

Geoguide 7 – Guide to Soil Nail Design and Construction

First Edition

AMENDMENT NO.: GG7/01/2017

BACKGROUND

This amendment sheet incorporates the recommendations given in the following GEO Technical Guidance Notes:

- (i) GEO Technical Guidance Note No. 31 (TGN 31) – Design of Soil Nails for Upgrading Loose Fill Slopes.
- (ii) GEO Technical Guidance Note No. 41 (TGN 41) – Amendments to British Standards References in Technical Guidance Documents for Migration to Eurocodes.

The amendments are given below.

AMENDMENTS

SECTION 5 DESIGN OF A SOIL-NAILED SYSTEM

- (a) Section 5.5 **Amend the section as follows:**

In item (a), line 2, delete ‘BS EN ISO 1461:1999 (BSI, 1999)’ and substitute ‘BS EN ISO 1461:2009 (BSI, 2009)’.

In item (a), line 4, delete ‘CEDD’ and substitute ‘HKSARG’.

In item (b), line 2, delete ‘BS EN ISO 1461:1999 (BSI, 1999)’ and substitute ‘BS EN ISO 1461:2009 (BSI, 2009)’.

In item (c), line 2, delete ‘BS EN ISO 1461:1999 (BSI, 1999)’ and substitute ‘BS EN ISO 1461:2009 (BSI, 2009)’.

- (b) Section 5.6.3 **Delete Equation (5.3) and explanatory notes and substitute the following:**

$$T_{GR} = \frac{2.25\eta_1\eta_2f_{ctd}P_rL}{F_{GR}} \quad (5.3)$$

η_1 = the coefficient related to the quality of the bond condition and the position of the bar during concreting in accordance with Clause 8.4.2 of BS EN 1992-1-1:2004 (BSI, 2004)

η_2 = the coefficient related to the bar diameter in accordance with Clause 8.4.2 of BS EN 1992-1-1:2004 (BSI, 2004)

f_{ctd} = the design value of concrete tensile strength in accordance with Clause 3.1.6(2)P of BS EN 1992-1-1:2004 (BSI, 2004) and NA to BS EN 1992-1:2004 (BSI, 2005)

P_r = effective perimeter of the soil-nail reinforcement

L = bond length of the soil-nail reinforcement in the passive zone

F_{GR} = factor of safety against pullout failure at grout-reinforcement interface

(c) Section 5.6.4 **In Figure 5.5, item (3), delete ‘CEDD’ and substitute ‘HKSARG’.**

(d) Section 5.6.5 **Amend the section as follows:**

In paragraph 7, lines 1 to 3, delete ‘GEO Publication No. 1/2000 : Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (GEO, 2000b) and GEO Technical Guidance Note No. 20 (GEO, 2007b)’ and substitute ‘GEO Publication No. 1/2011 : Technical Guidelines on Landscape Treatment for Slopes (GEO, 2011)’.

In paragraph 7, lines 6 and 7, delete ‘GEO Report No. 56 (Wong et al, 1999)’ and substitute ‘GEO Publication No. 1/2009 (GEO, 2009)’.

In paragraph 7, line 8, delete ‘CEDD’ and substitute ‘HKSARG’.

(e) Section 5.8.1 **Replace paragraph 5 as follows:**

The use of soil nails in loose fill slopes should in-principle follow the recommendations given in the report “Design of Soil Nails for Upgrading Loose Fill Slopes” prepared by the Geotechnical Engineering Office, Civil Engineering and Development Department and the Hong Kong Institution of Engineers (Geotechnical Division) (GEO-HKIE, 2011). This report provides design recommendations to supplement the design guidance given in the report entitled “Soil Nails in Loose Fill Slopes – A Preliminary Study” promulgated by the Hong Kong Institution of Engineers (Geotechnical Division) (HKIE, 2003). The salient points of the recommendations and the supplementary guidelines are given in Sections 5.8.2 to 5.8.4.

(f) Section 5.8.2 **Replace paragraph 2 as follows:**

For design scenario (a), a minimum factor of safety of 1.1 should be achieved for any potential failure surface. For internal failure modes of the soil nail, the minimum factors of safety recommended in Section 5.6.2 should be followed, except that the factor of safety against tensile failure of soil-nail reinforcement should follow the recommendations in the HKIE-GD Report (HKIE, 2003). For design scenarios (b) and (c), the minimum factors of safety as recommended in Tables 5.4 to 5.6 in Section 5.6.2 should be achieved.

(f) Section 5.8.3(1) **Replace paragraph 1 as follows:**

(1) *Design Shear Strength for Loose Fill.* In order to address the concern that when loose fills are subjected to shearing, they may lose strength at such a rate that the forces mobilised in the soil nails will not be able to compensate for the loss of shear strength of the fill, large strain steady state undrained shear strength, c_{ss} , should be adopted for loose fill in the design. If site-specific laboratory testing is not carried out, a conservative value of steady state undrained shear strength equal to 0.2 times the mean effective stress, p'_{peak} , can be adopted, where p'_{peak} is the point at which the fill behaviour changes from drained to undrained in a possible failure scenario. It is strongly recommended that site-specific laboratory tests be carried out in order to

reduce the unnecessary conservatism in the design parameters. The use of the c_{ss}/p'_{peak} correlation to determine the shear resistance at the base of the grillage is not considered appropriate in view of the low stress level. The lower bound values of the shear resistance at the base of the grillage are likely to be within the range of 3 kPa to 10 kPa. If laboratory testing is to be carried out to derive the steady state undrained shear strength of the fill, the testing procedures and guidance given in the HKIE-GD Report (HKIE, 2003) should be followed.

(g) Section 5.8.3(2) **Replace paragraph 3 as follows:**

Soil nails should be designed to resist the forces acting on the grillage, including the normal and shear forces generated by the fill. GEO-HKIE Report (GEO-HKIE, 2011) has demonstrated that a hybrid nail arrangement comprising nails at two different orientations (i.e. sub-horizontal nails at the upper part and steeply inclined at the lower part) would limit slope movement and enhance the robustness of the system. It is recommended that the hybrid nail arrangement be adopted as far as possible. The ratio of sub-horizontal nails to steeply inclined nails can be estimated by considering force equilibrium of the grillage facing. The number of sub-horizontal nails should be approximately 40% to 50% of the total number of soil nails to ensure sufficient sub-horizontal nails are present to counter sliding failure. In the hybrid system, it is not necessary to provide any toe fixity as the sub-horizontal nails near the upper part of the slope would counter the sliding of the grillage facing.

(h) Section 5.8.3(2) **Add the following after paragraph 3:**

If an alternative nail arrangement is intended to suit actual site conditions, the designer should demonstrate the effectiveness and robustness of the proposed nail arrangement using numerical analyses. In addition, an embedded concrete footing (where sufficient competent ground is present at shallow depth) should be provided in instead of vertical nails to provide toe fixity for the alternative nail arrangement.

(i) Section 5.8.3(2) **Add the following after paragraph 4:**

The grillage facing is an important structural component of the entire stabilising system. It is recommended that a nominal grillage embedment of 0.3 m be provided for both the steeply inclined nail arrangement and the hybrid nail arrangement to prevent the grillage from being undermined by erosion.

For the hybrid nail arrangement, in addition to bending, the individual grillage beams would be subjected to axial tensile force, which needs to be taken into account in the design of the grillage facing.

(j) Section 5.9 **Amend the section as follows:**

In paragraph 2, lines 2 and 4, delete ‘GEO Report No. 56 (Wong et al, 1999), GEO Report No. 165 (Lui & Shiu, 2005) and GEO Technical Guidance Note No. 9 (GEO, 2004a)’ **and substitute** ‘GEO Publication No. 1/2009 (GEO, 2009)’.

(k) Section 5.10 **Amend the section as follows:**

In paragraph 7, lines 1 and 2, delete ‘GEO Report No. 56 (Wong et al, 1999)’ and substitute ‘GEO Publication No. 1/2009 (GEO, 2009)’.

(l) Section 5.11

Amend the section as follows:

In paragraph 2, lines 9 to 11, delete ‘GEO Publication No. 1/2000: Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (GEO, 2000b)’ and substitute ‘GEO Publication No. 1/2011: Technical Guidelines on Landscape Treatment for Slopes (GEO, 2011)’.

In paragraph 2, lines 13 and 14, delete ‘GEO Technical Guidance Note No. 20 (GEO, 2007b)’ and substitute ‘GEO Publication No. 1/2011 (GEO, 2011)’.

(m) Section 5.12.1

Replace paragraph 1 as follows:

The design guidance given in Sections 5.3 to 5.11 is specific to the design of soil nails that are used to carry transient loads in slopes and retaining walls, and where there is no sign of continuous ground deformation. This guidance, in particular the design considerations regarding serviceability, durability, drainage provision, aesthetics and landscape treatment, is also applicable in general to other areas of application. Nevertheless, additional design guidelines and requirements given in the following sections should be followed under some specific circumstances.

SECTION 6

CONSTRUCTION

(j) Section 6.2.1

Amend the section as follows:

In paragraph 2, lines 2, delete ‘CEDD’ and substitute ‘HKSARG’.

In paragraph 2, lines 4, delete ‘CEDD’ and substitute ‘HKSARG’.

(j) Section 6.3.1

Amend the section as follows:

In paragraph 1, lines 7, delete ‘CEDD’ and substitute ‘HKSARG’.

REFERENCES

(a)

Add the following new references:

BSI (2004). *Eurocode 2: Design of Concrete Structures - Part 1-1: General Rules and Rules for Buildings (BS EN 1992-1-1:2004)*. British Standards Institution, London, 230 p.

BSI (2005). *UK National Annex to Eurocode 2: Design of Concrete Structures - Part 1-1: General Rules and Rules for Buildings (NA to BS EN 1992-1-1:2004)*. British Standards Institution, London, 26 p.

BSI (2009). *Hot Dip Galvanised Coatings on Fabricated Iron and Steel Articles - Specifications and Test Methods (ISO 1461:2009) (BS EN ISO 1461: 2009)*. British Standards Institution, London, 24 p.

GEO (2009). *Prescriptive Measures for Man-made Slopes and Retaining Walls (GEO Publication 1/2009)*. Geotechnical Engineering Office, Hong Kong, 74 p.

GEO (2011). *Technical Guidelines on Landscape Treatment for Slopes (GEO Publication No. 1/2011)*. Geotechnical Engineering Office, Hong Kong, 217 p.

GEO-HKIE (2011). *Design of Soil Nails for Upgrading Loose Fill Slopes*. Geotechnical Engineering Office and Geotechnical Division, The Hong Kong Institution of Engineers, Hong Kong, 96 p.

HKSARG (2006a). *General Specification for Civil Engineering Works (2006 Edition) (Incorporating all Amendments)*. The Government of Hong Kong Special Administrative Region, Hong Kong, Volumes 1 and 2.

(b) **Delete the following references:**

BSI (1999). *Hot Dip Galvanised Coatings on Fabricated Iron and Steel Articles - Specifications and Test Methods (BS EN ISO 1461: 1999)*. British Standards Institution, London, UK, 22 p.

CEDD (2006a). *General Specification for Civil Engineering Works*. Civil Engineering and Development Department, Hong Kong.

CEDD (2006b). *Project Administration Handbook*. Civil Engineering and Development Department, Hong Kong.

GEO (2000b). *Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (GEO Publication No. 1/2000)*. Geotechnical Engineering Office, Civil Engineering Department, Hong Kong, 146 p.

GEO (2004a). *Updating of GEO Report No. 56 : Application of Prescriptive Measures to Slopes and Retaining Walls (2nd Edition) (GEO Technical Guidance Note No. 9)*. Geotechnical Engineering Office, Civil Engineering and Development Department, Hong Kong, 4 p.

GEO (2007b). *Update of GEO Publication No. 1/2000 - Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (GEO Technical Guidance Note No. 20)*. Geotechnical Engineering Office, Civil Engineering and Development Department, Hong Kong, 8 p.

Lui, B.L.S. & Shiu, Y.K. (2005). *Prescriptive Soil Nail Design for Concrete and Masonry Retaining Walls (GEO Report No. 165)*. Geotechnical Engineering Office, Civil Engineering and Development Department, Hong Kong, 76 p.

Wong, H.N., Pang, L.S., Wong, A.C.W., Pun, W.K. & Yu, Y.F. (1999). *Application of Prescriptive Measures to Slopes and Retaining Walls (GEO Report No. 56)*. Geotechnical Engineering Office, Civil Engineering Department, Hong Kong, 73 p.