design / drawings, whichever is the higher standard.
- 1.3 Documents referenced in this Part are listed below:
- a) AS 4130 Polyethylene (PE) pipes for Pressure Applications.
  - b) AS 1012.5 Determination of mass per unit volume of freshly mixed concrete.
  - c) AS 1012.9 Determination of the compressive strength of concrete specimens.
  - d) AS 1214 Hot-dip Galvanized Coatings on Threaded Fasteners.
  - e) AS 1237 Flat Metal Washers for General Engineering Purposes.
  - f) AS 1252 High-strength Steel Bolts, etc.
  - g) AS 3679 Hot Rolled Structural Steel Bars and Section.
  - h) AS 4671 Steel Reinforcing Materials.
  - i) AS 4680 Hot-dip Galvanized (Zinc) Coatings on Fabricated Ferrous Articles.

### Definitions

- 1.4 The following definitions apply to terms used in this Part:

Term	Definition
Representative Section	A zone of soil that can be considered as having homogeneous soil properties and design parameters.

### 2 Quality Requirements

- 2.1 The Contractor must prepare and implement a Quality Plan that includes, at a minimum, the following documentation:
- a) Excavation:
    - i) method and sequence for excavation of soil;
    - ii) method to protect the exposed soil surface from water and protection from drying out prior to nail and wall installation;
    - iii) method for preventing water from ponding at the base of temporary excavations; and
    - iv) procedure to inspect and verify the soil profile conforms to the design assumptions and identify unfavourable ground conditions.
  - b) Drilling and Nail Installation:
    - i) procedure for drilling of holes including identification and protection measures of utilities, method of drilling, proposed use of temporary casing in unstable ground and method to remove drill casings without lowering the grout to soil bond strength;
    - ii) procedure for inspection of the holes and reporting their condition;
    - iii) procedure for removal or treatment of loose or softened soil; and
    - iv) procedure for installation of nails.

- c) Grouting:
    - i) complete and comprehensive details of the grout proportions, additives, mixing and pumping equipment;
    - ii) details of the experience of the personnel supervising grouting activities; and
    - iii) procedure for grouting, included proposed grouting pressure and method for ensuring that the grout completely fills the hole to the line of the excavated surface (particularly when temporary sleeves are used).
  - d) Drainage:
    - i) procedure for installation of drainage mats, strips and slotted pipes as applicable which is to include the methodology of ensuring the minimum facing thickness across the drain can be achieved.
  - e) Testing:
    - i) soil nail test plan to demonstrate compliance with Clause 5;
    - ii) methodology for selecting test nails and frequency of testing to ensure a uniform distribution of tests both vertically and horizontally;
    - iii) methodology for ensuring that unrecognised Representative Sections are identified during installation and additional Verification Testing carried out if required; and
    - iv) methodology for replacement of any nails failing the test.
  - f) Wall Facing:
    - i) procedure for the installation of facing and methods to ensure targeted design thicknesses are achieved; and
    - ii) lateral design swell pressures need to be considered in the soil nail head to sprayed concrete facing connections design. A method to test these connections needs to be developed and applied to ensure that the connection design is sufficient.
  - g) Monitoring Systems:
    - i) methods of monitoring movements during construction and over the service life (i.e. after installation of architectural facing panels) to verify whether movements are within predicted limits; and
    - ii) magnitude of movements (intervention levels) of faces and retained surface levels that if encountered during construction will trigger an immediate design and construction review.
- 2.2 If not provided beforehand, the documentation must be submitted at least 28 days prior to the commencement of site work.
- 2.3 Provision of the documents listed in this Clause shall constitute a **Hold Point**.

### 3 Materials

#### Central Nail and Metal Anchor Components

- 3.1 Unless specified otherwise on the drawings, nails must be hot dipped galvanized 500N deformed high strength steel reinforcing bar. Nails must be formed in one length with no joints and must not be welded. Each nail must be threaded for a minimum length of 150 mm. Nails must be free of corrosion, damage and surface abrasions.
- 3.2 Centralisers must be fabricated from plastic, stainless steel, or other material non-detrimental to the nail. The bearing plate must be fabricated from mild steel and not smaller than 200 mm x 200 mm x 20 mm thick. All metal components must be hot-dipped galvanized in accordance with AS 4680 to produce a minimum coating thickness of 50 µm. Threads of the nails and nuts must be cleaned by centrifuging, brushing or similar process after galvanizing in accordance with AS 1214. Care must be taken during transportation handling storage and installation of the nails to prevent damage to the galvanizing.

## Grout

3.3 Grout properties must comply with the requirements specified in Table ST-RE-C2 3-1.

**Table ST-RE-C2 3-1 Grout requirements**

Property	Requirement
Minimum compressive strength at 7 days	25 MPa
Water cement ratio	Not exceeding 0.45
Consistency	Free from lumps and undispersed cement
Bleeding	Not to exceed 4% of the initial volume. All bleed water must be reabsorbed after 24 hours
Volume change after 24 hours	within the range 0% to +5%

3.4 Documented evidence that the proposed grout mix complies with the specified requirements must be submitted at least 7 days prior to grouting operations commencing.

3.5 Provision of the documentation shall constitute a **Hold Point**.

## 4 Installation

### General

4.1 The Contractor must provide at least 14 days' notice of the day that installation will commence, and 24 hours' notice of the time that drilling of soil nails will commence.

4.2 Provision of the above notices shall constitute a **Hold Point**.

### Drilling and Insertion of Nails

4.3 Following setting out of the soil nail locations, a **Hold Point** shall apply.

4.4 Water must not be used to remove drill cuttings. After drilling and prior to the nail being installed, the Contractor must inspect the holes and provide a report confirming that:

- a) the holes are in a condition suitable for installation of the nails;
- b) the holes are located within the tolerance specified in Clause 7; and
- c) the nails are not corroded or damaged.

4.5 Provision of the inspection result for each hole shall constitute a **Hold Point**.

4.6 The soil nail must be inserted and grouted on the same day as the completion of the drilling. Centralisers must be used to ensure a minimum of 50 mm of grout cover over the nail. The centralisers must:

- a) be placed at the top and bottom ends of the nail, with each not further than 0.3 m from the top and bottom of the hole;
- b) be placed at sufficient locations not exceeding 2.5 m, to keep the nail centralised and to maintain the minimum grout cover at all points along the nail;
- c) not scrape away or otherwise disturb the soils at the surface of the drilled hole during installation of the nail; and
- d) be fixed to the nail and not move relative to the nail during installation or grouting.

4.7 The soil nail must be installed in one operation and at a controlled rate to avoid damage to the nail and the drill hole. The nail must be inserted into the hole to the required depth without difficulty. If the nail cannot be completely inserted, the Contractor must remove the nail and clean or redrill the hole to permit insertion.

### Grouting

4.8 The grout equipment must:

- a) produce a grout that is free of lumps and undispersed cement;
  - b) include a positive displacement grout pump;
  - c) be equipped with a pump pressure gauge that can measure at least twice the intended grout pressure;
  - d) have a minimum of bends, valves and changes in diameter in the piping;
  - e) be sized to enable the grout to be pumped in one continuous operation; and
  - f) include a mixer capable of continuously agitating the grout.
- 4.9 Grout tubing must be high density polyethylene type 50 to AS 4130, with a minimum internal diameter of 12 mm and wall thickness of at least 2.0 mm. Grouting must be in accordance with proven and accepted practice. The grout must be injected at the lowest point of each drill hole and the hole must be filled progressively from the bottom up.
- 4.10 The quantity and pressure of the grout must be carefully controlled and recorded. If a temporary sleeve has been used, the sleeve must be withdrawn immediately following the initial grouting and while the grout is still in a fluid state.
- 4.11 A record must be kept during each session of grouting and will include soil nail identification, total amount of cement (number of bags) and water (litres) used and any problems with grouting equipment and soil nail hole filling.
- 4.12 If a sprayed concrete facing is to be applied to a pre-grouted soil nail, the surface of the grout inside the drilled soil nail hole must be thoroughly cleaned prior to application of the concrete.

## Tensioning the Nail

- 4.13 Plates and nuts must be attached as shown on the Drawing. If precast panels are used, bearing plates must be set normal to the nail by the use of non-shrink epoxy mortar (Epirez 633 or similar approved) and heavy duty grease must be applied to the exposed section of the nail immediately prior to tensioning.
- 4.14 Unless specified otherwise on the drawings, the nut must be tightened with 150 Nm of torque after the grout and any sprayed concrete have obtained 50% of their 7-day compressive strength and the epoxy grout has cured.

## 5 Testing

### Verification Tests

- 5.1 Verification Tests (i.e. ultimate bond friction tests) are carried out to the failure load on sacrificial nails. These must be carried out using the same equipment, methods and hole diameter as proposed for the production nails. The frequency of Verification Tests must be as specified in the Contract Documents, or if no frequency is specified, a minimum of 2 per Representative Section.
- 5.2 Verification Testing must be repeated if there is any change to equipment, methods or hole diameter or a new Representative Section has been identified. Verification Tests must be successfully completed prior to the installation of production soil nails.
- 5.3 Test nails must be installed with a free zone (stressing length), a bonded zone (anchor length), and sufficient steel area such that the test load is less than 90% of the yield strength of the nail. The free zone must be at least 1500 mm long and the bonded zone must be at least 3000 mm long.
- 5.4 The ultimate resistance of the nails must be determined by loading in increments of approximately 16% of the theoretical ultimate resistance, with each increment held until deflections stabilise, or 5 minutes, whichever is longer, up to bond failure. After failure, the nail must be removed in its entirety such that the free zone (stressing length) and bonded zone (anchor length) can be accurately measured.
- 5.5 Completion of the Verification Tests and provision of results shall constitute a **Hold Point**.

## Production Tests

- 5.6 Production Tests (i.e. proof load tests) are non-destructive tests carried out to demonstrate that the design assumptions remain valid during production. The nails are loaded to the design load and the creep measured during one hour. Testing must only be carried out when the grout has attained a minimum compressive strength of 15 MPa.
- 5.7 The frequency of Production Tests must be as specified in the Contract Documents, or if no frequency is specified, a minimum of 5% of all soil nails must be subject to Production Tests. Unless specified otherwise, nails used for proof testing may be either sacrificial or used as permanent nails.
- 5.8 Production Tests must be carried out using the following procedure:
- The nail must be initially seated using a small load typically 5% of the design load, which must be released. The loading jack must use a reaction frame to distribute the load over the soil face.
  - The nail must be loaded in 5 increments of approximately 16% of the design load, with each load held until deflections stabilise, or 5 minutes, whichever is longer, up to 80% of the design load. The load must then be increased in 2 more increments of 10% of the design load, with the first load increment held for 10 minutes, and the second for 60 minutes.
  - The nail deflection must be noted at each load increment and at the design load at time intervals of 0, 0.5, 1, 2, 3, 5, 10, 30 and 60 minutes. The loads must be maintained within 5% of the intended load by means of the load cell. If movement is continuing after 60 minutes then further extension of time may be necessary to plot the rate of creep. The Contractor must not load a nail beyond 80% of its breaking load as specified in AS 1313 at any time throughout the soil nail test. Production testing must be performed using a bearing plate that imposes a maximum bearing pressure of 100 kPa onto the soil face during the testing.
  - If at any stage attempts to further increase the test load simply results in continued pull-out movement of the test nail then the test will be considered unsatisfactory.
  - The nail must be unloaded in increments of 20% of the design load, with the nail deflection noted 2 minutes after each unloading.
- 5.9 Completion of the Production Tests and provision of test results shall constitute a **Hold Point**.

## Test Equipment

- 5.10 Stressing equipment must be used in accordance with the manufacturer's instructions. The Contractor must submit current calibration certificates (no older than 6 months at the date of testing) for stressing and measuring equipment from a NATA registered laboratory.
- 5.11 Provision of the calibration certificates shall constitute a **Hold Point**.
- 5.12 Stressing equipment must be capable of tensioning the complete nail to at least 80% of its breaking load in one operation. The design and control of the stressing system must be such as to allow measurements to be taken to the accuracy specified.

## Acceptance of Test Results

- 5.13 Unless specified otherwise by the Design, a nail is deemed to be acceptable if the following criteria are achieved:
- the plot of creep against log time is linear or shows a decreasing rate of creep at the design load;
  - the creep rate is less than 1 mm between the 1 and 10 minute readings and 2 mm between the 6 and 60 minute readings;
  - the maximum total nail displacement at the design load does not exceed 6 mm beyond the theoretical elastic extension of the stressing length; and
  - unless specified otherwise in the Design, the pull out force exceeds:
    - 5 kN/m for nails embedded in materials within a vertical distance of 2 m from the existing batter crest; or



- ii) 18 kN/m for nails founded in materials below this depth.

## Replacement Nails

- 5.14 If a production test fails, the Contractor must install sufficient additional soil nails to achieve the design load capacity and undertake additional testing necessary to demonstrate that this has been achieved. The Contractor may increase the diameter of the additional drilled holes.

## 6 Hold Points

- 6.1 The following is a summary of Hold Points referenced in this Part:

Document Ref.	Hold point	Response time
2.3	Submission of Quality Documentation	7 days
3.4	Grout prequalification test results	7 days
4.2	Notice of Installation	1 day
4.3	Set out of the soil nails	1 day
4.5	Inspection of holes	2 hours
5.5	Completion of Verification Tests	6 hours
5.9	Completion of Production Tests	6 hours
5.11	Provision of test equipment calibration certificates	3 days

## 7 Verification Requirements and Records

### Test Records

- 7.1 The Contractor must undertake the testing specified in this Clause and supply written evidence of compliance with the lot package.

Table ST-RE-C2 7-1 Verification Requirements and records

Document Ref.	Subject	Property	Procedure	Frequency	Acceptance limits
33.3	Grout	Water Cement Ratio	Site density test to AS1012.5, calibrated to reflect the water cement ratio on grout discharged from the injection nozzle	First batch each day, prior to commencement of grouting.	Refer Table ST-RE-C2 3-1
		Other properties specified in Table 3.2.1	Testing of 200 mm high by 100 mm diameter specimens to AS1012.9	3 samples from each batch of grout.	Refer Table ST-RE-C2 3-1
4.2	Nail Geometry	Nail Position on facing	Site measurement	Each nail	± 150 mm from specified location
		Nail Length	Site measurement	Each nail	+ 300 mm /- 0 mm from specified length
		Nail Inclination:	Site measurement	Each nail	± 30 from specified inclination
5	Nail load capacity	Nail adhesion and displacement under load	Refer Clause 5	Refer Clause 5	Refer clause 5

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