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

GEO Technical Guidance Note No. 56 (TGN 56)
Design of Flexible Debris-resisting Barriers Using Energy Approach

1. SCOPE

1.1 This Technical Guidance Note (TGN) stipulates the recommendations on the design of flexible debris-resisting barriers using the Energy Approach.

1.2 Any feedback on this TGN should be directed to the Chief Geotechnical Engineer/Landslip Prevention 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 on 16 October 2024.

3. RELATED DOCUMENTS

3.1 EOTA (2013). *Guideline for European Technical Approval of Falling Rock Protection Kits (ETAG 027).* European Organisation for Technical Approvals, 59 p.

3.2 EOTA (2018). *Falling Rock Protection Kits (European Assessment Document EAD 340059 00 0106).* European Organisation for Technical Assessment, 28 p.

3.3 Fugro (2022). *Detailed Study of the October 2021 Landslide on the Natural Hillside above Ma Wan New Village, Pa Mei, Tung Chung (Landslide Study Report No. LSR 2/2022).* Geotechnical Engineering Office, Hong Kong, 95 p.

3.4 GEO (1984). *Geotechnical Manual for Slopes (Second Edition).* Geotechnical Engineering Office, Hong Kong, 302 p.

3.5 GEO (2011). *Guidelines on the Assessment of Debris Mobility for Channelised Debris Flows (GEO Technical Guidance Note No. 29).* Geotechnical Engineering Office, Hong Kong, 6 p.

3.6 GEO (2012). *Guidelines on Assessment of Debris Mobility for Open Hillslope Failures (GEO Technical Guidance Note No. 34).* Geotechnical Engineering Office, Hong Kong, 16 p.

3.7 GEO (2013a). *Guidelines on the Assessment of Debris Mobility for Failures within Topographic Depression Catchments (GEO Technical Guidance Note No. 38).* Geotechnical Engineering Office, Hong Kong, 8 p.

3.8 GEO (2013b). *Stability of Man-made Slopes Affected by Debris Retained behind Landslide Debris-resisting Barriers (WGGC Paper No. 3/2013).* Geotechnical Engineering Office, Hong Kong, 2 p.

3.9 GEO (2014). *Guidelines on Empirical Design of Flexible Barriers for Mitigating Natural Terrain Open Hillslope Landslide Hazards (GEO Technical Guidance Note No. 37)*. Geotechnical Engineering Office, Hong Kong, 18 p.

3.10 GEO (2019). *Detailing of Flexible Debris-resisting Barriers (GEO Technical Guidance Note No. 48)*. Geotechnical Engineering Office, Hong Kong, 9 p.

3.11 GEO (2023). *Stability of Slopes below Debris-resisting Barriers (GEO LPM Branch Design Technical Note No. DES-03)*. Geotechnical Engineering Office, Hong Kong, 2 p.

3.12 Ho, H.Y. & Roberts, K.J. (2016). *Guidelines for Natural Terrain Hazard Studies (GEO Report No. 138) (Second Edition)*. Geotechnical Engineering Office, Hong Kong, 173 p.

3.13 Hungr, O. (1995). A model for the runout analysis of rapid flow slides, debris flows, and avalanches. *Canadian Geotechnical Journal*, Volume 32, No. 4, pp. 610-623.

3.14 Kwan, J.S.H. & Cheung, R.W.M. (2012). *Suggestions on Design Approaches for Flexible Debris-resisting Barriers (Discussion Note DN 1/2012)*. Geotechnical Engineering Office, Hong Kong, 90 p.

3.15 Lam, H.W.K., Sze, E.H.Y. & Wong, E.K.L. (2021). *Review of Energy Approach in Designing Flexible Debris-resisting Barriers (Technical Note No. TN 4/2021)*. Geotechnical Engineering Office, Hong Kong, 27 p.

3.16 Law, R.P.H. & Ko, F.W.Y. (2018) *Validation of Geotechnical Computer Program "2d-DMM (Version 2.0)" (GEO Report No. 332)*. Geotechnical Engineering Office, Hong Kong, 98 p.

3.17 Law, R.P.H., Kwan, J.S.H. & Ko, F.W.Y. (2022) *Validation of Geotechnical Computer Program "3d-DMM (SPH Version 2.0)" (GEO Report No. 353)*. Geotechnical Engineering Office, Hong Kong, 60 p.

3.18 Sun, H.W. & Law, R.P.H. (2015). *A Preliminary Study on Impact of Landslide Debris on Flexible Barriers (GEO Report No. 309)*. Geotechnical Engineering Office, Hong Kong, 47 p.

3.19 Wong, E.K.L. Law, R.P.H. & Li, I. (2020). *Modelling of Entrainment and Development of an Improved Debris Mobility Modelling Program "2d-DMM (Version 3.0)" (Technical Note No. TN 3/2020)*. Geotechnical Engineering Office, Hong Kong, 28 p.

3.20 Wong, E.K.L. & Lau, J.W.C. (2022). *Back Analysis of Flexible Barrier Response following Impact from the October 2021 Open Hillslope Landslide at Pa Mei, Lantau Island (Special Project Report No. SPR 3/2022)*. Geotechnical Engineering Office, Hong Kong, 51 p.

3.21 Wong, E.K.L. & Lau, J.W.C. (2024). *Supplementary Review of Energy Approach in Designing Flexible Debris-resisting Barriers (Technical Note No. TN 1/2024).* Geotechnical Engineering Office, Hong Kong, 26 p.

4. BACKGROUND

4.1 Kwan & Cheung (2012) and GEO (2014) provide some suggestions on design approaches for energy-rated flexible rockfall barriers for resisting landslide debris. GEO (2019) gives recommendations on the detailing of flexible barriers including alignment, anchor location and special considerations for barriers traversing a stream course.

4.2 A series of reviews supplemented by numerical analyses, landslide studies and back analyses of field impacts was carried out by the GEO (Lam et al., 2021; Fugro, 2022; Wong & Lau, 2022; Wong & Lau, 2024) to investigate the performance of proprietary energy-rated flexible rockfall barriers subjected to landslide debris impacts close to their rated energy capacities. The performance of these rockfall barriers subjected to adverse impact scenarios was also studied.

4.3 Following the technical development work above involving numerical analyses, landslide studies and back analyses of impact cases on flexible barriers, this TGN makes recommendations on the design of flexible debris-resisting barriers using the Energy Approach.

4.4 In this TGN, debris refers to landslide debris comprising primarily of granular soil which may contain boulders.

5. TECHNICAL RECOMMENDATIONS

5.1.1 The maximum design debris impact energy that may be resisted by an energy-rated rockfall barrier may be taken as the energy capacity established by full-scale rockfall (or other single-mass) tests. The full-scale rockfall test should be carried out in accordance with standards acceptable to the GEO (e.g. EOTA, 2013; EOTA, 2018). For the avoidance of doubt, the energy capacity of the rockfall barrier needs not be reduced by a scaling factor to account for the differences between rockfall and debris impacts.

5.1.2 The retention capacity of a flexible barrier should be checked with due regard of the dimensions of the barrier and the topographic conditions on the ground behind the barrier where debris would deposit.

5.1.3 The retention capacity of a flexible barrier should be assessed based on the deformed dimensions (e.g. reduced barrier height after deformation) of the barrier upon debris impact.

In the absence of deformation characteristics from detailed structural assessments or physical or field tests simulating debris impact, the residual height of a flexible barrier upon debris impact may be taken as 60% of the original height of the principal net.

5.1.4 The debris impact energy to be resisted by a flexible barrier should be duly assessed through debris mobility modelling with an algorithm accepted by the GEO. Different numerical tools are available for carrying out debris mobility modelling (e.g. Hungr, 1995; Law & Ko, 2018; Wong et al., 2020; Law et al., 2022).

The rheological parameters to be used should follow those recommended in GEO TGN No. 29 (GEO, 2011), GEO TGN No. 34 (GEO, 2012) and GEO TGN No. 38 (GEO, 2013a). Realistic topographical profiles, including the geometry of the drainage lines, should be incorporated in the mobility analysis.

The debris impact energy to be resisted by a flexible barrier should be taken as the cumulative free-field kinetic energy passing through a cross section at which the flexible barrier is located (Wong & Lau, 2024). The debris impact energy should not be taken as the total kinetic energy of the debris trail at the moment the debris front hits the flexible barrier because the travelling speed of the remainder of the debris trail may continue to change after the initial impact. For the avoidance of doubt, the approach for estimating the energy transferred to a flexible barrier under the pile-up and run-up mechanisms described by Kwan & Cheung (2012) and Sun & Law (2015) should not be used in conjunction with paragraphs 5.1.1 and 5.1.3.

5.1.5 Where a flexible barrier is located on or near the crest of a man-made or natural slope, the overall stability of the slope should be assessed and where necessary stabilisation measures should be implemented to achieve a minimum factor of safety in accordance with the Geotechnical Manual for Slopes (GEO, 1984) for man-made slopes or Ho & Roberts (2016) for natural slopes. The effects of foundation load on slope stability should also be assessed where necessary.

5.1.6 In addition to paragraph 5.1.5 above, for a man-made or natural slope being affected by an increased loading due to the landslide debris retained by the barrier, the overall stability of the slope affecting facilities under Consequence-to-Life Category 1, 2, or 3 should be assessed and where necessary stabilisation measures should be implemented to achieve a minimum factor of safety of 1.2, 1.1 or 1.0, respectively (GEO, 2013; GEO, 2023). However, this assessment is not necessary for flexible barriers prescribed under a holistic risk mitigation strategy (Ho & Roberts, 2016).

5.1.7 The energy capacity of a flexible barrier may be reduced if an impact occurs at its edge panel instead of its central portions (Wong & Lau, 2024). The deformation of the barrier may also be notably larger. There is a higher possibility of permanent structural damage, especially to the edge posts, resulting in greater repair or replacement costs. A flexible barrier should be positioned such that the most probably debris flow path does not intersect the barrier at the edge panel. For open hillslope catchments, it is prudent to provide suitable overlapping between adjacent barriers.

At the edge of open hillslope catchments where a flexible barrier usually terminates, an impact close to the energy of the full design event is usually unlikely, in the absence of evidence to the contrary. The risk of such an impact occurring at an edge panel should be considered when deciding whether additional measures (e.g. providing an extra panel or other supplementary protective measures) is warranted to cater for such impact.

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