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Geotechnical standards in Hong Kong

L. M. Mak
President, Hong Kong Geotechnical Society
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1. INTRODUCTION

Hong Kong has a very hilly terrain as shown in Figure 1 below. After the war, Hong Kong has experienced rapid economic growth, together with extensive civil engineering and building works. This resulted in the formation of a considerable number of man-made slopes and retaining walls in the dense urban environment. Before 1977, slopes and walls were designed and formed by the rules of thumb. So the slopes and walls on such hilly terrain were prone to landslides during seasonal tropical rainstorms.

Figure 1 – Hilly terrain and concentrated developments in Hong Kong

The 18th June 1972 must be the darkest day in the landslide history of Hong Kong. Tragedies struck one after another. The first occurred in the afternoon on a fill slope in Sau Mau Ping after days of heavy rain. 78 squatter huts were buried and 67 people were killed. Natural disasters make no distinction between rich and poor. In the evening on the same day, another landslide occurred at Po Shan Road in the mid-levels. A 12-storey apartment building was completely knocked down by the landslide debris, killing 71 people. Four years later in 1976, a fill slope behind Sau Mau Ping Estate collapsed during heavy rain. The landslide debris poured into the lower floors of Block 9 as shown in the photo, killing 18 people.

These three fatal landslides in the 1972 and 1976 resulted in a very great loss of life and property. So in 1977, the Hong Kong Government set up the Geotechnical Control Office to deal with slope safety problems in the territory. The GCO was renamed to the Geotechnical Engineering Office, i.e. GEO, in 1992 and is now under the Civil Engineering and Development Department of the Hong Kong SAR Government. The primary responsibilities of the GEO are setting geotechnical standards, exercising geotechnical control, upgrading sub-standard slopes and providing public education on slope safety.

Since its establishment, the GEO has strived to ensure the highest standard of slope safety in Hong Kong. The successful results can be reflected in this slide in the drastic drop in the landslide fatality rate since the GEO was formed in 1977.

2. SETTING OF GEOTECHNICAL STANDARDS IN HONG KONG

2.1 Setting Standards

An important function of the GEO is setting geotechnical standards. Since its establishment, the GEO has produced many publications covering a wide range of geotechnical engineering topics. The more comprehensive ones are called Manuals, Geoguides and Geospecs (Table 1). The main objective of publishing these documents is to allow the profession to use a series of common, up-to-date and comprehensive geotechnical standards which are appropriate to Hong Kong conditions. The documents present recommended standard of good practice for various geotechnical activities.

Figure 2 - Some publications by the GEO

Table 1: List of Manuals, Geoguides and Geospecs

Manuals:
• Geotechnical Manual for Slopes, 2nd edition
• Highway Slope Manual
Geoguides:
• Geoguide 1: Guide to Retaining Wall Design, 2nd edition
• Geoguide 2: Guide to Site Investigation
• Geoguide 3: Guide to Rock and Soil Descriptions
• Geoguide 4: Guide to Cavern Engineering
• Geoguide 5: Guide to Slope Maintenance, 3rd edition
• Geoguide 6: Guide to Reinforced Fill Structure and Slope Design
Geospecs:
• Geospec 1: Model Specification for Prestressed Ground Anchors
• Geospec 3: Model Specification for Soil Testing

Apart from the above, the GEO has also published other documents series. They document results of comprehensive literature reviews, or generally present results pf applied researches and studies. Another series is theTechnical Guidance Notes.

Up to mid-2006, the GEO has released some 300 publications. A full list of GEO publications is available from the CEDD website (www.cedd.gov.hk).

2.2 Status of the Publications

Regarding the status of GEO's publications, the prevailing government policy is that the details of all permanent geotechnical works of public or private projects shall be submitted to the GEO for checking or approval. The policy also stipulates that related activities, including investigations, designs and works, shall be carried out in accordance with the prevailing standards. A certain GEO guidance documents are adopted as local geotechnical standards by the HK SAR Government.

The standards adopted for public development projects are generally also adopted for private building and civil engineering developments in Hong Kong. This is achieved through the Buildings Ordinance (Law of Hong Kong – Chapter 123) and its related Regulations and Practice Notes.

2.3 Process of Production of Guidance Documents

The GEO prepares new standards and guidance documents as needed. In the process of producing standards or documents, the GEO will benchmark against international geotechnical standards and adapt them in Hong Kong as appropriate. This is to suit local conditions, practice and environment. Extensive consultation among practitioners is always carried out in the setting of geotechnical standards. This is to ensure that the document is considered a consensus document by interested parties in Hong Kong.

3. STANDARDS FOR DIFFERENT TYPES OF GEOTECHNICAL WORKS

Different design approaches have been adopted in Hong Kong for different types of geotechnical works. This is evolving to suit the local conditions and practices within each type of work. Traditionally, all types of works are designed using the global factor of safety approach. But developments in limit state design with the use of partial factor method has also been gaining experience in Hong Kong. Let's go through the design standards of some major geotechnical works.

3.1 Slopes Works

For slope works, the GEO first published the Geotechnical Manual for Slopes in 1979 and then a second edition in 1984. The Manual gives guidance for the standard of practice for slope design and construction. The Highway Slope Manual published in 2000 further supplements the Geotechnical Manual by giving a standard of good practice on highway slope engineering. The slope design approach adopted by the Manuals is the theoretical global stability analysis based on limit equilibrium methods. Minimum global factors of safety are stipulated for slopes of different consequence categories. Also, slopes should be designed for the groundwater conditions that would result from rainfall with a return period of 1 in 10 years.

3.2 Retaining Structures

The Geoguide 1 – Guide to Retaining Wall Design published in 1993 gives a standard of good practice for the design and construction of new permanent earth retaining wall. Besides, Geoguide 6 – Guide to Reinforced Fill Structure and Slope Design published in 2002 provides a standard of good practice for the design and construction of new permanent reinforced fill structures and slopes.

Geoguide 1 – Guide to Retaining Wall Design (GEO, 1993) recommends a standard of good practice Both Geoguides 1 and 6 share the same design approach. It is to use limit state design against the occurrence of different limit states. We generally focus on the Serviceability Limit State and the Ultimate Limit State. Then different partial factors of safety will be used for different types of loadings and material parameters. As illustrated below, the partial factor at the Ultimate Limit State for the dead weight and the drained shear strength of soil is 1.0 and 1.2 respectively. The factor for the dead weight of the retaining wall is also 1.0. But the factor for surcharge will be 1.5 to cater for more uncertainty. The design groundwater level should be based on the worst credible groundwater conditions that will arise in extreme events.

Table 2: Minimum Partial Load and Material Factors for Use in Retaining Wall Design against Ultimate Limit States

Loading/Material	**Partial Factor**
Dead load due to weight of the retaining wall, soil, rock and water	1.0
Surcharge	1.5
Seismic load	1.0
Water pressure	1.0
Unit weight of soil, rock, water and structural material	1.0
Drained shear strength and base friction angle of soil	1.2
Undrained shear strength of soil	2.0
Shear strength of rock joint	1.2
Compressive strength of rock	2.0
Permeability of soil/rock	1.0
Permeability of granular filter and drainage material	10.0

3.3 Foundation Works

The Code of Practice for Foundation issued by the Buildings Department sets the standards and provides guidelines on design and construction of foundations for private developments in Hong Kong. The GEO first published in 1996 a technical reference document on pile design in Hong Kong. The second edition was published in 2006, i.e. GEO Publication 1/2006 – Foundation Design and Construction. Piles are generally designed on the basis of an adequate global factor of safety against ultimate failures of compression, tension and lateral resistance.

3.4 Temporary Excavation

For temporary excavation, GCO Publication 1/90 – Review of Design Methods for Excavations presents a review of design of temporary excavation and lateral support systems in Hong Kong. The Publication adopts the global factor of safety approach for the design of temporary excavation works to guard the retaining structures against sliding, uplift and overturning.

On the other hand, the CIRIA Report No. C580 "Embedded retaining walls – guidance for economic design", published in 2003, gives a different design framework. They advocate soil-structure interaction analyses with the limit state partial factor method of design. Both design approaches can be adopted for design of the temporary excavation and lateral support works in Hong Kong.

3.5 Cavern Construction

There has been an increasing interest in Hong Kong in placing some facilities underground, e.g. refuse transfer stations. So the GEO Geoguide 4 – Guide to Cavern Engineering recommends standard of good practice for civil engineering aspects of rock caverns. The cavern design adopts empirical methods with rock support assessment systems, e.g. Q-system or the Rock Mass Rating (RMR) Classification.

3.6 Reclamation

For Reclamation works, the Port Works Design Manual (CEO, 2002) gives guidance and recommendations on reclamation design, covering design considerations, stability analysis, settlement assessment and monitoring. The global factor of safety approach is used when designing the foundation of marine works against slip failure.

3.7 Summary of Design Approaches

Different design approaches have been adopted in Hong Kong for different types of geotechnical works as described above. This is evolving to suit the local conditions and practices within each type of the various geotechnical works. Traditionally, all types of works are designed using the global

factor of safety approach. Developments in limit state design with the use of partial factor method has been gaining experience in Hong Kong.

4. FURTHER STANDARDS AND GUIDELINES RELATED TO SLOPE ENGINEERING

Other than the basic standards documents mentioned above, the GEO has also produced a number of guidance documents on specific subjects of geotechnical works. Geoguide 2 and Geoguide 3 present recommended standard of good practice for site investigation and description of Hong Kong rocks and soils respectively. Geospec 3 – Model Specifications for Soil Testing also gives the recommended standard methods for testing of soils in Hong Kong for civil engineering purposes. Some examples of the further standards and guidelines related to slope engineering are given in Table 3 and described below.

Table 3: Further Geotechnical Standards and Guidelines Related to Slope Engineering

Subjects	**Titles of Publication**
Site investigation	• Geoguide 2 – Guide to Site Investigation • Geoguide 3 – Guide to Rock and Soil Description • TGN 3 – Use of Downhole Geophysical Methods in Identification of Weak Layers in the Ground • TGN 24 – Site Investigation for Tunnel Works
Laboratory testing	• Geospec 3 – Model Specifications for Soil Testing
Prescriptive measures	• GEO Report No. 56 – Application of Prescriptive Measure to Slopes and Retaining Walls • TGN 9 – updating of GEO Report No. 56 • TGN 13 – Guidelines on the Use of Prescriptive Measures for Rock Cut Slopes • TGN 17 – Prescriptive Soil Nail Design for Concrete and Masonry Retaining Walls
Soil nailing	• TGN 18 – Acceptance of Methods for Quality Control • TGN 19 – Installation of Soil Nails and Control of Grouting • TGN 21 – Design of Soil Nail Heads • TGN 23 – Good Practice in Design of Steel Soil Nails for Soil Cut Slopes • HKIE Publication on Soil Nails in Loose Fill Slopes: A Preliminary Study (Final Report) • GEO Report No. 133 – Non-destructive Test for Determining the Lengths of Steel Soil Nails
Drainage	• GEO Publication No. 1/93 – Review of Granular and Geotextile Filters • TGN 27 – Hydraulic Design of Stepped Channels on Slopes
Fill slope recompaction	• TGN 7 – Fill Slope Recompaction – Investigation, Design and Construction Considerations
Slope maintenance	• Geoguide 5 – Guide to Slope Maintenance • GEO Report No. 136 – Guidelines on Safe Access for Slope Maintenance
Maintenance of water-carrying services	• Code of Practice on Inspection and Maintenance of Water Carrying Services Affecting Slopes
Natural terrain	• GEO Report No. 75 – Landslides and Boulder Falls from Natural Terrain : Interim Risk Guidelines • GEO Report No. 104 – Review of Natural Terrain Landslide Debris-

	resisting Barrier Design • GEO Report No. 138 – Review of Natural Terrain Hazard Studies • TGN 22 – Guidelines on Geomorphological Mapping for Natural Terrain Hazard Studies
Landscaping	• GEO Publication 1/2000 – Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls • TGN 20 – Updating of GEO Publication No. 1/2000

Proper slope maintenance is extremely vital to the continued stability of a slope. So the GEO published Geoguide 5 – Guide to Slope Maintenance gives guidance to slope owners on good practice for slope maintenance. The guidance requires at least annual Routine Maintenance Inspections and five-yearly Engineer Inspections for Maintenance by professional geotechnical engineers for man-made slopes and walls with high consequence to life.

Soil nailing has been commonly used as a slope stabilization technique in Hong Kong since the 1980s. It is in fact in the form of a steel bar installed into a slope or retaining wall by drill-and-grout method without prestressing. GEO has been conducting a series of soil nail studies. Improved technical guidelines for soil nail design and construction have been developed and published in TGN no. 19 and 23. Besides, the GEO is in fact preparing a new Geoguide on this area.

Other than the conventional analytical approach for slope design, the GEO first formulated the Prescriptive Measures in 1995. Prescriptive measures are pre-determined, experience-based and suitably conservative works prescribed to a man-made slope and retaining wall to improve its stability. No detailed ground investigation and design analysis is required. The GEO Report No. 56 gives a standard of good practice for using prescriptive measures as improvement works on soil cut slopes and masonry retaining walls. This slide here shows how soil nailing works can be prescribed on a cut slope.

It is common in Hong Kong to have water-carrying services, no matter buried or exposed, in the vicinity of slopes. The services include water mains, stormwater and sewer drains. Leakage from these services may cause slope failure even without notable signs of leakage. Therefore the GEO takes the lead to prepare this Code of Practice which gives guidance on monitoring and maintenance of water-carrying services affecting slopes.

In 1993, the GEO started studies on risk of landslides and boulder falls from natural terrain. GEO Report No. 75 established appropriate tolerable risk criteria for risk assessment purposes. The interim societal risk criteria for natural terrain landslide hazards recommended by the report are shown in Figure 2. The risk criteria framework, adopted by many overseas countries, consists of the following three regions: (i) unacceptable region, (ii)"as low as reasonably practicable" (ALARP) region, and (iii) broadly acceptable region. Two options are available but Option 1 is preferred. They serve as a basis for the evaluation of quantitative risk assessment results. The GEO has also produced guidelines on how to conduct a natural terrain hazard study in GEO Report No. 138. Apart from hazard assessment, the design of mitigation measures is also critical. GEO Report No. 104 gives guidelines on the design of debris-resisting barriers.

In the past decade, the GEO has been making concerted efforts to provide good aesthetics to slopes and retaining walls. So they published the GEO Publication 1/2000 which provides guidance on good aesthetic design for landscape treatment and bio-engineering for man-made slopes and retaining walls.

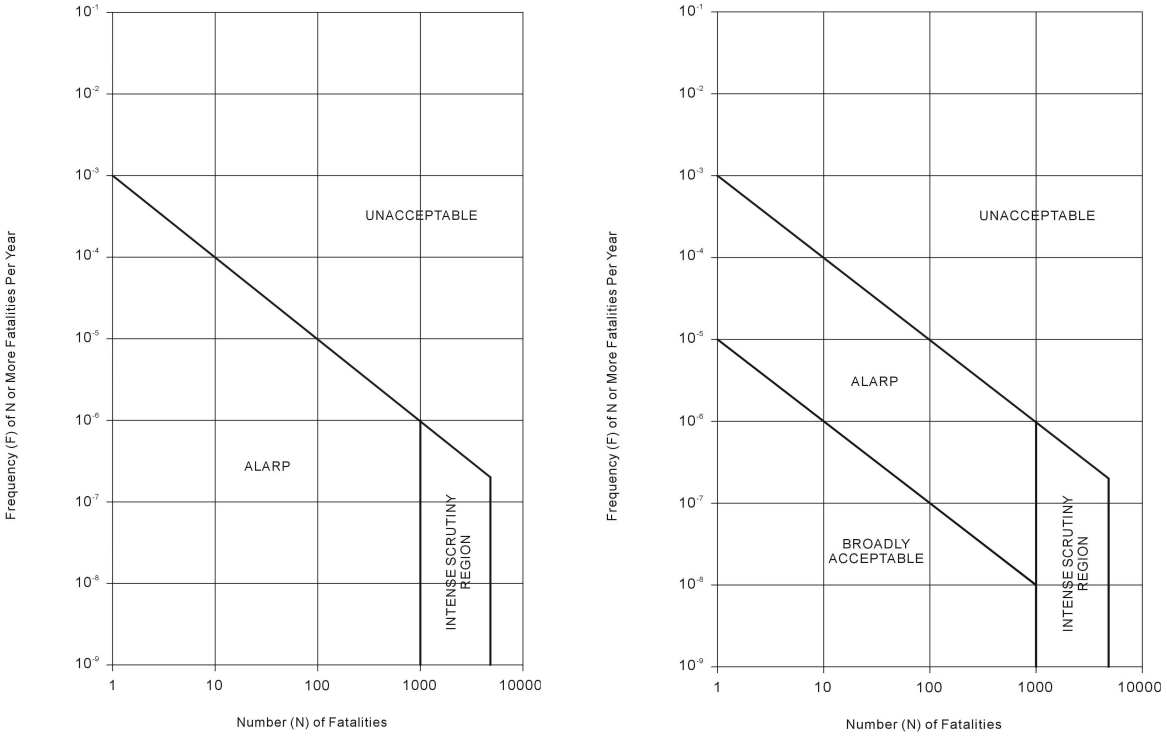

Figure 2 – The Recommended Interim Societal Risk Criteria for Landslides and Boulder Falls from Natural Terrain

4. CONCLUSIONS

There have been a number of geotechnical guidance documents produced in Hong Kong, in the form of Manuals, Geoguides, Geospecs and other publications and reports for the use of local practitioners. These documents aim to promote standards and good practice in different aspects of geotechnical engineering. These standards have been benchmarked against international ones and are adapted to suit local conditions and practices.

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