Geotechnical Engineering Office, Civil Engineering and Development Department
The Government of the Hong Kong Special Administrative Region

GEO Technical Guidance Note No. 35 (TGN 35)
Detailing of Rigid Debris-resisting Barriers

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1. SCOPE

1.1 This Technical Guidance Note (TGN) supplements relevant guidance given in GEO Report No. 104 and highlights areas that require particular attention in respect of detailing of rigid debris-resisting barriers.

1.2 Any feedback on this TGN should be directed to Chief Geotechnical Engineer/Landslip Preventive Measures 2 of the Geotechnical Engineering Office (GEO).

2. TECHNICAL POLICY

2.1 The technical recommendations promulgated in this TGN were agreed by GEO Geotechnical Control Conference in 7 November 2012.

3. RELATED DOCUMENTS

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

3.2 Kwan, J.S.H. (2012). *Supplementary Technical Guidance on Design of Rigid Debris-resisting Barriers (GEO Report No. 270).* Geotechnical Engineering Office, Hong Kong, 88 p.

3.3 Lo, D.O.K. (2000). *Review of Natural Terrain Landslide Debris-resisting Barrier Design (GEO Report No. 104).* Geotechnical Engineering Office, Hong Kong, 91 p.

3.4 Shum, L.K.W. & Lam, A.Y.T. (2011). *Review of Natural Terrain Landslide Risk Management Practice and Mitigation Measures* (*Technical Note No. TN 3/2011).* Geotechnical Engineering Office, Hong Kong, 167 p.

3.5 Sun, H.W., Lam, T.T.M. & Tsui, H.M. (2005). *Design Basis for Standardised Modules of Landslide Debris-resisting Barriers (GEO Report No. 174).* Geotechnical Engineering Office, Hong Kong, 161 p.

3.6 SWCB (2005). *Soil and Water Conservation Handbook (水土保持手冊).* Soil and Water Conservation Bureau of the Council of Agriculture, Executive Yuan, Taiwan and Chinese Soil and Water Conservation Society, Taiwan, 692 p. (in Chinese)

3.7 VanDine, D.F. (1996). *Debris Flow Control Structures for Forest Engineering*. Ministry of Forests, British Columbia, Canada, 68 p.

3.8 Wong, D.K.K. (2012). *Brainstorming Workshop on Optimum Schemes in the Clearance of Landslide Debris Retained by Debris-resisting Barriers (Training Report No. TR 1/2012).* Geotechnical Engineering Office, Hong Kong, 167 p.

3.9 Zhou, B., Li, D., Luo, D., Lu, R. & Yang, G. (1991). *Guide to Mitigation of Debris Flows (泥石流防治指南)*. Science Press, China, 217 p. (in Chinese)

4. BACKGROUND

4.1 Lo (2000) presents guidelines for the design of rigid debris-resisting barriers. Sun et al (2005) introduce standardised barriers together with related design calculations. Local practitioners have made reference to these publications for design of rigid barriers. Supplementary design guidance of rigid barriers is provided by Kwan (2012). As of August 2012, some 50 rigid debris-resisting barriers have been completed under Landslip Prevention and Mitigation Programme. A desk study review and site inspection of selected barriers have been undertaken with a view to consolidating areas for attention that are pertinent to the proper detailing of rigid barriers.

5. TECHNICAL RECOMMENDATIONS

5.1 General Zoning of Rigid Debris-resisting Barriers

5.1.1 In the context of a rigid debris-resisting barrier, three zones can be broadly distinguished (see Figure 1): (a) debris approaching zone, (b) debris retention zone, and (c) runoff discharge zone. The zoning is intended to assist the identification of key elements to be considered in the detailing of rigid barriers. In general, the key design consideration for the debris approaching zone is to direct debris effectively to the debris retention zone. The key design considerations for the debris retention zone are deposition control and discharge of surface runoff, whilst the key design consideration for the runoff discharge zone is erosion control.

5.1.2 Designers should consider the areas for attention and underlying principles presented in this TGN in the detailing of rigid barriers. The considerations presented in this TGN are generic in nature and should not be taken as exhaustive. Designers should formulate appropriate detailing to cater for all the specific concerns associated with the actual site setting.

5.2 Debris Approaching Zone

5.2.1 <u>Debris routing</u> - The topography of the debris approaching zone should be carefully reviewed, especially if the debris approaching zone is relatively flat and broad. Debris flow direction can be sensitive to changes in topography. Where deemed necessary, consideration should be given to incorporating debris flow routing provisions (e.g. deflection structures or transport channels).

5.2.2 <u>Drainage provision</u> - A relatively flat and broad debris approaching zone is susceptible to water ponding. Appropriate drainage measures (e.g. surface channels) should be provided to avoid the problem.

5.2.3 Erosion and entrainment control - Terminal debris-resisting barriers are usually located on gently sloping ground where previous landslide debris may have been deposited. Attention should be given to the presence of bare ground surfaces or loose surface materials in the vicinity of the barrier inlet area (Plate 1), as these can be prone to erosion and can become sources of entrainment (Shum & Lam, 2011). If the loose surface materials consist of a large amount of boulders, designers may consider using the boulders to form gabion mats for erosion control purposes.

5.2.4 Debris over-shooting - The possibility of over-shooting of fast-moving debris over the top of a barrier wall should not be overlooked, in particular where the height of the barrier wall stem is not significant and the elevation difference between the debris approaching zone and the invert of the debris retention zone is large (Figure 2).

5.3 Debris Retention Zone

Debris confinement

5.3.1 The debris flow path and debris deposition profile should be considered three-dimensionally. Attention should be paid to the appropriate location and configuration of a barrier to avoid uneven deposition of debris in the debris retention zone, which may result in overflow at the location of excessive debris deposition. Figure 3 shows the location of a barrier that may cause uneven debris deposition. In typical design of rigid barriers, calculation of retention volume usually assumes a uniform deposition thickness across the width of the debris retention zone. If uneven debris deposition is likely, the assumption of uniform deposition thickness may not be appropriate and the calculation of retention volume should account for this.

5.3.2 Side (or wing) walls are sometimes not provided to open-type retention zones. Attention should be paid to ensure that landslide debris would be effectively confined within the debris retention zone.

Drainage provision

5.3.3 Drainage of a barrier should be designed taking into account three situations, viz. landslide debris-free situation (i.e. before the arrival of landslide debris), normal operation where the volume of debris is as designed, and extreme situation where the retention capacity of the barrier is exceeded. Channels with adequate self-cleansing capacity under dry weather flow conditions should be provided within the debris retention zone in order to avoid settling of silts and possible blockages during the landslide debris-free situation. Under normal operation, a barrier should aim to retain all the coarse fractions of a debris flow and allow water to discharge in a controlled manner. The water will likely carry fines, gravels and cobbles. Provision should be made to allow the gravels and cobbles to deposit in the retention zone as much as possible. De-silting facilities may also be provided (see also paragraph 5.4.3). During extreme situation, debris overflow is likely. Robust and designated discharge point(s) should be provided at the barrier to allow debris to overflow from the barrier in a controlled manner. The designated discharge point(s) should be sufficiently large, otherwise debris could overflow from other undesirable points.

5.3.4 Drainage can be easily blocked by debris or fines and as such a robust design of the drainage provisions is called for. Designers should provide adequate drainage outlets on barrier walls and make suitable allowance for possible blockages by debris.

5.3.5 Uncontrolled overflow may result in scouring of the downstream area. Possible debris overflow situations and measures to direct the debris overflow to designated discharge points with suitable anti-scouring provisions should be duly considered (Zhou et al, 1991). In addition, consideration should be given to the provision of surface drainage along the toe of barriers (see also paragraph 5.4.4).

Design robustness

5.3.6 Designers may consider providing debris flow impediments (e.g. baffles) within the debris retention zone to retard and promote lateral spreading of debris flow. Some qualitative recommendations on the design of flow impediments are given by VanDine (1996). However, bulky and excessive debris flow impediments, which can result in notable reduction in debris retention capacity, should be avoided.

5.3.7 Experience in other regions (SWCB, 2005) indicates that the cushioning effect brought about by suitable materials (e.g. gabions) at the back of a rigid barrier, which deform readily upon impact, could lead to a reduction in the impact load. Such cushioning materials are sometimes prescribed with a view to enhancing the robustness of the design.

Maintenance considerations

5.3.8 Suitable means to facilitate debris clearance and routine maintenance should be carefully planned. Reference may be made to Wong (2012) for some of the basic considerations.

5.4 Runoff Discharge Zone

Drainage provisions

5.4.1 The ground adjoining the connection point of the existing public drains and the new drains for rigid barrier can be susceptible to erosion due to possible overflow of water and/or debris.

5.4.2 Attention should be paid to the adequacy of the drainage capacity of the existing public drainage system, to which runoff from a barrier is fed. Where a large amount of surface water from a barrier is collected and conveyed away through underground public drains for major traffic routes, the possibility of flooding of the traffic route arising from possible blockage of the drainage system (e.g. culvert) by debris should not be overlooked. Where necessary, designer should carry out appropriate study (e.g. event tree analysis with assumptions of blockages of road gullies, etc.) to assess the consequence of potential flooding and identify the necessary preventive and/or mitigation measures. Where appropriate and feasible, consideration may be given to having designated drainage provisions for the traffic routes, which are separated from the existing public drainage system that conveys runoff from the barrier.

5.4.3 Consideration should be given to providing measures to address the problem of blockage of drainage provisions (e.g. debris traps, de-silting facilities at drainage inlets, etc).

Erosion protection of barrier's front area

5.4.4 The ground in front of a debris barrier can be vulnerable to scouring by the runoff discharge or overflow from the barrier. Plate 2 shows an example of a barrier foundation having been undermined after a debris flow event. Attention should be paid to protecting the ground and side banks from scouring, in particular where scouring action could adversely affect the stability of the barrier foundation (see also paragraph 5.3.5).

5.5 Landscape Treatments and Architectural Input

5.5.1 Consideration should be given to minimising physical and visual impacts to the existing landscape (GEO, 2011). Landscape input should be provided at an early stage of the barrier design. Suitable landscape treatments should be provided.

5.5.2 Appropriate architectural input should also be provided at an early stage of the barrier design with respect to the general arrangement, shape and finish of the structure.

5.6 Other Considerations

5.6.1 Consideration should be given to balancing the cut and fill operations in the site formation works for barrier construction. The use of local excavated material for barrier construction, where feasible, would help to reduce the amount of material to be transported to and off site. An example is the re-use of excavated material to construct gabion structures in Wang Hang Village, Lantau Island (see Figure 4.7 of Shum & Lam (2011)).

6. ANNEXES

6.1 TGN35 A1 - Figures

6.2 TGN35 A2 - Plates

(Raymond W M Cheung)
Head, Geotechnical Engineering Office

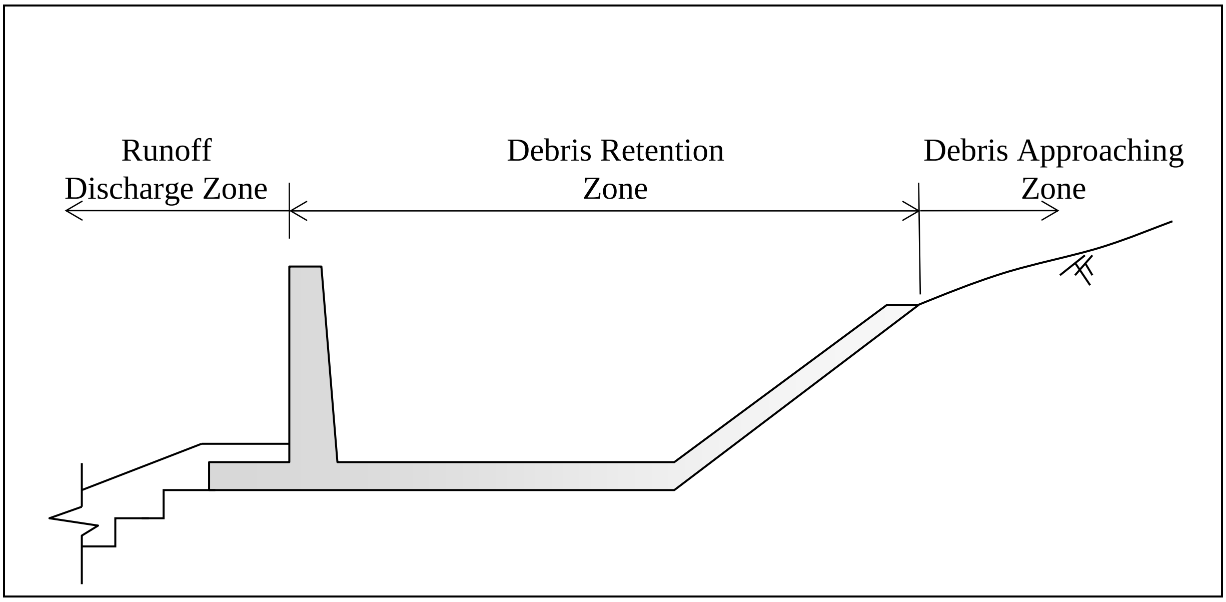

Figure 1 - Typical Zoning of Rigid Debris-resisting Barrier

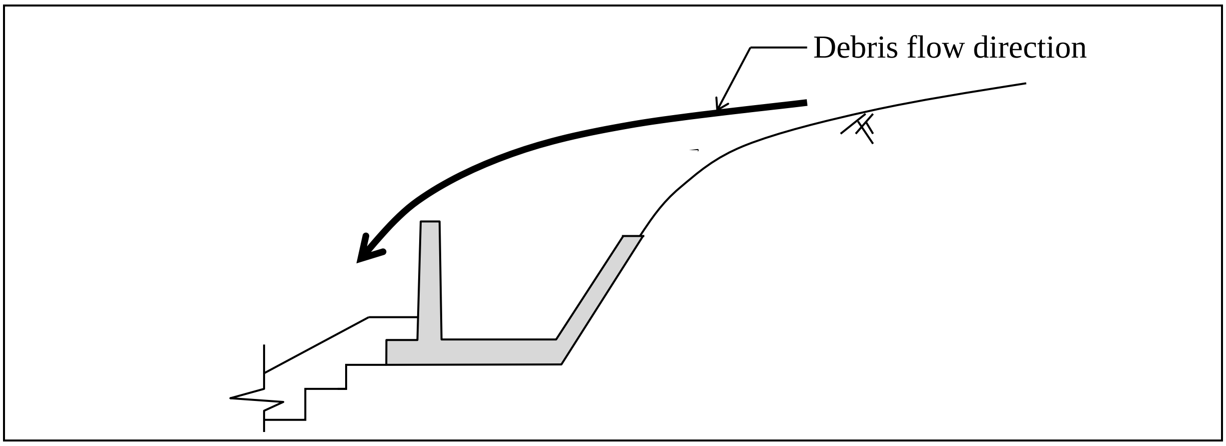

Figure 2 - Overshooting of Debris across Barrier Wall

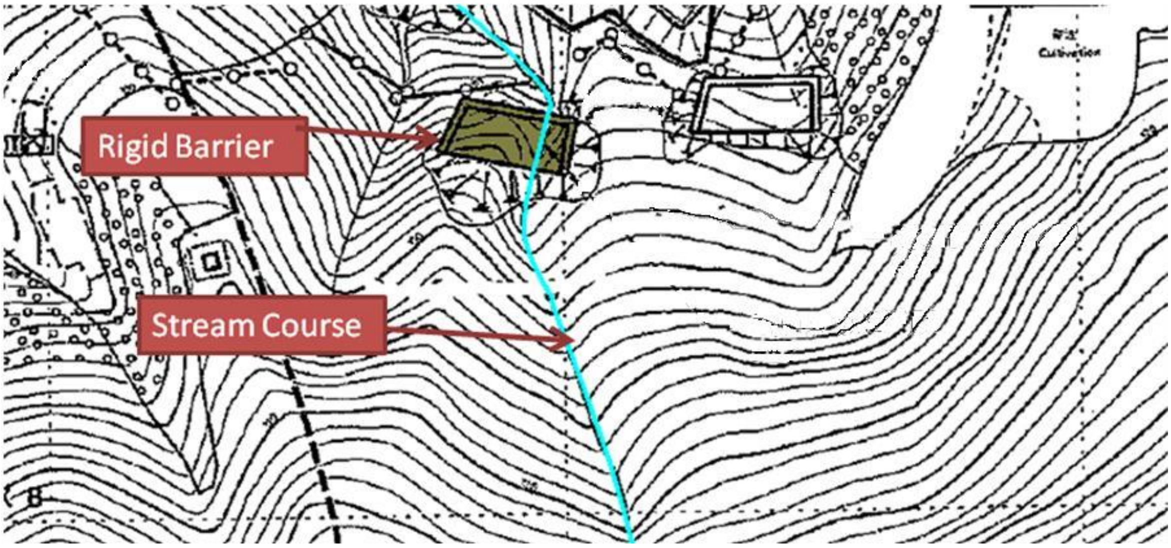

Figure 3 - Barrier with Potential Problem of Uneven Accumulation of Debris in the Debris Retention Zone

Plate 1 - Loose Surface Materials at Debris Approaching Zone

Plate 2 - Foundation of a Barrier Undermined after a Debris Flow Event