GEO Technical Guidance Note No. 55 (TGN 55)
Design of Flexible Debris-resisting Barriers Using Force Approach

1. SCOPE

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

1.2 Any feedback on this TGN should be directed to the 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 on 16 October 2024.

3. RELATED DOCUMENTS

3.1 BD (2023). *Code of Practice for the Structural Use of Steel 2011 (2023 Edition)*. Buildings Department, Hong Kong, 399 p.

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

3.3 GEO (2013). *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.

3.4 GEO (2015). *Assessment of Landslide Debris Impact Velocity for Design of Debris-resisting Barriers (GEO Technical Guidance Note No. 44)*. Geotechnical Engineering Office, Hong Kong, 4 p.

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

3.6 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.

3.7 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.

3.8 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.

3.9 Kwan, J.S.H. & Koo, R.C.H. (2018). *Enhanced Technical Guidelines for Design of Debris-resisting Barriers (GEO Report No. 333).* Geotechnical Engineering Office, Hong Kong, 34 p.

3.10 Lam, H.W.K., Sze, E.H.Y. & Wong, E.K.L. (2020). *Study of Dynamic Soil Debris Impact Load on Flexible Debris-resisting Barriers (Technical Note No. TN 2/2020).* Geotechnical Engineering Office, Hong Kong, 48 p.

3.11 Ma, M.K.H., Wong, E.K.L. & Lau, J.W.C. (2024). *A Numerical Study of Boulder Impact Effects and Dynamic Soil Debris Impact Load on Flexible Debris-resisting Barriers (Technical Note No. TN 2/2024).* Geotechnical Engineering Office, Hong Kong, 30 p.

4. BACKGROUND

4.1 Kwan & Cheung (2012), GEO (2015) and Kwan & Koo (2018) provide some suggestions on design approaches for flexible debris-resisting barriers. 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 Lam et al. (2020) and Ma et al. (2024) studied the hydrodynamic impact load on flexible barriers subjected to landslide debris impact with and without boulders. Recommendations were made regarding the design value of the coefficient of hydrodynamic debris impact pressure.

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

5. TECHNICAL RECOMMENDATIONS

5.1 Loading on Barrier

5.1.1 Loading on flexible barriers should include (i) dynamic impact load due to debris impact, and (ii) static load arising from the debris that have been stopped and deposited behind the barrier. If debris overflow is allowed, the corresponding drag force induced on the barriers should also be included. The area of application of the loadings should be such that it produces the most adverse effect on the particular aspect or components of the barrier structure being designed.

5.1.2 Based on results of large-scale flume tests and numerical analysis, prediction of the dynamic debris impact pressure (p_d) should be evaluated using Equation (1).

$$p_d = \alpha \rho v^2 \quad (1)$$

where α = coefficient of dynamic debris impact pressure
ρ = mass density of debris, taken as 2,200 kg/m^3 as a minimum
v = debris velocity

If v > 12 m/s, justifications for the appropriateness of using Equation (1) to evaluate the dynamic impact pressure should be provided.

5.1.3 The coefficient of dynamic debris impact pressure (α) should be taken as 1.0 for debris consisting primarily of soil, with boulders of diameter up to 1 m. Impact effects from boulders up to 1 m in diameter need not be separately considered.

5.1.4 If the debris front is expected to comprise boulders larger than 1 m and up to 2 m in diameter, the coefficient of dynamic debris impact pressure (α) should be taken as 2.0 unless the impact loads from boulders are explicitly considered or unless separate mitigation measures are taken to address the presence of boulders.

Where boulders with diameter greater than 2 m (or with volume exceeding a 2 m diameter sphere) in the debris front are anticipated, suitable independent measures (e.g. baffles, debris-straining structures or in-situ boulder stabilisation) should be provided to reduce the impact of boulders on the flexible barrier.

5.1.5 The static pressure of the deposited debris (p_s) should be evaluated using Equation (2).

$$p_s = K d \rho g \quad (2)$$

where K = coefficient of earth pressure, taken as 1.0
d = depth below upper surface of moving debris
ρ = mass density of debris, taken as 2200 kg/m^3 as a minimum
g = gravitational acceleration

5.1.6 The debris may hit a barrier in the form of surges which fill up the barrier progressively. For design purpose, the design event should be assumed to involve multiple surges. The impact scenarios as shown in Figure 1 should be considered.

5.1.7 Where a series of flexible barriers is used to retain the whole of the active volume or where debris overflow is allowed in design, drag forces due to debris overflow should be considered under the loading scenario as shown in Figure 2.

The shear stress which gives rise to drag forces should be determined by Equation (3).

$$\tau = h\,\rho\,g\,\tan\phi_e \qquad (3)$$

where h = thickness of debris surge

ρ = mass density of debris, taken as 2,200 kg/m^3 as a minimum

$\tan\phi_e$ = equivalent coefficient of friction at interface of overtopping debris surge and deposited debris, to be taken as $\tan\phi + v^2/(h\xi)$ where v is velocity of overflow, ϕ and ξ are apparent friction angle and turbulence coefficient adopted in debris mobility analysis respectively (the second term, $v^2/(h\xi)$, can be dropped when frictional rheological model is used)

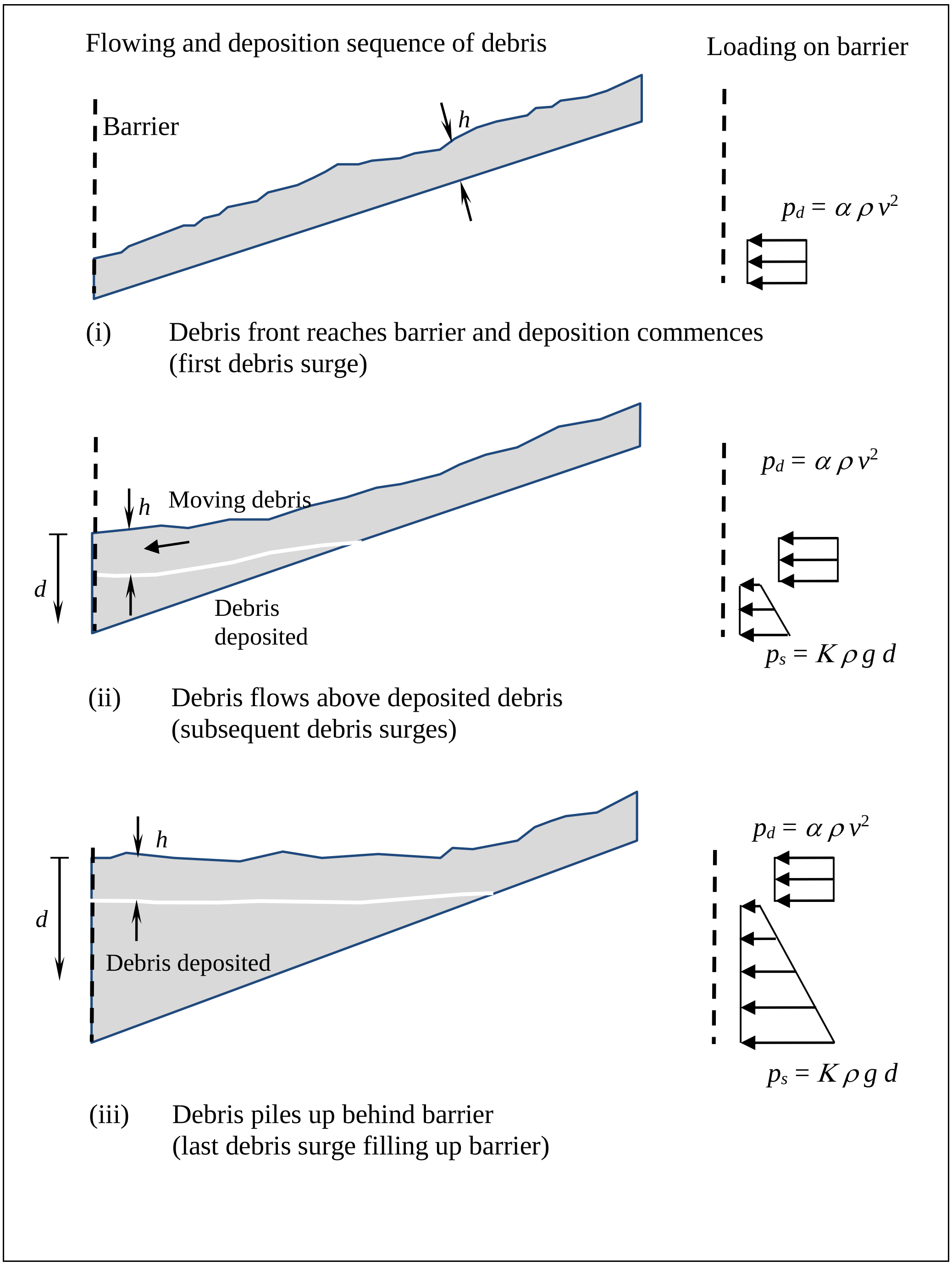

Figure 1. Design impact scenarios

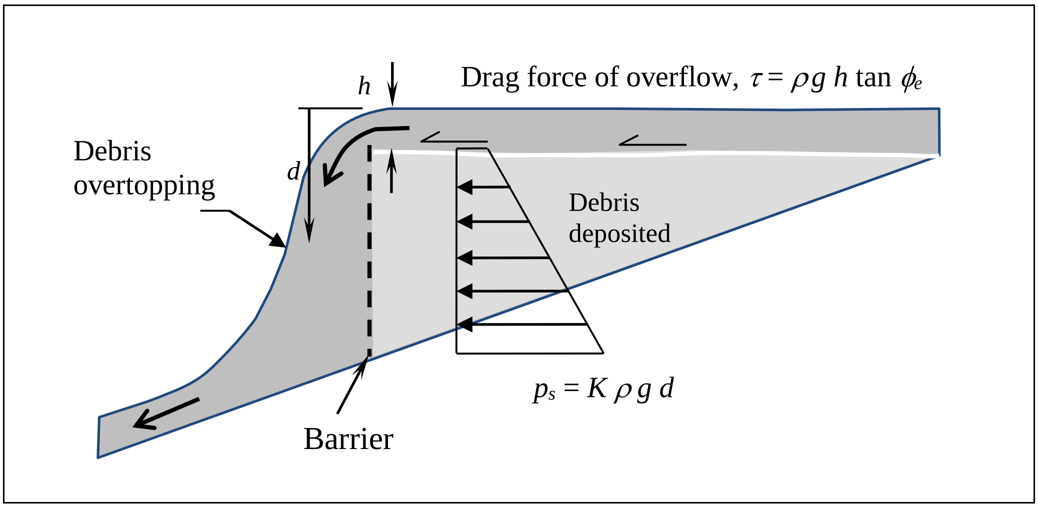

Figure 2. Loading on a barrier due to debris overtopping

5.1.8 The thickness of debris surge (*h*) and the velocity (*v*) in each surge should be determined in accordance with GEO TGN No. 44 (GEO, 2015).

5.1.9 For barriers at which over-topping is anticipated, appropriate protection measures to the top rope of the barrier against abrasion should be provided.

5.1.10 As a flexible barrier will deform under the effect of debris loading, the deformed height should be used in assessing the total force acting on the barrier (e.g. under the over-topping scenario). In addition, the weight of debris which could act on the deformed barrier should be taken into account in the structural design.

5.2 Structural Capacity of Barrier

5.2.1 The structure of a flexible barrier including the foundations for end and intermediate supports should be designed in accordance with relevant structural codes and standards, e.g. Code of Practice for the Structural Use of Steel (BD, 2023). The load factor on the ultimate design loads acting on the structural members of the barrier derived from the debris loading given in Equations (1), (2) and (3) may be taken as unity. Appropriate partial safety factors on structural materials should be applied in accordance with the structural codes and standards.

5.2.2 Appropriate structural analysis that takes into account the load-deformation characteristics of all major structural components as well as the entire barrier system (e.g. finite element / finite difference method) should be carried out to demonstrate that the flexible barrier has sufficient structural capacity to resist the debris loading with multiple surges illustrated in Figure 1. The structural form of the barrier should be designed and detailed such that the shape, disposition and strength of its members including wire ropes, nets and energy dissipating devices can be effectively mobilised to withstand the debris loadings.

5.2.3 Structural properties (e.g. load-deformation characteristics of the structural components) assumed in the structural analyses should be verified by adequate and appropriate laboratory tests.

5.2.4 Deformation of the flexible barrier should be checked using structural analysis. The designer should ensure that there is a sufficient clearance between the deformed barrier and the facility being protected.

5.2.5 The structural design including structural analyses and component tests should be carried out by a competent structural engineer who has design experience in steel structures. The design should be independently checked and certified by a Registered Structural Engineer or Registered Professional Engineer (Structural).

5.3 Checking against Overall Stability

5.3.1 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.

5.3.2 In addition to paragraph 5.3.1 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).

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