

Quality Supervision of Soil Nailing Works

Introduction

The use of soil nails for upgrading existing slopes and in forming new slopes is becoming very common in Hong Kong. Close supervision and timely design review during construction are essential to ensure the quality of the soil nailing works. Buildings Ordinance (BO) section 17 provides that the Building Authority may impose qualified supervision as conditions of approval and consent to commence building works. PNAP 83 specifies the requirements and sets out the principles of such qualified supervision.

2. A soil nail, when constructed, is buried in the ground, and its built quality is not readily visible. There is a need to put in place reliable procedures for the supervision, testing and certification for acceptance of the soil nailing works during construction to ensure the quality of the works. This practice note promulgates the supervision, testing and certification requirements at various stages of soil nailing works and specifies the criteria for acceptance of the works.

3. Reference may be made to the Particular Specifications and standard drawings for soil nailing works as well as guidance notes and checklists for their supervision that are used by the Civil Engineering Department (CED) of the HKSAR Government under the LPM Programme which can be found on the CED website <http://www.ced.gov.hk/eng/generalinfo/generalinfo_f.htm>. GEO (2003)[#], which can also be downloaded from the CED website, gives guidance on non-destructive testing of soil nail length. These documents may be used as a guide for private development projects.

Buildability of Soil Nails

4. In designing soil nails, the designer should give due consideration to the buildability of the soil nails to ensure that the designs are practical and could be built. For long nails, say with length exceeding 20m, there is a higher chance of encountering loose or permeable ground, or buried stream course, leading to difficulties in construction. Examples include collapses of soil or rock along the drillhole (which may obstruct the insertion of the nail reinforcement assembly), and high grout loss. Grout quality may also be difficult to ensure as the length of nail increases. For cases where long nails are proposed or where the ground or groundwater conditions are likely to be adverse to soil nail construction, the AP may be required to undertake an assessment of buildability and the effects of soil nail installation on the existing ground and groundwater conditions, based on a site trial,

[#]GEO (2003). *Non-destructive Tests for Determining the Lengths of Installed Steel Soil Nails*. GEO Report No. 133, Geotechnical Engineering Office, Civil Engineering Department, the Government of the HKSAR, 54p. (This can be downloaded from the CED website <http://www.ced.gov.hk/eng/publications/geo/georpt_f.htm>.)

prior to carrying out the soil nailing works. The site trial may be incorporated in and should include the pull-out tests of soil nails where possible. Soil nails for site trials and pull-out tests should be installed and tested prior to the installation of working soil nails.

5. Examples of ground conditions that may present difficulties for soil nail construction include loose fill or colluvium, rockfill, presence of soil pipes, buried stream courses, rock mass with open discontinuities and fractures, alternating zones of soil and rock. The installation of soil nails in areas with groundwater flow will pose particular difficulties. The hole drilled may be more susceptible to collapse than dry ground and the quality of the grout may also be in doubt. Suitable measures, e.g. groundwater drainage, may have to be incorporated to facilitate installation of soil nails.

Particular Requirements for Approval of Plans

6. The AP is required to include the following particulars in the site formation submission for approval by the BA:

- (i) Details of the site trial, if required, to confirm the buildability of the soil nails, including its locations.
- (ii) Procedure adopted for the pull-out tests.
- (iii) Methodology and details of the proposed non-destructive test (NDT) for verifying the length of installed soil nails, with suitable provisions incorporated to allow the test to be carried out. Where the AP intends to use the Time Domain Reflectometry test mentioned in paragraph 17 as the proposed NDT, an electric wire should be incorporated in the soil nail details in the site formation plans. Standard details of the electric wire arrangement can be obtained from GEO (2003) which can be downloaded from the CED website.

Supervision Requirements for Soil Nailing Works

7. The paragraphs below set out the supervision requirements which will be imposed under BO s17 as conditions for qualified supervision of soil nailing works. It should be noted that this is in addition to the site safety supervision required under the Technical Memorandum for Supervision Plans and the relevant provisions of the BO (e.g. s16(3)(bc)).

8. Supervision of soil nailing works should be provided by the Category I* and Category III personnel nominated by the AP, as well as by the RSC(Site

* Where necessary, Category II qualified supervision will be imposed by the Building Authority.

Formation)'s senior and junior site supervisors (Construction Engineer and Construction Supervisor, respectively).

9. For all soil nailing works, at least one Category III personnel nominated by the AP and one Construction Supervisor under the RSC(Site Formation) are required to be resident full-time on site during every stage of the works for each soil nail. The RSC(Site Formation) is required to notify the Category III personnel before the commencement of any stage of the works. The RSC(Site Formation) is also required to prepare detailed inspection, measurement and testing records for each soil nail as per the approved plan requirements.

10. Key records on supervision of soil nailing works (Appendix A) should also be prepared and certified by the Category III personnel who carries out the inspection, measurement or check. A full set of all certified records should be kept on site for inspection by BD staff.

11. The Category I personnel should verify the design assumptions and carry out design review during construction. He should check whether there are any anomalies that may invalidate the functional requirements of his design during his periodic site inspections and follow them up. He should also follow up any anomalies reported to him by the Category III personnel. If necessary, the AP should make amendment submissions for the approval of the BA.

12. The extent of supervision required for different stages of soil nailing works is shown at Appendix B. Actual supervision requirements will be imposed at plan approval stage by the BA on a case-by-case basis depending on the scale and complexity of the slope and the soil nailing works, and the anticipated construction difficulties. The AP should nominate to the BA, an adequate number of qualified supervision personnel with suitable experience, taking into account the site conditions and the number of soil nails proposed and their lengths. During the construction stage, the AP should review the adequacy of the supervision team taking into account the likelihood of concurrent construction requiring close supervision under the construction programme. Where necessary, he should enhance the supervision requirements, e.g. increase the number of Category III personnel full-time on site.

Minimum Qualification and Experience Required for Site Supervisors for Soil Nailing Works

13. The minimum qualification and experience required for Categories I and III personnel are specified in PNAP 83.

14. The senior supervisor of the RSC(Site Formation), i.e. the Construction Engineer, should be at least a holder of a recognized degree in civil or geotechnical engineering with total relevant working experience of not less than 4 years. The junior supervisor, i.e. the Construction Supervisor, should be at least a holder of a Certificate or Diploma in civil or geotechnical engineering with at least 2 years relevant working experience.

15. A person without the required academic qualification but with 5 years relevant working experience and has satisfactorily completed a top-up training course acceptable to the BA, may also be accepted as the Construction Supervisor. This arrangement is only valid for a transition period ending December 2005. After this transition period, only those possessing the required qualification as specified in paragraph 14 will be accepted as the Construction Supervisor.

Non-destructive Testing of Installed Soil Nails

16. On completion of installation of soil nails, the AP shall submit to the BA key supervision records in the form of Appendix A certified by the Category III personnel. These records could be submitted prior to the construction of soil nail heads. Upon review of the supervision records, if the BA considers that there is cause for concern in relation to the quality of soil nailing works, the BA will require the AP to carry out non-destructive testing (NDT) of at least 1% of soil nails with a minimum of 2 nails per slope (including wall) to verify the length of the installed soil nails.

17. Several NDT methods for checking the length of installed soil nails are described in GEO (2003). For example, the Time Domain Reflectometry (TDR) test which requires the installation of an electrically conducting wire alongside the steel reinforcement and the magnetometer test which requires drilling of a hole parallel to the soil nail to be tested. Alternatively, the AP may propose other methods for BA's agreement at the design stage of the project. A test report with the test results and their interpretations together with re-assessment of the adequacy of the installed soil nails (if needed) shall be submitted to the BA for acceptance.

Commencement of Quality Supervision Requirements for Soil Nailing Works

18. The requirements for quality supervision specified in this PNAP will be imposed as conditions of consent to commence site formation works that comprise soil nailing works, under BO s17, the plans of which have been submitted for approval on or after 1st December 2003.



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Index under : Soil Nails
Soil Nailing Works, supervision of
Time Domain Reflectometry Test

Supervision of Soil Nailing Works

Stages of Soil Nailing Works	Objectives of Supervision and Critical Aspects	Inspection and check to be carried out by	
		AP#	RSC(Site Formation)#
(i) Pull-out test and any specified site trial	To check whether the test nails are being constructed and the test/site trial procedure is in accordance with the approved plans or as specified by the AP, and the acceptance criteria for the test/site trial are met.	III I/AP 100% at least 1 nail each of pull- out test and site trial	J S 100% at least 1 nail each of pull- out test and site trial
(ii) Setting out of soil nails	To check whether the positions of the soil nails agree with the approved plans.	III I AP FT AN AN	J S FT AN
(iii) Drilling of soil nail holes	To check whether the drillhole diameter, length, inclination and bearing are in accordance with the approved plans and any anomalies on ground and groundwater conditions and to report to the responsible person if necessary ⁽¹⁾ .	III I AP FT AN AN	J S FT AN
(iv) Assembly of soil nail reinforcement	To check whether the assembly is in accordance with the approved plans, in particular, the length, type and corrosion protection provisions of the reinforcement ⁽²⁾ , adequacy and tightness of any couplers used, adequacy of centralizers to ensure minimum grout cover and the grout pipes are not twisted and free from blockage and are extended to the bottom of the soil nail holes in accordance with the approved plans.	III I AP FT AN AN	J S FT AN

Stages of Soil Nailing Works	Objectives of Supervision and Critical Aspects	Inspection and check to be carried out by	
		AP#	RSC(Site Formation)#
(v) Insertion of soil nail reinforcement	<p>To check whether:</p> <ul style="list-style-type: none"> - cleaning of the hole, e.g. by air flushing is needed to remove any blockage or collapse, or there is any groundwater, which may require a change in construction method, and - the assembly is sufficiently rigid and the correct assembly of soil nail reinforcement is inserted. 	<p>III I/AP</p> <p>100% at least 2 working nails at early stage of nail construction</p>	<p>J S</p> <p>100% at least 2 working nails at early stage of nail construction</p>
(vi) Grout and preparation of grout	<p>To check whether the grout used, grout mix, preparation of grout and grout test results⁽²⁾ meet the requirements of the approved plans.</p>	<p>III I AP</p> <p>100% AN AN</p>	<p>J S</p> <p>100% AN</p>
(vii) Grouting of soil nail hole	<p>To check whether:</p> <ul style="list-style-type: none"> - grouting of soil nails is carried out on the same day as insertion of the soil nail reinforcement assembly, - grout is injected into the drillhole through the grout pipe with sustained grout return of satisfactory cleanliness and viscosity from the top of the drillhole, - grouting operation is carried out according to the approved plans, and - excessive grouting time or excessive grout volume consumed in any drillhole to maintain sustained grout return of satisfactory cleanliness and viscosity, or other anomalies such as excessive 'settlement' of grout (as measured along the length of the nail) on cessation of grouting, are reported to the responsible person and recorded⁽³⁾. 	<p>III I/AP</p> <p>100% at least 2 working nails at early stage of nail construction</p>	<p>J S</p> <p>100% at least 2 working nails at early stage of nail construction</p>

Stages of Soil Nailing Works	Objectives of Supervision and Critical Aspects	Inspection and check to be carried out by	
		AP#	RSC(Site Formation)#
(viii) Construction of soil nail heads and structural supports between nail heads	To check whether the soil nail heads and structural supports are constructed in accordance with approved plans, including the dimensions, materials used, structural detailing and workmanship.	III I/AP FT at least one soil nail head	J S FT at least one soil nail head

Legend: Under AP III = Category III, I = Category I
Under Contractor J = Construction Supervisor, S = Construction Engineer
FT = Full time on site during the relevant stages of the works AN = As necessary
= The role of the AP and his team of supervisors is specified in the Table above. The role of the RSC(Site Formation) team is to check and ensure that the works at different stages are carried out in accordance with the approved plans and as instructed by the AP or his team of site supervisors.

- % = percentage of soil nails per slope or wall to be inspected and checked
- (1) The supervision personnel should familiarize themselves with the anticipated ground and groundwater conditions. In case of doubt, or when loose or permeable zones or groundwater is encountered during drilling, the supervision personnel should report it to the responsible person nominated by the AP for the design review (normally the Category I personnel). Drilling records should always be maintained.
- (2) The supervision personnel should check the availability of valid manufacturer's certificates and test certificates from approved laboratories for the reinforcement and grout used. They should also supervise the site tests such as bleeding tests and flow cone tests on the grout and check and certify the test results. The test results should be kept on site for inspection by BD staff.
- (3) The supervision personnel should monitor and record the grout volume consumed in the drillhole (excluding the volume needed to fill the pumping and pipe system to be determined from a calibration and losses). If grout loss is significant, or there is a concern on the grout quality that can be achieved, the supervision personnel should report it to the responsible person nominated by the AP for approving changes in construction method (normally the Category I personnel).

Notes: (A) The persons who carry out the inspections, measurements and checks should certify the records and such records should be kept on site for inspection by BD staff.
(B) The Category III personnel in consultation with the Category I personnel where necessary should assess the adequacy of construction equipment and the sensitivity and accuracy of measuring instruments and their use by the RSC(Site Formation)'s team engaged for the drilling, insertion of reinforcement assembly and grouting of soil nails. An assessment should be done whenever there is a change in equipment/instruments and/or personnel by the RSC(Site Formation) (e.g. change in subcontractors).

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