

Master Specification

Part ST-RE-C2

Soil Nailing

September 2024



Government of South Australia
Department for Infrastructure
and Transport

Build.
Move.
Connect.

Document Information

Document Information	
K Net Number:	13523411
Document Version:	1
Document Date:	30/09/2024

Document Amendment Record

Version	Change Description	Date
0	Initial issue	31/08/2023
1	Updated cover page and amendment to Table ST-RE-C2 7-1 to fix error in the soil nail inclination tolerance (should be $\pm 3^\circ$ instead of 30 mm).	30/09/2024

Document Management

This document is the property of the Department and contains information that is confidential to the Department. It must not be copied or reproduced in any way without the written consent of the Department. This is a controlled document and it will be updated and reissued as approved changes are made.

Contents

Contents	3
ST-RE-C2 Soil Nailing	4
1 General	4
2 Documentation	4
3 Materials	6
4 Installation	7
5 Testing	9
6 Hold Points and Witness Points	11
7 Verification requirements and records	12

ST-RE-C2 Soil Nailing

1 General

- a) This Master Specification Part sets out the requirements for the supply of materials and the construction of permanent Soil Nail Structures, including:
 - i) the documentation requirements set out in section 2;
 - ii) the material requirements, as set out in section 3;
 - iii) the installation requirements, as set out in section 4;
 - iv) the testing requirements, as set out in section 5;
 - v) the Hold Point and Witness Point requirements, as set out in section 6; and
 - vi) the verification requirements and records, as set out in section 7.
- b) Soil Nail Structures must comply with the Reference Documents, including:
 - i) AS 1012.5 Methods of testing concrete, Method 5: Determination of mass per unit volume of freshly mixed concrete;
 - ii) AS 1012.9 Methods of testing concrete, Method 9: Compressive strength tests - Concrete, mortar and grout specimens;
 - iii) AS 1237 Tolerances for fasteners;
 - iv) AS/NZS 1214 Hot-dip galvanized coatings on threaded fasteners (ISO metric coarse thread series);
 - v) AS/NZS 1252 High-strength steel fastener assemblies for structural engineering - Bolts, nuts and washers;
 - vi) AS/NZS 3679 Structural steel;
 - vii) AS/NZS 4130 Polyethylene (PE) pipes for pressure applications;
 - viii) AS/NZS 4671 Steel for the reinforcement of concrete; and
 - ix) AS/NZS 4680 Hot dip galvanized (zinc) coatings on fabricated ferrous articles.
- c) The requirements for sprayed facings and precast facings are detailed in ST-SC-C4 "Sprayed Concrete Work" and ST-SC-S3 "Precast Concrete Units".
- d) Subject to obtaining any Approvals from the Principal required by the Contract Documents, the Observational Method must be adopted for both the design and construction of Soil Nail Structures.

2 Documentation

2.1 Construction Documentation

In addition to the requirements of PC-CN3 "Construction Management", the Construction Documentation must include:

- a) for testing:
 - i) a soil nail test plan to demonstrate compliance with section 5;
 - ii) a methodology for selecting test nails and frequency of testing to ensure a uniform distribution of tests both vertically and horizontally; and
 - iii) a methodology for ensuring that unrecognised Representative Sections are identified during installation and additional verification testing carried out if required;

- b) for 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;
- c) where couplers are proposed to be used for soil nails, evidence that that the couplers do not reduce the structural capacity of the soil nail, in accordance with section 3.1c); and
- d) evidence that the proposed grout mix complies in accordance with section 3.2b).

2.2 Construction Methodology

In addition to the requirements of PC-CN3 "Construction Management", the Construction Methodology must include:

- a) for excavations:
 - i) a method and sequence for excavation of soil;
 - ii) a method to protect the exposed soil surface from water and protection from drying out prior to nail and wall installation;
 - iii) a method for preventing water from ponding at the base of temporary excavations; and
 - iv) a procedure to inspect and verify the soil profile by a suitably experienced geotechnical engineer to:
 - A. confirm compliance with the Design Documentation; and
 - B. identify unfavourable ground conditions;
- b) for drilling and soil nail installation:
 - i) a procedure for drilling of holes including identification and protection measures of Utility Services, 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) a procedure for inspection of the holes and reporting their condition;
 - iii) a procedure for removal or treatment of loose or softened soil; and
 - iv) a procedure for the installation of nails;
- c) for 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) a procedure for grouting, including proposed grouting pressure and method for ensuring that the grout completely fills the hole to the line of the excavated surface (including when temporary sleeves are used);
- d) for drainage, a procedure for installation of drainage mats, strips and slotted pipes as applicable which must include the methodology of ensuring the minimum facing thickness across the drain can be achieved;
- e) for testing, a methodology for replacement of any nails failing testing; and
- f) for wall facings:
 - i) a procedure for the installation of facing and methods to ensure the requirements of the Design Documentation thicknesses are achieved; and

- ii) consideration of lateral design swell pressures 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; and
- g) a grouting procedure, in accordance with section 4.3j).

2.3 Quality Management Records

In addition to the requirements of PC-QA1 “Quality Management Requirements” or PC-QA2 “Quality Management Requirements for Major Projects” (as applicable), the Quality Management Records must include:

- a) the inspection report, required in section 4.2f); and
- b) the verification records required by Table ST-RE-C2 7-1.

3 Materials

3.1 Central soil nail and metal anchor components

- a) Soil nails must be hot dipped galvanized, 500 N deformed high strength steel reinforcing bar.
- b) Subject to section 3.1c), soil nails must be formed in one length with no joints and must not be welded.
- c) Soil nails may use couplers where it can be demonstrated as part of the Construction Documentation that they do not reduce the structural capacity of the soil nail.
- d) Each soil nail must be threaded for a minimum length of 150 mm.
- e) Soil nails must be free of corrosion, damage, and surface abrasions.
- f) Centralisers must be fabricated from material which is non-detrimental to the soil nail.
- g) Centralisers must be shaped to ensure achievement of the specified minimum cover during insertion of the nails, minimise disturbance to hole during insertion, and minimise obstruction to grouting.
- h) Metal centralisers must:
 - i) be of a similar material as the soil nail, to prevent galvanic corrosion incurred as a result of dissimilar metals; or
 - ii) if not of a similar material as the soil nail, be applied with galvanic protection.
- i) The bearing plate of soil nails must be fabricated from mild steel and must not be smaller than 200 mm x 200 mm x 20 mm thick.
- j) All metal components of soil nails must be hot-dipped galvanized in accordance with AS/NZS 4680 Hot-dip galvanized (zinc) coatings on fabricated ferrous articles, to produce a minimum coating thickness of 50 µm.
- k) Threads of the soil nails and nuts must be cleaned by centrifuging, brushing or similar process after galvanizing in accordance with AS/NZS 1214 Hot-dip galvanized coatings on threaded fasteners (ISO metric coarse thread series).
- l) Care must be taken during transportation handling storage and installation of the soil nails to prevent damage to the galvanizing.

3.2 Grout

- a) Grout properties must comply with the requirements specified in Table ST-RE-C2 3-1.
- b) The Construction Documentation must include evidence that the proposed grout mix complies with the specified requirements.

Table ST-RE-C2 3-1 Grout requirements

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

4 Installation

4.1 General

The Contractor must provide at least 14 days' notice of the day that installation will commence, which will constitute a **Witness Point**. The installation cannot commence until the Contractor has proceeded beyond the Witness Point.

4.2 Drilling and insertion of soil nails

- a) Following setting out of the soil nail locations, a **Hold Point** will apply. Drilling of the relevant soil nails must not commence until this Hold Point is released.
- b) Water must not be used to remove drill cuttings.
- c) After drilling and prior to the soil nail being installed, the Contractor must inspect the holes and provide a report to the Principal confirming that:
 - i) the holes are in a condition suitable for installation of the soil nails;
 - ii) the holes are located within the tolerance specified in section 7; and
 - iii) the soil nails are not corroded or damaged.
- d) The inspection in accordance with section 4.2c) for each hole will constitute a **Hold Point**. Installation of the soil nail must not commence until this Hold Point is released.
- e) In addition to the notification period requirements of Table ST-RE-C2 6-1, the inspection in accordance with 4.2d) must occur within 2 hours of the relevant hole being drilled.
- f) The inspection report in accordance with section 4.2c) for each hole must be submitted within 5 Business Days as part of the Quality Management Records and will constitute a **Hold Point**.
- g) The soil nail must be inserted and grouted on the same day as the completion of the drilling.
- h) Soil nail centralisers must be used to ensure a minimum of 50 mm of grout cover over the soil nail.
- i) The soil nail centralisers must:
 - i) be placed at the top and bottom ends of the soil nail, with each no further than 0.3 m from the top and bottom of the hole;
 - ii) be placed at sufficient locations to not exceed a length of 2.5 m, to keep the soil nail centralised and to maintain the minimum grout cover at all points along the soil nail;
 - iii) not scrape away or otherwise disturb the soils at the surface of the drilled hole during installation of the soil nail; and
 - iv) be fixed to the soil nail and not move relative to the soil nail during installation or grouting.

- j) The soil nail must be installed in one operation and at a controlled rate to avoid damage to the soil nail and the drill hole.
- k) The soil nail must be inserted into the hole to the required depth without difficulty. Where the soil nail cannot be completely inserted, the Contractor must remove the soil nail and clean or redrill the hole to permit insertion in accordance with this section 4.2.

4.3 Grouting

- a) The grout equipment must:
 - i) produce a grout that is free of lumps and undispersed cement;
 - ii) include a positive displacement grout pump;
 - iii) be equipped with a pump pressure gauge that can measure at least twice the intended grout pressure;
 - iv) have a minimum of bends, valves and changes in diameter in the piping;
 - v) be sized to enable the grout to be pumped in one continuous operation; and
 - vi) include a mixer capable of continuously agitating the grout.
- b) Grout tubing must be high density polyethylene type 50 to AS/NZS 4130 Polyethylene (PE) pipes for pressure applications, with a minimum internal diameter of 12 mm and wall thickness of at least 2.0 mm.
- c) Grouting must be in accordance with proven and accepted practice.
- d) The grout must be injected at the lowest point of each drill hole and the hole must be filled progressively from the bottom up.
- e) The quantity and pressure of the grout must be carefully controlled and recorded.
- f) Where the grout volume exceeds the expected volume by more than 20% this will be deemed a Non-Conformance, and subject to the processes as detailed in PC-QA1 "Quality Management Requirements" or PC-QA2 "Quality Management Requirements for Major Projects" (as applicable).
- g) Where a temporary sleeve is used:
 - i) a minimum 1.0 m must be filled with grout prior to removal of the sleeve; and
 - ii) the sleeve must be withdrawn progressively following the initial grouting and while the grout is still in a fluid state.
- h) A record must be kept during each session of grouting and must 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.
- i) Where 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.
- j) The Contractor's grouting procedure, submitted as part of the Construction Methodology, must ensure that there are no air/water inclusions left in grouted zone.
- k) Where seepage occurs following initial grouting, this will be deemed a Non-Conformance and subject to the processes as detailed in PC-QA1 "Quality Management Requirements" or PC-QA2 "Quality Management Requirements for Major Projects" (as applicable), which may require the Contractor to top up the soil nail hole with grout to the satisfaction of the Principal.

4.4 Tensioning the soil nail

- a) Plates and nuts must be attached as detailed in the Design Documentation.

- b) Where precast panels are used, bearing plates must be set normal to the soil nail by the use of non-shrink epoxy mortar (Epirez 633 or similar approved by the Principal) and heavy duty grease must be applied to the exposed section of the soil nail immediately prior to tensioning.
- c) The soil nail nut must be tightened with 150 Nm of torque after:
 - i) the grout and any sprayed concrete have obtained 50% of their 7-day compressive strength; and
 - ii) the epoxy mortar required by section 4.4b) has cured.

5 Testing

5.1 Verification tests

- a) Verification tests (i.e. ultimate bond friction tests) must be carried out to the failure load on sacrificial soil nails using the same equipment, methods and hole diameter as proposed for the production of the soil nails.
- b) The frequency of verification tests must be a minimum of 2 per Representative Section.
- c) Verification testing must be repeated if there is any change to equipment, methods or hole diameter or a new Representative Section has been identified.
- d) Verification tests must be successfully completed prior to the installation of production soil nails.
- e) Test soil 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 soil nail. The free zone must be at least 1,500 mm long and the bonded zone must be at least 3,000 mm long.
- f) The ultimate resistance of the soil 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 soil nail must be removed in its entirety such that the free zone (stressing length) and bonded zone (anchor length) can be accurately measured.
- g) The Contractor must submit completed verification test results, which will constitute a **Hold Point**. Installation of the production soil nails within the same Representative Section must not commence until this Hold Point is released.

5.2 Production tests

- a) Production tests (i.e. non-destructive proof load tests) must be carried out to demonstrate that the Design Documentation remains valid during the Works.
- b) Production tests must load the soil nails to the design load and measure the creep for one hour.
- c) Production testing must only be carried out when the grout has attained a minimum compressive strength of 15 MPa.
- d) A minimum of 5% of all soil nails or 3 soil nails, whichever is greater, must be subject to production tests.
- e) Soil nails used for production testing may be either sacrificial or used as permanent soil nails.
- f) Soil nails that fail production testing must not be used in the permanent works.
- g) Production tests must be carried out using the following procedure:
 - i) the soil nail must be initially seated using a small load typically 5% of the design load, which must be released;
 - ii) the loading jack must use a reaction frame to distribute the load over the soil face;

- iii) the soil nail must be loaded to 80% of the design load in 5 increments of approximately 16% of the design load. Each load increment is to be held until deflections stabilise, or for 5 minutes, whichever is longer;
 - iv) 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;
 - v) the soil 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;
 - vi) the loads must be maintained within 5% of the intended load by means of the load cell;
 - vii) where movement is continuing after 60 minutes then further extension of time may be necessary to plot the rate of creep;
 - viii) the soil nail must not be loaded beyond 80% of the ultimate tensile strength (UTS) of the soil bar, at any time throughout the soil nail test;
 - ix) 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;
 - x) where at any stage attempts to further increase the test load simply results in continued pull-out movement of the test soil nail then the test will be considered unsatisfactory; and
 - xi) the soil nail must be unloaded in increments of 20% of the design load, with the soil nail deflection noted 2 minutes after each unloading.
- h) The Quality Management Records must include all completed production test results.

5.3 Test equipment

- a) Stressing equipment must be used in accordance with the manufacturer's instructions.
- b) 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.
- c) Submission of the calibration certificates in accordance with section 5.3b) will constitute a **Witness Point**. Stressing with the relevant equipment must not occur until the Contractor may proceed beyond the Witness Point.
- d) Stressing equipment must be capable of tensioning the complete soil nail to at least 80% of its breaking load in one operation.
- e) The design and control of the stressing system must be such as to allow measurements to be taken to the accuracy specified.

5.4 Acceptance of test results

Where the Design Documentation has not specified acceptance criteria, the following must be achieved:

- a) the plot of creep against log time must be linear or show a decreasing rate of creep at the design load;
- b) the creep must be less than 1 mm between the 1 and 10 minute readings and 2 mm between the 6 and 60 minute readings;
- c) the maximum total soil nail displacement at the design load must not exceed the lesser of 0.1% or 6 mm beyond the theoretical elastic extension of the stressing length; and
- d) the pull out force must exceed:
 - i) 5 kN/m for soil nails embedded in materials within a vertical distance of 2 m from the existing batter crest; or

- ii) 18 kN/m for soil nails founded in materials below the depth in accordance with section 5.4d)i).

5.5 Replacement soil nails

- a) If a production test fails, the Contractor must install sufficient additional soil nails (in consultation with the Designer) to achieve the design load capacity and undertake additional testing necessary to demonstrate that this has been achieved.
- b) The Contractor may increase the diameter of the additional drilled holes where allowed by the Design Documentation or in accordance with the process set out in PC-EDM1 "Design Management" in consultation with the Designer.

6 Hold Points and Witness Points

- a) Table ST-RE-C2 6-1 details the review period or notification period, and type (documentation or construction quality) for each Hold Point referred to in this Master Specification Part.
- b) Table ST-RE-C2 6-2 details the review period or notification period, and type (documentation or construction quality) for each Witness Point referred to in this Master Specification Part.

Table ST-RE-C2 6-1 Hold Points

Section reference	Hold Point	Documentation or construction quality	Review period or notification period
4.2a)	Set out of the soil nails	Construction quality	24 hours notification
4.2d)	Inspection of holes	Construction quality	24 hours notification
4.2f)	Inspection report	Documentation	5 Business Days review
5.1g)	Verification test results	Documentation	48 hours review

Table ST-RE-C2 6-2 Witness Points

Section reference	Witness Point	Documentation or construction quality	Review period or notification period
4.1	Notice of installation	Construction quality	14 days notification
5.3c)	Test equipment calibration certificate	Documentation	3 Business Days review

7 Verification requirements and records

The Contractor must provide written verification as part of the Quality Management Records that the requirements listed in Table ST-RE-C2 7-1 have been complied with.

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

Section reference	Subject	Property	Procedure	Frequency	Acceptance limits
3	Grout	Water cement ratio	Site density test to AS 1012.5 Methods of testing concrete, Method 5: Determination of mass per unit volume of freshly mixed concrete, calibrated to reflect the water cement ratio on grout discharged from the injection nozzle	First batch each day, prior to commencement of grouting	In accordance with Table ST-RE-C2 3-1
		Other properties specified in Table ST-RE-C2 3-1	Testing of 200 mm high by 100 mm diameter specimens to AS 1012.9 Methods of testing concrete, Method 9: Compressive strength tests - Concrete, mortar and grout specimens	3 samples from each batch of grout	In accordance with Table ST-RE-C2 3-1
4	Nail geometry	Soil nail position on facing	Site measurement	Each soil nail	±100 mm from the specified location
		Soil nail length	Site measurement	Each soil nail	+300 mm / -0 mm from the specified length
		Soil nail inclination:	Site measurement	Each soil nail	±3° from the specified inclination
5	Nail load capacity	Soil nail adhesion and displacement under load	In accordance with section 5	In accordance with section 5	In accordance with section 5