Procedures for Implementation of Revised Quality Assurance Framework for Application of Time Domain Reflectometry Tests at LPMit Sites

1. General

Time domain reflectometry tests (TDR) based on pre-installed wire shall be carried out on selected steel soil nails installed in LPMit sites. The TDR tests provide a third party audit tool to enhance the quality assurance of the soil nailing works and act as a deterrence against short nails. The TDR tests shall not be taken as a compliance test.

2. Testing Frequency for TDR tests on Soil Nails

2.1 Soil nails installed in each LPMit site are to be grouped into one or more sample lots and randomly selected for TDR tests. All soil nails in the sample lot should have similar characteristics as far as quality assurance is concerned and have the same type of pre-installed wire and same grout mix, regardless of the diameter and length of steel bar.

2.2 The testing frequency for different sizes of sample lot is given in Table A1.

3. Procedures for Conducting TDR tests

3.1 The resident site staff (RSS) shall inform the Public Works Laboratory (PWL) of the Standards and Testing (S&T) Division the total number of soil nails to be installed, at least two weeks before the anticipated time required for conducting TDR tests. RSS should mean Engineer's Representative, Resident Site Engineer, Inspector of Works and Works Supervisors.

3.2 The division of the sample lots should be determined by the RSS. A proper record of the division of the sample lots shall be maintained by the RSS together with a summary indicating the number of TDR tests conducted so far for the site. A sample summary is given in Appendix B.

3.3 RSS shall submit a standard Test Request Form (Appendix C) to PWL (via fax: 2795 9611) at least two working days in advance of testing.

- For each sample lot, the RSS shall select at least three soil nails to be used as calibration nails. Guidelines on selection of calibration nails are given in "Guidelines on Test Procedure Using Time Domain Reflectometry (TDR) to Determine the Length of Installed Soil Nails" (available for download in http://www.cedd.gov.hk/eng/publications/geo/tdr.htm).

- PWL shall select the soil nails for TDR tests (known as test nails hereafter). The number of test nails shall be in accordance with that specified in the Test Request Form.

- The head of the steel bar and that of the preinstalled wire selected for testing shall be accessible.

- The TDR tests shall be carried out within the period specified in the Test Request

Form. A minimum of two working days should be allowed for carrying out the TDR tests.

3.4 PWL or its term testing contractor will conduct the TDR tests on site and advise the RSS the quantity of soil nails tested.

Calibration Nails

- Prior to the commencement of the test on site, the RSS shall provide to PWL the as-built length of the soil nails selected as calibration nails using Appendix D.

Test Nails

- The RSS shall not inform the testing contractor the as-built length of the test nails, other than those selected for calibration purpose.

3.5 The RSS shall provide the as-built lengths of all test nails to PWL using Appendix D within two working days after completion of the TDR tests.

3.6 Preliminary TDR test results would be provided to the RSS within five working days after completion of the field tests. Final test results will be provided to the RSS within 12 working days upon completion of the field tests.

4. Assessment of TDR Results

4.1 TDR test procedures and guidance to interpret the test data for determining the length of soil nails are summarized in "Guidelines on Test Procedure & Sample Test Results using Time Domain Reflectometry (TDR) to Determine the Length of Installed Soil Nails" (available from http://www.cedd.gov.hk/eng/publications/geo/tdr.htm). A soil nail with the TDR-deduced length less than 85% of the design length is considered as having an anomalous result. Pun et al (2008), Cheung & Lo (2011) and Tang & Cheng (2012) present the fundamental principle of TDR tests, and report results of a number of case studies of using TDR test for quality control of soil nailing works. They also provide useful background information for TDR result interpretation and investigation of the cause(s) of detected anomalous TDR test results.

4.2 Based on the 85% criterion, PWL shall identify those test nails that have anomalous TDR result. The TDR test results should be provided to the RSS, who shall then check if the "Alert Criterion" given in Table A1 has been exceeded for the sample lot concerned.

5. Follow-up Actions

5.1 Where the "Alert Criterion" is not exceeded

5.1.1 No further testing is required for the remaining soil nails within the sample lot.

5.1.2 For those test nails found to have anomalous TDR result, the RSS shall forward the TDR result to the Design Engineer (DE) and seek for advice on necessary revision of details of works. The DE may choose to recommend replacement of the soil nails concerned, or alternatively, to undertake a design review to assess whether there is a need to replace the

soil nails with anomalous result.

5.1.3 Any soil nails added shall be subject to TDR test.

5.2 Where the "Alert Criterion" is exceeded

5.2.1 The RSS determines if the number of test nails with anomalous result have already exceeded the "Alert Criterion" for the next sample lot size. If so, an investigation as given in Section 5.2.6 below shall be conducted.

5.2.2 If the “Alert Criterion” for the next sample lot size is not exceeded, the RSS requests for additional soil nails to be tested by TDR based on the testing frequency for the next sample lot size given in Table A1.

[For example, if the current sample lot size is between 26-50 and 8 TDR tests have been conducted, another 5 soil nails should be selected for TDR tests. Total number of test nails is therefore 13; corresponding to the sample lot size of 51-90. See illustration given in Appendix A.]

5.2.3 The RSS submits the Test Request Form to PWL as in Section 3.3; and PWL selects the soil nails for TDR tests as given in Section 3.4. For selection of additional soil nails, consideration may be given to those nails that are adjacent to the test nails found to have anomalous result.

5.2.4 Upon receipt of results of further testing from PWL, the RSS checks if the total number of test nails with anomalous result exceeds the corresponding "Alert Criterion". Follow-up actions as given in Section 5.1 shall be followed if the "Alert Criterion" is not exceeded.

5.2.5 If the total number of test nails with anomalous result exceeds the corresponding "Alert Criterion" for the increased testing frequency, an investigation as given in Section 5.2.6 below shall be carried out.

Complete TDR testing and Conduct Investigation

5.2.6 When an investigation is considered necessary, the RSS and DE should determine if it is warranted to test all soil nails by TDR test. Other investigative techniques such as Electrical Resistance Method, Magnetometry or extraction of soil nail, may also be useful. DE and RSS should determine the cause(s) of the anomalous TDR test result, and carry out follow-up actions as appropriate. If necessary, the RSS/DE can seek S&T Division (Attention: SGE/S1) for advice. A flow chart of the above quality assurance framework is presented in Appendix E.

5.3 Other Investigation Approach

5.3.1 While the framework provides general guidance on the application of TDR tests to quality assurance of soil nailing works, it should not replace or deter the use of engineering judgement in assessing the nature, severity and causes of the detected anomalies. The RSS and DE may, upon consideration of the particular circumstances of the case, undertake follow-up actions other than those proposed by this framework.

6. References

Cheung R.W.M & Lo D.O.K. (2011). Use of time-domain reflectometry for quality control of soil-nailing works. *Journal of Geotechnical and Geoenvironmental Engineering*, vol. 137, no. 12, pp 1222-1235.

Pun W.K., Cheung W.M., Lo D.O.K. & Cheng P.F.K. (2008). Application of time domain reflectometry for quality control of soil nailing works. *Proceedings of the 23007 International Forum on Landslide Disaster Management 10-12 Dec 2007 Hong Kong*, Hong Kong, vol. 1, pp 667-686.

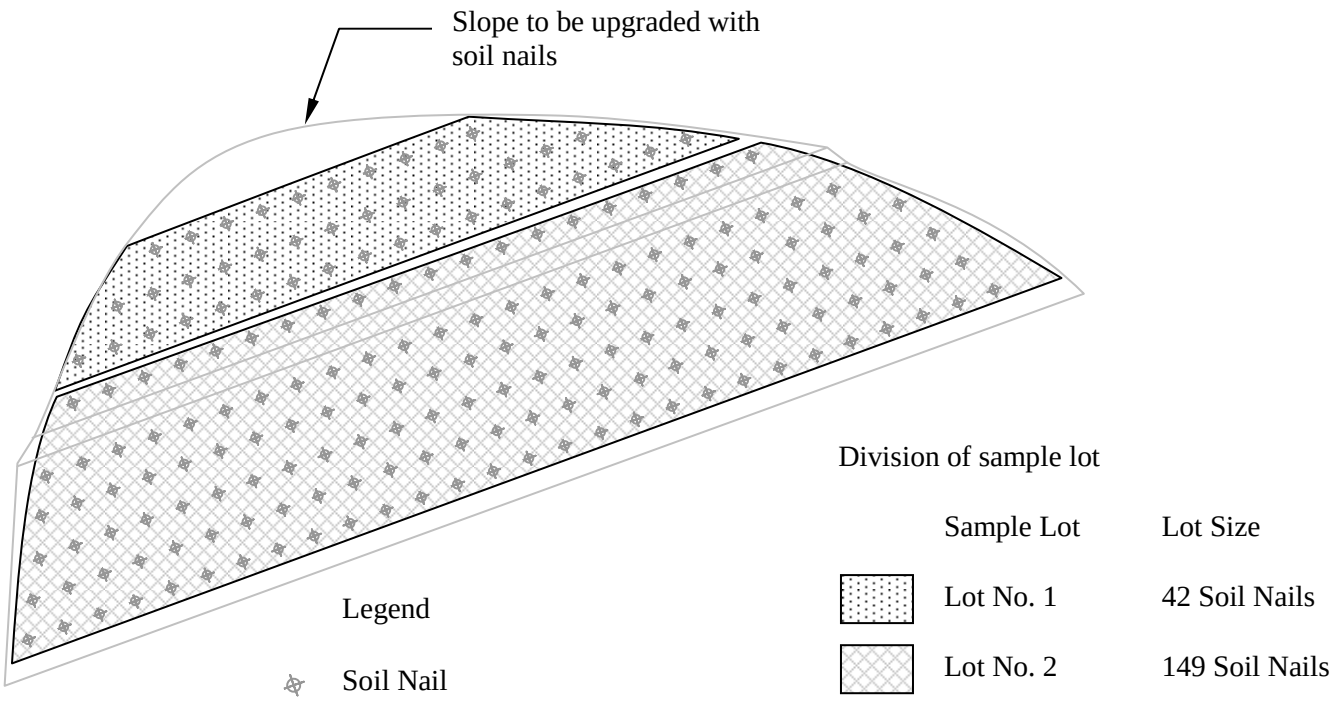
Tang C.S.C. & Cheng P.F.K. (2012). *Use of Time Domain Reflectometry (TDR) with Pre-installed Wires to Check the Grout Integrity of Soil Nails (Technical Note No. TN 4/2012).* Geotechnical Engineering Office, 31 p.

Table A1 – Testing Frequency and Alert Criterion for Triggering Follow-up Actions for Soil Nails Installed in LPMit Sites

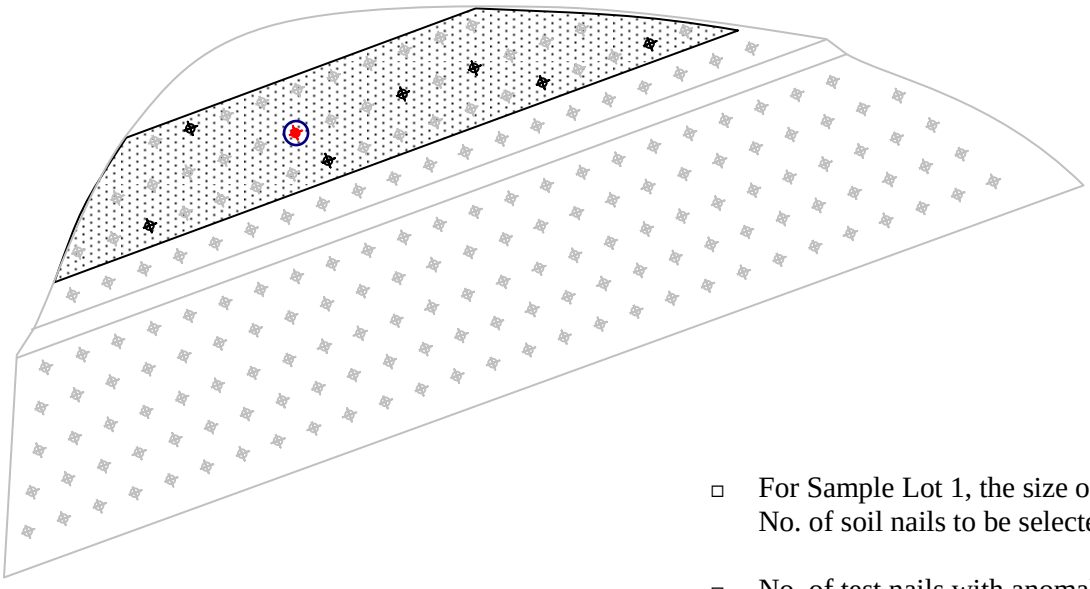
Sample Lot Size	Testing Frequency (Minimum no. of soil nails to be tested by TDR)	Alert Criterion (No. of nails with anomalous TDR result)
≤ 25	5	≥ 1
26 – 50	8	≥ 1
51 – 90	13	≥ 1
91 –150	20	≥ 2
151 – 280	32	≥ 4
281 – 500	50	≥ 6
501 – 1200	80	≥ 11

Notes:

1. Soil nail with a significant length of exposed rebar, relative to the total nail length, at the soil nail head may not be suitable for calibration and testing purposes.
2. Soil nails shall be divided into sample lots with the same type of pre-installed copper wire and grout mix. Division of the sample lots should consider factors such as programme of soil nail installation, availability of access for conducting tests, and subsequent works, if found necessary, etc. The size of sample lots shall generally be greater than 50 nails where possible. Calibration nails shall not be counted as test nails when determining the testing frequency.
3. Anomalous TDR result means that the TDR-deduced length is less than 85% of the designed length.

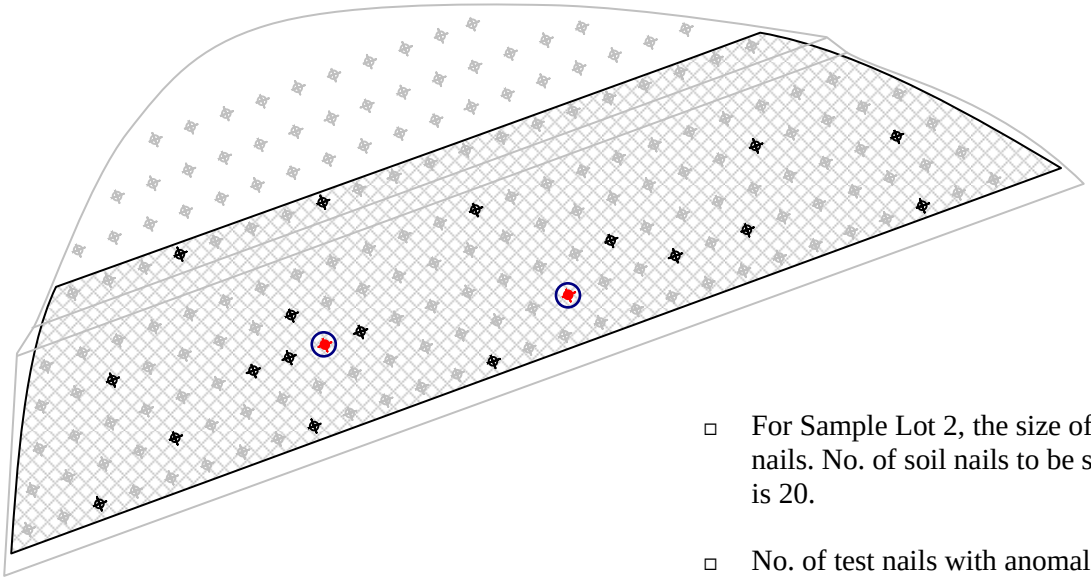


(a) Layout of soil nails in slope and division of soil nails into two sample lots



- For Sample Lot 1, the size of sample lot is 42 nails. No. of soil nails to be selected for TDR test is 8.
- No. of test nails with anomalous TDR result = 1 and it has already exceeded the Alert Criterion for the next sample lot size (i.e. Sample lot size between 51 and 90 nails).
- Conduct investigation to identify the scale and cause of the problems. All remaining soil nails in the sample lot shall be tested by TDR and other investigative techniques may be required.

(b) Application of sample plan for Sample Lot No. 1



Legend

Lot No. 2

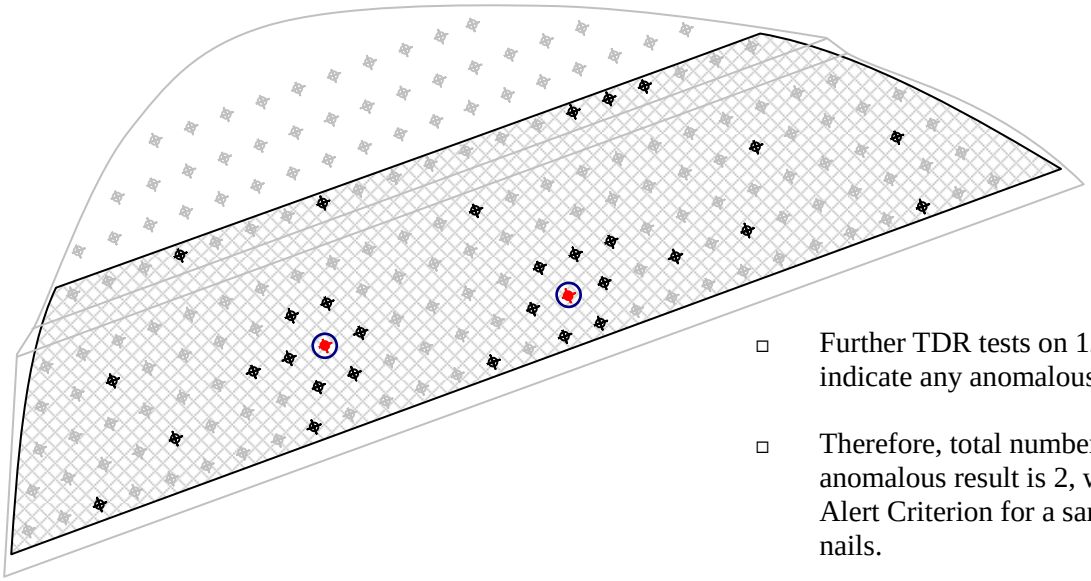
Soil nails

Soil nails with anomalous result

Soil nails subject to TDR tests

- For Sample Lot 2, the size of the sample lot is 149 nails. No. of soil nails to be selected for TDR test is 20.
- No. of test nails with anomalous TDR result = 2 and it does not exceed the Alert Criterion for the next sample lot size (i.e. Sample lot size between 151 and 280 nails)
- Carry out TDR tests based on testing frequency for the next sample lot size, i.e. additional 12 nails. Altogether, TDR tests are conducted on 32 test nails for Sample Lot 2.

(c1) Application of second sampling plan for Sample Lot 2



Legend

Lot No. 2

Soil nails with anomalous result

Soil nails

Soil nails subject to TDR tests

- Further TDR tests on 12 additional nails do not indicate any anomalous result.
- Therefore, total number of test nails with anomalous result is 2, which does not exceed the Alert Criterion for a sample lot size with 151-280 nails.
- No further TDR test or investigation is required. Follow-up actions as given in Section 5.1 should be carried out.

(c2) Application of ***second*** sampling plan for Sample Lot 2

PROJECT DETAILS

Job Title : _____ Contract No. : _____

Site Location : _____ Feature No. : _____

Engineer's Representative : _____ Contact Tel. No. : _____ Email : _____

Post : _____ Fax No. : _____

SUMMARY OF TDR TESTS CONDUCTED SO FAR AT THE SITE

Sample Lot No.	Soil Nail No.	No. of Soil Nails in Each Lot	No. of TDR Tests Required	No. of Soil Nails Tested by TDR (Cumulative)	Service Order No.	Date of TDR Tests Conducted	Remaining No. of Soil Nails to be Tested for the Sample Lot	No. of Soil Nails with Anomalous TDR Result
1	R1-1 to R1-30; R2-1 to R2-35; R3-31 to R3-65	100	20	5	SON 1	23.7.2007	15	0
1	R1-1 to R1-30; R2-1 to R2-35; R3-31 to R3-65	100	20	15	SON 2	4.8.2007	5	0
1	R1-1 to R1-30; R2-1 to R2-35; R3-31 to R3-65	100	20	20	SON 7	10.8.2007	0	1
2	R4-1 to R4-20; R2-36 to R2-40; R3-1 to R3-30	65	13	5	SON 4	5.8.2007	8	0

Notes:

1. Attach a plan showing the division of soil nails into different sample lots.
2. Data above are given as an example only.
3. Refer to "Procedures for Implementation of Revised Quality Assurance Framework for Application of Time Domain Reflectometry Tests at LPM Sites", for the "Alert Criterion" and follow-up actions.

Prepared by

Name : _____ Consultant (If applicable) : _____

Contact Tel. No. : _____ Post : _____

Date : _____ Fax No. : _____

For PWL use only	
Service Order No. (SON)	

REQUEST FOR CONDUCTING TDR TEST TO DETERMINE THE LENGTH OF INSTALLED STEEL SOIL NAIL FOR LPMit SITES

Client (tick as appropriate) : ☐ CGE/LPM1 ☐ CGE/LPM2 ☐ CGE/LPM3 Client Ref. No. : _____

☐ CGE/GP ☐ CGE/P ☐ (please specify) _____

Job Title : _____ Contract No. : _____

Site Location : _____ Feature No. : _____

Engineer's Representative: _____ Post : _____ Email : _____

Contact Tel. No. : _____ Fax : _____

To : PWL (Fax number : 2795 9611)

1. Total number of soil nails to be installed in the above feature is _____.
2. _____ number of soil nails are available for TDR tests for the period from _____ to _____ inclusive, and _____ number of soil nails are to be tested.
3. A location plan (or part plan) of soil nails in the sample lot(s) covered by this request form is attached.
4. TDR tests to be conducted on the following calibration nails for the sample lot(s) covered by this request form:

Sample Lot No.	Calibration Nail No. (Assigned by RSS)	Remarks

5. TDR tests to be conducted on the following soil nails:

Sample Lot No.	Soil Nail No. Available for TDR Tests	Test Nail No. (Assigned by PWL)#

Notes: 1. Soil nail with a significant length of exposed rebar, relative to the total nail length, at the soil nail head may not be suitable for calibration and testing purposes.
2. Soil nails in each sample lot shall have similar properties, e.g. grout mix and type of copper wires. Soil nails to be tested by TDR should generally evenly distributed amongst all soil nails in the sample lot(s).
3. Results will be sent to the Engineer's Representative managing the Works Contract.
4. # Refer to Table A1 of the Procedures for Implementation of Revised Quality Assurance Framework prepared by the S&T Division regarding the frequency of TDR tests.

Request form prepared by (site contact person):

Signature : _____ Consultant (If applicable) : _____

Name & Post : _____ Contact Tel. No. : _____

Fax No. : _____ Date : _____

Request form checked by (an RSS member who is at least one rank higher than the person who prepared the request form):

Signature : _____ Contact Tel. No. : _____

Name & Post : _____ Date : _____

For PWL use only	
Service Order No. (SON)	

TDR TEST FOR THE DETERMINATION OF LENGTH OF INSTALLED STEEL SOIL NAIL FOR LPMIT SITES

AS-BUILT LENGTH OF SOIL NAILS

Client (tick as appropriate) ☐ CGE/LPM1 ☐ CGE/LPM2 ☐ CGE/LPM3 Client Ref. No.: _____
☐ CGE/GP ☐ CGE/P ☐ (Please specify)

Job Title: _____ Contract No.: _____

Work/Site Location: _____ Feature No.: _____

To: PWL (Fax number : 2305 1334)

1. As-built length of calibration nail(s):

Calibration nail No.	As-built nail length (m)	Length of calibration nail exposed to air at nail head during TDR testing (m) Fig. 1

2. As-built length of test nails:

TDR test for the determination of the length of installed steel soil nails was carried out on _____

Soil nail No.	As-built nail length (m)	Length of test nail exposed to air at nail head during TDR testing (m) Fig. 1

Reported by : _____
: (Signature)
Name : _____
Post : _____
Consultant (If applicable) : _____
Date : _____

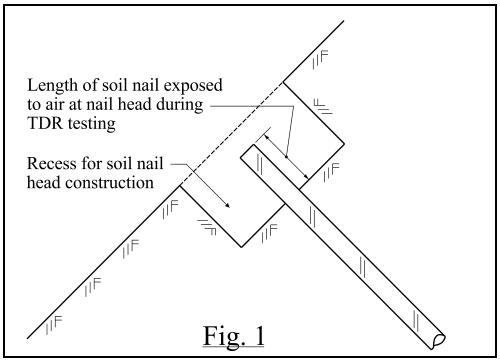


Fig. 1

Flow Chart on Revised Quality Assurance Framework for Application of TDR tests at LPMit Sites