APPENDIX B

Standardised Specification : Soil Nails

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STANDARDISED SPECIFICATION : SOIL NAILS

This document has been prepared with reference to the COLTO Standard Specifications for Road and Bridge Works for State Road Authorities, Section 7500 and the British Standard Code of Practice for Ground Anchorages, BS 8081:1989.

1. SCOPE

This Specification pertains to; the supply, installation, construction, and testing of the following components of the required lateral support:

- Soil Nails

2. DEFINITIONS

Rock bolts / soil nails / anchors are permanent installations manufactured from a high-yield deformed bar of specified diameter and length, fully column-bonded with resin or cement grout, equipped with a face plate, washer and hemispherical or hexagon nut attached to the protruding end of the steel bar. (The use of resin or cement grout for column-bonding shall be at the Contractor's discretion, unless specifically detailed.) Greased-sleeve free lengths, and ribbed-sheath fixed lengths are often required.

3. GENERAL REQUIREMENTS

3.1 Protective Measures

Protective measures are the precautions which the Contractor must take to avoid any damage to the existing structures and materials below and within the work area as a result of the movement of plant and other construction activities required to undertake the soil nailing operations or any

other reason related to the Contractor's construction activities in this regard.

If any element of the lateral support system is damaged or becomes ineffective due to any cause, it shall be repaired or replaced. Such repair or replacement of damaged or ineffective lateral support elements shall be carried out by the Contractor without additional payment.

3.2 Access to Construction Area

Drive on access for the Contractor's plant, equipment, materials and other resources will be available. However, the Contractor is to coordinate with Others to construct bench working platforms from which to carry out the works. A top-down procedure is envisaged.

3.3 Inspections by Engineer

Excavation beyond/below (soil nail) installation level will only be undertaken once the soil nails have been tested and written approval of the Engineer has been obtained. The Contractor will give the Engineer at least 48hr advance notice of any inspection required.

The Contractor shall make available suitable equipment together with a qualified operator with which the specialist representative of the Engineer can be brought to within half a metre of any part of the surface of the slope.

4. MATERIALS AND EQUIPMENT

4.1 Materials for Rock Bolts / Soil Nails / Anchors

All soil nails shall be hot-rolled, continuously-threaded, high-tensile steel bars which comply with the requirements of SABS 920. ‘Threadbars’ shall be used in areas of anticipated ‘favourable’ geology. Self-drilling Hollow Anchors (SDA) shall be used in areas of anticipated ‘adverse’ geology (that is; in collapsible and/or saturated soils, clays, boulder horizons, etc.). All soil nails shall be corrosion protected as follows;

- Threadbar: Hot-dip galvanising to SANS 763/ISO 1461 (minimum 85µm)
- SDA: Thermal zinc diffusion (minimum 45µm) to SANS 53811.2006

*The free-length of the anchor to be encased in a greased sleeve.

The anchors shall be supplied with 200x200x10mm steel faceplates, washers, and hemispherical or hexagon nuts with sufficient capacity to resist the loads to which they will be subject. All faceplates, washers and nuts shall be galvanised to SANS 763/ISO 1461.

In general, the design of the lateral support system shall be based on the following.

Table 1. Design Data (DYWIDAG-SYSTEMS INTERNATIONAL, *GEWI* Threadbar System)

Bar Diameter (mm)	**Cross-sectional Area** (mm²)	**Tensile Strength** f_t (N/mm²)	**Ultimate Tensile Force** F_t (kN)	**Maximum Test Load** WL_{150} (kN)	**Maximum Working Load** WL (kN)
16	210	550	111	83	**55**
20	314	550	173	130	**87**
25	491	550	270	203	**135**
32	804	550	442	332	**221**

Notes: 1. $WL_{150} = 0.75F_t$ for geotechnical applications.
2. $WL_{150} = 1.5WL$

Table 2. Design Data (DYWIDAG-SYSTEMS INTERNATIONAL, *DYWI* Drill Hollow Bar System)

Bar Diameter (mm)	**Cross-sectional Area** (mm²)	**Load at Yield** F_y (N/mm²)	**Ultimate Tensile Force** F_t (kN)	**Maximum Test Load** WL_{150} (kN)	**Maximum Working Load** WL (kN)
R32-210	340	160	210	158	**105**
R32-250	370	190	250	188	**125**
R32-280	410	220	280	210	**140**
R32-320	470	250	320	240	**160**
R32-360	510	280	360	270	**180**
R32-400	560	330	400	300	**200**
R38-420	660	350	420	315	**210**
R38-500	750	400	500	375	**250**
R38-550	800	450	550	413	**275**

Notes: 1. $WL_{150} = 0.75F_t$ for geotechnical applications.
2. $WL_{150} = 1.5WL$

5. MANUFACTURE

5.1 Materials for Rock Bolts / Soil Nails / Anchors

Soil Nails shall be manufactured from high yield, deformed bar to the diameter indicated in the design drawing. The bar length specified shall be the required length of bar to be bonded to the

geological profile, and due extra allowance in the cutting length shall be made for any length (including the threaded portion protruding from the geological profile) as required for installation. The bar shall be threaded with a course thread which shall not reduce the overall specified bar diameter.

Faceplates shall be 200mm square, 10mm thick, load-indicating type, with working load carrying capacities as specified. Hemispherical and hexagon nuts shall also be manufactured to suit this loading requirement.

Hot-dip galvanising of soil nails and soil nail accessories is required.

6. HOMING AND GROUTING

6.1 Drilling

Holes for soil nails shall be drilled to a diameter of at least 130mm and to the angle indicated in the design drawing. Any drilling machine or procedure may be employed that can produce a stable hole that is of adequate dimension (within the permitted tolerance) and free of obstructions in order to freely accommodate the soil nail and grout.

The drilling method shall be such as to keep disturbance of the surrounding ground to a minimum and shall also ensure that drilling or flushing does not give rise to excessive loss of ground when compared to the nominal volume of the drill hole. The general geology is detailed in the Specification to which this document is attached. The Contractor shall have all the relevant equipment (bits, casings, etc.) available to drill efficiently in areas of both anticipated ‘favourable’ and ‘adverse’ geology.

Localised distortions such as sudden change of drill hole section or deviation from the straight shall not be permitted. Particular care in this respect is required when advancing the hole with handheld machines and extension steel.

After each hole has been drilled to its full length and flushed out by compressed air and water to remove all loose materials, the hole shall be probed to ensure that no collapse has occurred and that it has been cleaned over its full length. The hole shall be plugged immediately after drillingto prevent debris from entering.

6.2 Soil Nail Insertion

6.2.1 Procedure

The soil nails are to be fitted with non-metallic spacers and homed centrally in the holes and grouted for the full drill-hole length. There shall be free lengths (greased sleeves) for all soil nails as indicated in the design drawings, and ribbed sheaths for all ‘Threadbar’ anchors. The soil nail

must not protrude more than 150mm from the slope face on completion and shall be tensioned to a load specified by the Engineer.

6.2.2 Tolerances

Permissible deviations (PD) appropriate to the degree of accuracy required shall be applied to linear dimensions, position, verticality and level. The range of permissible deviation is given as follows:

- Diameter of Drill Hole PD of diameter of hole from specified diameter (PD = ± 5mm).
- Alignment PD of alignment of hole from that specified (PD = ± 5°).
- Length of Drill Hole PD of length of drill hole from that specified (PD = ± 100mm).
- Face Excavation as specified on drawings (PD = ± 50mm).

6.2.3 Records

During the drilling operations, all changes in penetration rate and changes in ground type shall be recorded together with notes on water levels encountered, drilling rates, flushing losses or gains, and stoppages.

The Contractor shall, notwithstanding the above, notify the Engineer immediately of any ground conditions encountered contrary to that indicated in the Specification to which this document is attached. The Contractor shall further record the date, times during which each hole is drilled, the soil material encountered at various depths in the drill hole, and the subsequent date on which the soil nails are grouted and installed. The Contractor shall submit these records to the resident engineer daily for approval and measurement purposes.

On completion, the Contractor is to submit an As-Built face drawing and the completed Quality Control Sheets with the Soil Nail Numbers referenced to the Quality Control Sheets. A typical Quality Control Sheet is attached to this document.

6.3 Grouting

6.3.1 Procedure

All soil nails shall be grouted the full length, as indicated in the design drawing. Grouting may be either by way of ordinary cement grouting with or without additives, or by using cement or resin cartridges all as approved by the Engineer. The holes must be filled by pressure-grouting (that is; pumped into the hole and filled from the base up). The Contractor shall ensure that whatever method he proposes to use, the grout cover to the soil nail is continuous and completely fills the annular space between the soil nail and wall of the hole. In the case of a high water table and potential hole collapse it is likely to be necessary to install a temporary casing, to be retracted as the grout is injected. Special precaution is required in this regard with respect to hole collapse,

the possible shrinkage of cement grouts upon setting, and the mixing of resin or cement filled cartridges respectively.

If, for any reason, grouting is interrupted and/or the installation of the soil nail is delayed beyond the setting period of the grout, the soil nail shall be removed from the hole. The grout shall then be removed by flushing or re-drilling, and the soil nail homing and grouting stages repeated.

The Contractor shall provide the Engineer with a method statement of his proposed method of grouting. The Contractor will be required to prove to the satisfaction of the Engineer the effectiveness of his proposed method. In particular the Contractor shall demonstrate to the Engineer that he is able to comply with the requirements of these specifications before approval will be given by the Engineer for the Contractor to proceed with his proposed method. It is integral that all soil nails are grouted from the base of the hole up.

Soil nail pull-out tests will be undertaken on 100% of all soil nails installed. The work associated with these trials shall be measured and paid for at the rates tendered for. Trials which are unsuccessful and/or, in the opinion of the Engineer, do not meet the requirements of the Specification will not be measured or paid for.

All soil nails are to be locked off at 75% of the working load for temporary structures and 90% of the working load for permanent soil nails once a grout strength of 25MPa (minimum) is achieved. The contractor must provide the necessary jacking equipment to achieve these lock off loads.

6.3.2 Cement Grout

Only Portland cement complying with SABS ENV 197-1 CEM-1 and which is less than one month old shall be used. The temperature of the cement shall be less than 40°C.

Fine aggregate shall consist of siliceous granules, finely ground limestone or very fine sand. It shall pass a 0.600mm sieve and shall be subject to the approval of the Engineer. The aggregate content in the grout shall not exceed 30% of the mass of the cement.

Admixtures shall not be used in the grout without the approval of the Engineer. Admixtures shall be free of any product liable to damage the steel or the grout itself, such as halides, nitrates, sulphides, sulphates, etc. The amount of admixture to be used shall be in accordance with the manufacturer's instructions. If groundwater/seepage is encountered, the Contractor will need to use a suitable curing agent additive to assist concrete curing below the water table. A suitable example product is CHRYSO Aquabeton. The mixed grout shall have the following properties:

- C1-ions content shall not exceed 750mg per litre.
- The viscosity shall be between 500 cP and 2500 cP. The viscosity, 20 minutes after mixing, shall not exceed 2 500 cP.
- Bleeding at 20°C shall not exceed 2% by volume, 3 hours after mixing, and the maximum bleeding shall not exceed 4%. In addition, the separated (bleed) water shall be

reabsorbed after 24 hours.

- The compressive strength of 100mm cubes made of the grout and cured in a moist atmosphere for the first 24 hours and thereafter in water at 20°C shall exceed 20MPa at 7 days and 35 MPa at 28 days.

6.3.3 Resin Grout

Resin grout shall comply with the recommendations of BS 8081 and be prepared and applied in accordance with the manufacturer's prescription.

A sufficient number of cartridges shall be used to ensure the annulus around the soil nail is completely full over the full length of the hole.

End cartridges for the anchorage zone shall be of fast-setting resin whilst the column shall be filled with slow-setting resin or cement cartridges. Tensioning shall be carefully controlled to ensure thatit takes place after setting of the end cartridges but prior to commencement of setting of the column grout.

Those parts of the soil nails due to be grouted or surrounded with mortar or epoxy resin shall be cleaned of grease, oil, loose rust, or other matter that may impair the bond.

7. TESTING

7.1 Soil Nail Pull-out Tests

The Engineer will require the Contractor to undertake routine soil nail pull-out tests to demonstrate that the soil nails are able to resist the working loads specified. 100% of the soil nails installed will be tested after a minimum grout strength of 25MPa is achieved. The soil nails will be tested to 125% of the working load for temporary soil nails and 150% for permanent soil nails.

The tests will be undertaken with a suitably light hydraulic jack fitted with a dial gauge which can be read to an accuracy of 0.1kN. The jack and dial gauge will be required to be calibrated by an accredited laboratory approved by the Engineer at the commencement of the project, and again whenever this may be required by the Engineer. The certificate of calibration must be submitted to the Engineer for his acceptance.

All pull-out tests must be undertaken in the presence of and to the satisfaction of the Engineer. Table 2 below outlines the pull-out test procedure.

Table 2. Recommended Load Increments & Minimum Periods of Observation for On-site Pull-out Tests

Permanent Soil Nails			Temporary Soil Nails		
Loading Increments		Minimum Period of Observation	Loading Increments		Minimum Period of Observation
25%	Working Load	5min	25%	Working Load	5min
50%	Working Load	5min	50%	Working Load	5min
75%	Working Load	5min	75%	Working Load	5min
100%	Working Load	5min	100%	Working Load	5min
125%	Working Load	5min	125%	Working Load	5min
150%	Working Load	5min			

Should a soil nail fail a test, the Engineer will instruct the Contractor to either remove, re-drill and install the defective soil nail, or (if this is not possible) to drill and install a new soil nail at a position and at the orientation directed by the Engineer. This additional work will be undertaken at the Contractor's own expense. Payments for the soil nails which have been measured and subsequently found to be defective will be subtracted from the following payment certificate. The soil nail will be tested again once it has been re-installed/replaced. Once the Contractor has demonstrated that the soil nail can withstand the required load it will be re-measured for payment.

7.2 Tests on Cement Grouts

The fluidity of the grout shall be measured with a flow cone, immersion apparatus, or viscometer, as allowed. Test cubes of grout shall be made on site and the unconfined compressive strength thereof tested by an approved laboratory and the results submitted by the Contractor to the Engineer for his approval. The cost of all such tests shall form part of the Contractor's normal process control and shall be deemed to be included in his tendered rates and shall not be paid for separately.

8. MEASUREMENT AND PAYMENT

The cost of delays and disruption shall not be included under items for installation of lateral support elements. Such costs shall be deemed to be included in the relevant item for excavation.

8.1 Establishment on Site for Drilling

The tendered amount shall include full compensation for establishing on the site and subsequently removing all structural platforms, rafts and all special plant and equipment for drilling and for carrying out operations, the cost of which does not vary with the actual amount of drilling done.

This work will be paid for by way of a lump sum, 50% of which will become payable when all

equipment is on the site and the first hole has been drilled. The second instalment of 25% of the lump sum will be payable after half the total number of holes and the final instalment of 25% after all the holes have been drilled and the equipment has been removed from the site.

8.2 Moving to, and Setting Up the Equipment at Each Position for Drilling the Holes

The unit of measurement shall be the number of positions to which the installation equipment has to be moved and set up in position. The quantity measured shall be the number of holes drilled plus the number of holes re-drilled at the instruction of the Engineer, plus any holes provided in addition for load tests, which do not form part of a specific soil nail group.

The tendered rate shall include full compensation for all costs involved in moving and setting up any equipment.

8.3 Soil Nails

The unit of measurement shall be the number of effective soil nails installed and approved.

Any costs incurred due to soil nail installation delaying or disrupting the advance of the excavation shall be priced for by the Contractor under the soil nail items.

The rate tendered shall include full compensation for access to the slope, dismantling, moving, erecting and commissioning all plant, equipment and instruments required at each soil nail location.

The rate tendered shall include full compensation for the drilling of holes, temporary casing where necessary, supply and installation of the soil nails, and grouting of the annulus. The rate shall also include for undertaking the required pull-out tests, lock-off loading of all bars, and providing the Engineer with access to the slope face. This item shall be paid for only after the entire soil nailing operation has been completed and approved by the Engineer.

A motivated Variation Order will be required in the event that a suitable curing agent additive is necessary to assist concrete curing in areas of seepage or below the water table following consultation with/approval by the geotechnical professional.