Highway Slope Manual

First Edition

AMENDMENT NO.: HSM/01/2017

BACKGROUND

This amendment sheet incorporates the recommendations given in the GEO Technical Guidance Note No. 10 (TGN 10) - Enhancement of Rock Slope Engineering Practice Based on Findings of Landslide Studies. The amendments are given below.

AMENDMENTS

SECTION 3 SITE INVESTIGATION

(a) Section 3.2 **Add the followings after paragraph 6:**

In the mapping of discontinuities, special emphasis should be given to identifying adverse geological features and dilated rock joints or open joints with infill or sediment, which could indicate progressive slope deterioration and/or adverse groundwater conditions. The key characteristics of these adverse geological features should be adequately mapped. In addition, care must be taken to ensure that apparently minor, but kinematically significant joint sets or individual joints are not overlooked (Evans & Irfan, 1991). However, sample of joint measurements should be representative of the overall picture, in order to avoid collection of large quantities of measurements that may have little relevance to stability assessment.

Large-scale rock slope failures have occurred involving laterally persistent discontinuities such as sheeting joints. The waviness of a sheeting joint could involve local steepening of the joint dip angle behind the slope face, which can be difficult to detect in practice (HCL, 2001).

Site-specific laboratory tests may be carried out to characterise the operational joint shear strength where considered necessary, with consideration given to the roughness and persistence of the joint, influence of any weak infill, etc. (Hencher, 1981).

SECTION 4 DESIGN OF SLOPES AND RETAINING WALLS

(a) Section 4.4 **Add the followings after paragraph 1:**

The practice of relying on conventional stereographic projections and generalised assumptions about joint strength, groundwater, block size, etc. may not be adequate to cater for local weaknesses in the rock mass. Local variations in the slope surface profile that could make minor instabilities kinematically feasible may not be identified if generalised assumptions about the slope profile are made in stereographic analysis. In addition, where a slope has a plan curvature and the presence of an undulating joint set is evident, some localised, potentially unstable, rock blocks may not be reflected in the stereoplots (Hui, 2006). Where appropriate, sensitivity analysis should

be carried out to allow for local variations in the slope surface profile.

Caution should be exercised to avoid over-reliance on simple statistical computer programs because kinematic analysis using joint sets derived from a contoured stereoplot may obscure the variability of discontinuity orientations. With the use of statistical computer programs, the significance of some of the infrequent but critical joints may be missed. Designers should be involved in the site mapping and examine the original uncontoured joint data to critically appraise the results of stereographic analysis.

Large-scale engineering geological drawings and marked-up transparent overlays to photographs showing all salient features of the rock mass, including locations and extent of potentially unstable blocks and areas of seepage as well as dimensioned locations, extent and details of the proposed support and drainage measures should be prepared.

The majority of engineered rock cut slope failures in Hong Kong involve minor rockfalls due to local adverse groundwater regimes, root wedging and/or loose or unstable blocks. The latter may be associated with the presence of weaker, more weathered and/or closely jointed rock within a generally strong rock mass, which can be especially vulnerable to deterioration. Such minor rockfalls can be difficult to guard against in design. Although the chance of direct impact by a small rockfall is not high, the consequence in the event of direct impact could be serious given the nature of the material. A pragmatic approach is to provide suitable protective and mitigation measures such as rock mesh netting, rockfall fence, rock trap or rock ditch, rockfall barrier or buffer zone (where space permits) in order to mitigate the consequence and hence reduce the risk of minor rockfalls. In this regard, minor rockfalls successfully retained by these mitigation measures as intended should not be regarded as a failure.

Specific unstable blocks and seepage locations should be dealt with by means of appropriate local support and drainage measures. However, in the case of a heavily jointed or intensely fractured rock mass, patterned rock dowelling in conjunction with prescriptive subsurface drainage measures and rock mesh netting could be an appropriate solution (MGSL, 2002). Adequate number of fixing pins should be provided to ensure that rock mesh netting closely follows the rock slope profile as far as practical, particularly along the edge of the rock mesh netting on rugged rock surface to prevent any potential loose blocks from falling out from the opening between the netting and the rock surface (Lee et al, 2014). Where potentially unstable blocks exceed the maximum size that rock mesh netting could retain, other appropriate methods (e.g. stabilisation, removal, etc.) should be considered (Hui, 2006). The identification of the weaker parts of the rock mass and seepage locations requiring works can only be specified in detail once the rock face is exposed during construction. A hard cover, such as shotcrete, to the entire rock face is generally not necessary and should be avoided on aesthetic grounds. However, the provision of a hard cover (e.g. stone pitching) together with subsurface drainage measures to local patches of weaker rock mass to limit infiltration and deterioration may be justified from slope stability point of view, subject to appropriate landscape treatment.

General guidance on the use of prescriptive concrete buttresses for rock cut slopes is given in Section 5.6 of the Prescriptive Measures for Man-made Slopes and Retaining Walls (GEO, 2009). However, the use of prescriptive

concrete buttresses should only be confined to the treatment of small local overhangs or rock blocks. Detailed stability assessment and structural design of reinforced concrete buttresses should be carried out when they are used to stabilize sizeable unstable rock blocks.

(b) Section 4.4 **Replace paragraph 2 with the following:**

The nature of rock cuts dictates that the design can only be finalised and the extent of stabilisation works ascertained following detailed mapping after the rock face is excavated. Notwithstanding this, all available information including ground investigation and geological mapping data should be used to determine the initial profile of a rock cut. General principles and key considerations relating to the development of engineering geological models are given in Section 3 of the Engineering Geological Practice in Hong Kong (GEO, 2007).

(c) Section 4.4 **Add the followings after paragraph 2:**

As only a small amount of water is needed to fill up rock joints and lead to high cleft water pressure, extreme caution should be exercised in assessing the design groundwater condition. Sufficient subsurface drainage provisions should be prescribed in order to minimise the uncertainty and sensitivity associated with groundwater response in rock slopes.

The designer should assess at an early stage the need for the provision of berms and/or catch ditches taking into account all relevant requirements, constraints and available ground information (see Section 2.4). Table 4.6 summarises the key factors that need to be considered in the design of new rock slopes along highways, with particular reference to the provision of berms or catch ditches.

SECTION 6 LANDSCAPE ASPECTS

(a) Section 6.1 **In paragraph 4, lines 2 and 3, delete** 'GEO Publication No. 1/2000 (GEO, 2000)' **and substitute** 'GEO Publication No. 1/2011 (GEO, 2011)'

SECTION 7 CONSTRUCTION CONTROL

(a) Section 7.2 **Add the following after paragraph 1:**

Site inspections by geotechnical professionals responsible for independent checking of the slope design should be carried out at critical stages of the works including site inspections to vet the design assumptions (and proposed design amendments as appropriate) based on the actual ground conditions encountered.

(b) Section 7.2 **Add the following after paragraph 9:**

Detailed as-built records should include large-scale engineering geological drawings (e.g. marked-up transparent overlays to photographs) depicting all the major geological features and dimensioned locations, extent and details of all support, drainage and mitigation measures. Photographic record of the exposed rock face should be made as part of the as-built record,

especially where a surface cover (e.g. shotcrete to local weak zones or fibre-reinforced soil) is provided.

(c) Section 7.3.1 **Add the followings after Table 7.1:**

In the formation of new rock cuts involving substantial rock breaking using expanding agents, adequate measures need to be taken to prevent the uncontrolled flow of the expanding agents, which may adversely affect the stability of rock faces. Moreover, as expanding agents can continue to expand for at least several days, time-dependent deterioration in stability can occur where there is uncontrolled or unintended flow of the expanding agents into joints.

(d) Section 7.4 **Replace paragraph 2 with the following:**

Often the best time to carry out the design review and to confirm the ground conditions at slope features is when the ground is exposed at various stages of excavation where extensive access scaffolding is available for mapping. For a road project, the examination of exposures should be carried out for all slopes in the same area, in an integrated manner. Attention should be given to assessing the influence of variations in rock mass weathering on the design (see Section 3.2 and Table 4.6). Provision should be made in the programme for the mapping and stability assessment of rock slopes, and for amending the design and construction details of the slope stabilisation and rockfall mitigation works.

(e) Section 7.4 **Add the followings after paragraph 2:**

Extra care should also be exercised in verifying the boundaries of different weathering grades of rocks, particularly when detailed mapping of the rock face has not been carried out at the design stage (FSWJV, 2006). Design reviews during construction call for input by geotechnical professionals with adequate engineering geological knowledge and local experience.

REFERENCES

(a) **Add the following new references:**

Evans, N.C. & Irfan, T.Y. (1991). *Landslide Studies 1991 : Blast-induced Rock Slide at Shau Kei Wan, November 1991.* Special Project Report No. SPR 6/91, Geotechnical Engineering Office, Hong Kong, 115 p.

Fugro Scott Wilson Joint Venture (2006). *Review of Landslide Incident at Slope No. 11SE-D/C57, Sai Wan Service Reservoir, Tai Tam Road.* Landslide Study Report No. LSR 2/2006, Geotechnical Engineering Office, Hong Kong, 49 p.

Geotechnical Engineering Office (2007). *Engineering Geological Practice in Hong Kong (GEO Publication No. 1/2007).* Geotechnical Engineering Office, Hong Kong, 278 p.

Geotechnical Engineering Office (2009). *Prescriptive Measures for Man-made Slopes and Retaining Walls (GEO Publication No. 1/2009).* Geotechnical Engineering Office, Hong Kong, 76 p.

Geotechnical Engineering Office (2011). *Technical Guidelines on Landscape Treatment for Slopes (GEO Publication No. 1/2011).* Geotechnical Engineering Office, Hong Kong, 219 p.

Halcrow China Limited (2001). *Detailed Study of Selected Landslides on Slope No. 11NE-D/C45, Hiu Ming Street, Kwun Tong.* Landslide Study Report No. LSR 7/2001, Geotechnical Engineering Office, Hong Kong, 96 p.

Hencher, S.R. (1981). *Report on Slope Failure at Yip Kan Street (11SW-D/C86) Aberdeen on 12th July 1981.* Geotechnical Control Office Report No. GCO 16/81, Geotechnical Control Office, Hong Kong, 26 p.

Hui, T.H.H. (2006). *Detailed Study of the 6 June 2003 Rockfall Incident on Slope No. 11NE-C/C71 at Kung Lok Road, Kwun Tong.* GEO Report No. 192, Geotechnical Engineering Office, Hong Kong, 68 p.

Lee, R.W.H, Leung, J.C.W & Lo, D.O.K. (2014). *Review of Landslides in 2012.* Landslide Study Report No. LSR 1/2014, Geotechnical Engineering Office, Hong Kong, 43 p.

Maunsell Geotechnical Services Ltd. (2002). *Detailed Study of the 9 June 2001 Rockfall Incident at Slope No. 11NW-A/C58 at Castle Peak Road below Wah Yuen Tsuen.* Landslide Study Report No. LSR 4/2002, Geotechnical Engineering Office, Hong Kong, 72 p.

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

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

(c) **Replace the footnote as the followings**

* denotes copies of GEO Internal Reports are available for inspection in the Civil Engineering Library, Civil Engineering Department. Some of the GEO Internal Reports may be turned into GEO Publications in future. Readers are advised to check the latest list of GEO Publications at the CED website http://www.cedd.gov.hk/eng/publications/index.html on the Internet.