

**GEO Technical Guidance Note No. 7 (TGN 7)
Fill Slope Recomaction – Investigation, Design and Construction
Considerations**

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1. SCOPE

- 1.1 This Technical Guidance Note (TGN) provides technical guidance on the investigation of fill slopes, together with pertinent design and construction considerations in respect of upgrading of substandard fill slopes with particular reference to compaction of the upper 3 m of fill. It draws on past experience of upgrading of old fill slopes as well as key lessons learnt from the investigation of notable fill slope failures in recent years. This TGN is intended to supplement the guidance given in the Geotechnical Manual for Slopes (GCO, 1984) and Works Bureau Technical Circular No. 13/99 (Works Bureau, 1999).
- 1.2 Any feedback on this TGN should be directed to the Chief Geotechnical Engineer/Standards & Testing of the GEO.

2. TECHNICAL POLICY

- 2.1 The technical recommendations promulgated in this TGN were agreed by the GEO's Geotechnical Control Conference (GCC) on 29 December 2001.

3. RELATED DOCUMENTS

- 3.1 Geotechnical Control Office (1984). *Geotechnical Manual for Slopes. (Second Edition)*. Geotechnical Control Office, Hong Kong, 295 p.
- 3.2 Geotechnical Control Office (1993). *Review of Granular and Geotextile Filters. (GEO Publication No. 1/93)*. Geotechnical Engineering Office, Hong Kong, 141 p.
- 3.3 Government of Hong Kong (1992). *General Specification of Civil Engineering Works, Volume 1*, 280 p.
- 3.4 Independent Review Panel on Fill Slopes (1976). Report of the Independent Review Panel on Fill Slopes. *Report on the Slope Failures at Sau Mau Ping, August 1976*, Government of Hong Kong, pp 6-53. (Reprinted as GEO Report No. 86, Geotechnical Engineering Office, Hong Kong, 36 p).
- 3.5 Law, K.T., Lee C.F., Luan M.T., Chen H. & Zhai, Y. (1998). *Laboratory Investigation of Fundamental Behaviour of Loose Fill Under Shear, Volumes 1 & II*. Reports produced under Agreement No. GEO 16/96, Geotechnical Engineering Office.
- 3.6 Law, K.T., Lee C.F., Luan M.T., Chen H. & Ma X. (1999). *Appraisal of Performance of Recomacted Loose Fill Slopes. (GEO Report No. 58)*. Geotechnical Engineering Office, Hong Kong, 86 p.

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- 3.7 Public Works Department (1978). *Compaction of New Fill Slopes (Public Works Departmental Technical Circular No. 13/78)*. Hong Kong Government, 1p.
- 3.8 Works Bureau (1999). *Geotechnical Manual for Slopes Guidance on Interpretation and Updating (Works Bureau Technical Circular No. 13/99)*. Works Bureau, Government Secretariat, Hong Kong, 12p.

4. TECHNICAL RECOMMENDATIONS

4.1 DESK STUDY & SITE RECONNAISSANCE

- 4.1.1 In carrying out a desk study and site reconnaissance for old fill slopes, special attention should be given to identifying all water-carrying services that could affect, or be affected by, any necessary slope upgrading works. To assist in the assessment of how best to deal with any water-carrying services, key information including the locations of all pipes, details of pressurised pipes in particular, types of pipe material and nature of jointing, approximate age of the pipes, findings of any previous leakage detection tests, history of leakage (preliminary information on water pipe leakage is available on the Slope Information System at web-site <http://geosis.ccgo.hksarg>), etc., should be obtained.
- 4.1.2 Care should be taken in assessing the site setting, in particular the potential for concentrated water ingress (e.g. ponding within an uncovered crest area with inadequate drainage), or uncontrolled surface flow causing washout failure. In addition, attention should also be given to identifying buried stream courses, old drainage lines, and the extent of fill.
- 4.1.3 In reviewing aerial photographs and old topographical maps, attention should be given to establishing the mode of fill slope formation (e.g. by end tipping) and whether the site setting involves an infilled valley which could have a large depth of loose fill with the potential for preferential subsurface flow.

4.2 GROUND INVESTIGATION AND LABORATORY TESTING

- 4.2.1 The nature and thickness of fill, including its variability across the site, should be established (e.g. by trial pits, GCO probes or drillholes as appropriate). Attention should be given to the possible presence of weak layers such as significant organic content or mud layer within the fill.
- 4.2.2 The locations and alignment of utilities should be established by reference to record plans and utility company detection surveys, together with the use of trial pits which may be supplemented by geophysical surveys where considered appropriate. CCTV surveys may also be useful for examining the condition of specific pipe runs or road

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drainage systems above the slope crest.

- 4.2.3 In-situ density tests (e.g. sand replacement tests) and standard compaction tests must be carried out to establish the in-situ density and relative compaction of the fill material. Due regard should be given to the variability of the fill across the site (e.g. by reference to the GCO probe results) in deciding on the number and locations of trial pits for in-situ density measurements. Attempts should be made to establish a site-specific correlation between the GCO probe results and the in-situ density.
- 4.2.3 In the case of a slope with bouldery fill, care should be taken in determining the boulder content and its degree of variability across the site as far as practicable. Whilst there may be abundant boulders within local areas, the overall slope behaviour may be dominated by areas with a relatively small boulder content.
- 4.2.4 Retrieval of undisturbed samples in loose fill using conventional techniques is generally not recommended as the fill is liable to be densified during sampling, transportation and preparation of undisturbed test specimens in the laboratory. Hence, the corresponding test results could be unconservative and misleading. The direct shear test is not capable of determining reliably the post-peak strength of loose fill with a metastable structure that is prone to collapse. Where an assessment of the shear strength and collapse potential of the loose fill is required, this can be done by undrained triaxial compression tests with pore water pressure measurements on remoulded fill specimens from representative bulk samples prepared by means of moist tamping in accordance with the procedures used by the Public Works Central Laboratory and Law et al (1998). Carbon dioxide gas may be used to flush through the specimen before saturation in order to speed up the saturation process. Care needs to be exercised in interpreting the test results as the dry density of the specimens would change during the saturation and consolidation stages.

4.3 **DESIGN CONSIDERATIONS**

- 4.3.1 Where a loose fill slope is to be stabilised against flowslide, the approach of compacting the top 3 m has generally proved to be adequate based on review of performance records (Law et al, 1999). This is in accordance with the recommendation of the 1976 Independent Review Panel on Fill Slopes, with the exception that compaction should start from the slope toe as opposed to the slope crest from the buildability point of view. In this approach, benches should be formed and a drainage blanket must be placed at the interface between the newly compacted fill and the existing material, irrespective of whether seepage is observed from the slope face during re-construction.
- 4.3.2 The drainage blanket, which should satisfy the filter requirements as stipulated in GEO Publication 1/93 (GEO, 1993), should be extended up the excavated surface as far as practicable in order to intercept any subsurface flow, including leakage from buried water-carrying services. Where a geosynthetic material is proposed as the drainage

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blanket, extreme care must be exercised in assessing the effect of incorporating a weak smooth plane on slope stability.

- 4.3.3 Where there are water-carrying services that would affect the fill slope in the event of leakage, the designer should discuss with the relevant parties the possibility of permanent diversion of the services away from the slope, particularly if the services are located within the loose fill stratum. If diversion is not deemed to be feasible because of other considerations, a leakage protection system (e.g. provision of ducting such as a concrete trough) should be provided for the water-carrying services.
- 4.3.4 Where there are concerns about possible build-up of groundwater pressure due to subsurface seepage flow (e.g. in the case of fill over an old valley), rise in the base groundwater table or leakage from water-carrying services, prescriptive raking drains may be specified in the design.
- 4.3.5 Ground movements may be induced during the excavation and recompaction process. These may be brought about by the formation of a steep temporary cut near the slope crest and construction of temporary support measures (e.g. soil nails, sheetpiles, minipiles or pipe piles, etc.) which may result in ground vibration or ground loss. Where substantial temporary works are anticipated or where there are sensitive facilities in close proximity to the fill slope, the likely scale of the ground movements together with their potential effects during construction should be assessed. A monitoring scheme together with a contingency plan should be prepared.
- 4.3.6 Where a newly compacted fill layer is placed over an existing loose fill slope (involving no or minimal excavation) with a large depth of fill that may have a significant variation in thickness such as in the case of an old infilled stream course or valley, the surcharge may lead to post-construction ground movement. The possibility of this resulting in cracking of the concrete drainage channels, and possible disturbance of the overlying recompacted fill zone, should be considered. Sufficient movement joints should be incorporated in the channels and the use of more stepped channels to minimise the length of channel sections along berms and the slope crest may be considered.
- 4.3.7 Rockfill has sometimes been used as the fill material together with an underlying filter/drainage blanket. The fill compaction operation involving the use of rockfill is less sensitive to inclement weather as compared with that of soil fill. In addition, rockfill allows a steeper gradient of the final slope profile. Where rockfill is used, adequate measures should be taken to prevent any underlying loose fill from being wetted up by excessive surface infiltration through the permeable rockfill, which could lead to instability (e.g. flowslide of the underlying loose fill). In some cases, a hard surface cover with suitable landscape treatment has been employed.
- 4.3.8 If potential instability due to wetting of the underlying materials is not a concern or has been adequately mitigated by other means, a thin layer of topsoil (generally 150 mm to 300 mm thick) may need to be provided at the surface of the rockfill for planting

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purposes. The potential instability of the soil capping layer must be considered. Consideration should also be given to preventing potential loss of fines from the capping layer into the underlying rockfill (e.g. provision of a transition zone comprising granular material). Care should be exercised in the specification of a geosynthetic filter fabric at the interface of the capping soil layer and rockfill because, if not detailed properly, this would give rise to a smooth weak plane with potential instability problems. Special attention to enhancing the detailing of surface drainage provisions and/or allowing for sufficient redundancy in the drainage design is needed because the soil capping layer in this instance is especially vulnerable to surface erosion and washout failure. As such, the provision of an erosion protection mat should be considered, which would need to be properly secured onto the slope using fixing pins.

4.4 CONSTRUCTION CONSIDERATIONS

- 4.4.1 The consequences of a flowslide of loosely placed fill can be disastrous. Adequate site supervision must be provided, particularly for critical activities such as fill compaction, construction of drainage blanket, in-situ density tests, etc., to ensure strict compliance with the specification requirements (Public Works Department, 1978). Stringent site control is essential especially where imported fill from more than one source is used.
- 4.4.2 The earthworks should be carried out in the dry season as far as practicable. However, the design, together with the sequence of works (including temporary works), should be sufficiently robust as the works may have to be undertaken in the wet season (e.g. due to delay in the construction programme).
- 4.4.3 The surface of any temporary cutting in the loose fill should be adequately protected against erosion and direct water ingress. Where a hard cover (e.g. shotcrete) is used for protection, the removal of the cover and provision of benching on the surface of the temporary cut should be carried out prior to placement of the drainage blanket/compacted fill. Care should be exercised in the construction of the drainage blanket to avoid mixing-up of the fine and coarse granular filter/drainage layers and their contamination by the fill material, which would otherwise undermine the effectiveness of the drainage blanket.
- 4.4.4 Protection should be provided to any stockpiles of excavated material prior to recompaction as the spoil is loose and susceptible to surface erosion and washout. Adequate temporary drainage measures should be provided to deal with surface water during the construction period, with due regard to topographical low points and any large catchment areas. Where necessary, the contractor should be required to demonstrate, through stability assessment, the adequacy of slope stability during the construction stage taking into account surcharging effects arising from stockpiling of the excavated material.
- 4.4.5 The relationship between the number of passes required of the proposed compaction

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plant and the thickness and water content of each layer to achieve the required compaction level can serve as an indirect means to facilitate general site monitoring. The relationship should be established during trial compaction at the commencement of the works, or where there are significant changes in the nature of the fill.

- 4.4.6 Apart from the standard testing requirements stipulated in the General Specification for Civil Engineering Works (Government of Hong Kong, 1992) on the fill materials, additional random standard compaction tests and particle size distribution tests may be conducted on representative samples retrieved from the locations of sand replacement tests following compaction for control purposes, depending on the variability of the fill. All sampling and testing locations should be selected by the Engineer's staff. The Engineer should supervise closely the sampling process and the storage and transportation of all samples for testing. The Contractor should have no influence on the selection, handling and payment of compliance sampling and testing.
- 4.4.7 Consideration should be given to the use of nuclear densometer as a quick means of gauging the variability of fine-grained or medium-grained fill and identifying locations of potential substandard compaction to serve as a tool to supplement sand replacement tests. The results of densometer tests should be calibrated against sand replacement tests, as required in the General Specification for Civil Engineering Works.
- 4.4.8 Care should be exercised where a trench excavation has to be made (e.g. for utility services) near the slope toe following completion of the fill compaction works because the associated ground movement induced by an inadequately supported trench could lead to significant loosening of the compacted layer. For trench excavations near the crest of a fill slope, adequate measures should be taken to prevent ponding at the trench excavation and water ingress into the slope, both during and after fill compaction.
- 4.4.9 Particular attention should be paid to detecting significant seepage or presence of preferential flow paths throughout the construction stage, particularly upon completion of excavation of the fill. Consideration should be given to specifying raking drains at these specific locations.

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