MANAGING SLOPE STABILITY IN HONG KONG

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ABSTRACT

The scale of the problem of landsliding in Hong Kong is explained. There are more than 60,000 man-made slopes in an area of only 1,076 sq. km and many of these threaten buildings or roads. Furthermore there are major risks from the hilly natural terrain which makes up more than 40% of the territory. The Government management structure whereby the landslide risk is reduced is explained. There is an extensive programme whereby all new slopes are checked, old slopes are inspected, rated and upgraded as necessary. A formal scheme for regular maintenance has been introduced.

In addition, considerable efforts are being made to understand the causes of landslides better, to enable improved recognition and appreciation of future instability, to improve safety in construction and to move to a more rational, risk-based assessment system for allocating resources.

INTRODUCTION

Hong Kong, a special Administration Region of China since July 1997, has an area of about 1,076 sq. km and a population of about 6.4 m which is expected to rise to 8 m by the year 2011. On Hong Kong island and Kowloon, there is very little naturally flat land. Hills rise rapidly from the sea to over 500 m and about 40% of the natural terrain is steeper than 30 degrees (Brand, 1985). The pressure for useable land has meant that much of the development for infrastructure and housing has required deep cutting into the hillsides. The total number of man-made slopes is of the order of 60,000 (Tam, 1997). Geotechnical conditions are not good. Urban areas are predominantly underlain by granite and volcanic tuffs, which have been considerably weakened by sub-tropical weathering to depths of more than 100 m locally.

Rainstorms can be severe in Hong Kong with more than 600 mm rain falling within 24 hours. The highest annual rainfall since records began in 1884 was in 1997 when more than 3.3 metres of rain were recorded.

Many landslides occur during major tropical storms and typhoons (which occur typically between May and August). For example over 500 landslide incidents were reported in 1997 and this number does not include the numerous landslides in natural terrain, which can pose risks to developed areas.

The first well-documented tragedy caused by slope failure in Hong Kong occurred in 1925 when 75 people were killed following the collapse of a retaining wall onto a row of houses. The problem increased as the population grew following the Second World War (there were only 1.8 m people in 1948) and the demand for space grew with consequent slope formation works.

Most of the existing slopes in Hong Kong were never designed in any modern sense and were cut as steeply as 75 degrees in the weathered terrain. Failures were commonplace but generally inconsequential (Eves, 1913, quoted in Lumb, 1975). Even by 1968 most "designs" of slopes were based solely on inspection of the ground and judgement by

the "designer" that the proposed slope would be stable.

In 1972, 138 people died as a result of two landslides, one of which destroyed a high-rise building. A further 18 people were killed in a landslide in 1976. The outcry following these disasters led to an official Commission of Inquiry. Expert review resulted in the establishment of a Geotechnical Control Office (GCO) in 1977 to regulate all aspects of slope works in Hong Kong. The first draft of a Geotechnical Manual for Slopes was published in 1979 (GCO, 1979). The scope of the Office was broadened in 1991 to cover other geotechnical works and renamed the Geotechnical Engineering Office. By 1994 the Office had grown to a total staff of more than 600 including 156 professional staff each with more than 4 years experience post-graduation.

GOVERNMENT CONTROL

The main office for controlling geotechnical standards and development in Hong Kong is the Geotechnical Control Office (GEO). The office has various responsibilities with respect to landslides:

(i) to check that new engineering works are not defective,
(ii) to assess and repair old slopes to reduce the risk of landslides,
(iii) to set the standards by which slope stability is to be judged,
(iv) to make recommendations to improve quality of investigations, analysis, design, construction and maintenance.
(v) to study landslides to refine knowledge on causes and to try to learn lessons that can be presented as guidelines to the geotechnical industry,
(vi) to carry out fundamental research and studies in an attempt to improve practice.

Government departments such as Highways, Housing, Lands, Water Supplies and Drainage Services are responsible for their own slopes and are expected to maintain their slopes to the standards set by the GEO.

There are more than 20 Geotechnical Consultancy Practices in Hong Kong with major commissions to study and improve the stability of slopes.

PRIVATE SLOPES

Tam (1997) reports that GEO estimate that there are 15,000 private slopes in Hong Kong and the poor state of many has been a major factor behind many landslides.

It is not legally required that private owners maintain their slopes so GEO uses a policy of education to enlighten the public on the need to maintain their slopes (e.g. GEO, 1995a). In cases where Government suspect that the slope is below the required standard of stability, Dangerous Hillside Orders can be issued to owners forcing them to take action. Nevertheless such work can be very expensive and many owners are reluctant to make the necessary improvements. If the work is not carried out, however, Government may instruct the works themselves and recover costs from owners.

NATURAL SLOPES

The threat of landslides from natural slopes has been recognised relatively recently following "near-misses". In particular a channelised debris flow in 1990 resulted in about 20,000 m^3 travelling more than 1,000 m downslope. The debris was deposited on an area originally scheduled for housing development. Such a failure could clearly do serious damage if it struck a habited area. As a result there has been and is continuing to be intense study into the occurrence and likelihood of natural landslide. This is entailing the use of quantitative risk studies as discussed later.

GENERAL ASSESSMENT OF SLOPES

Government has conducted surveys of all slopes in Hong Kong, initially on the basis of air photograph identification.

There has been a systematic registration of these slopes so that they can be maintained and upgraded as necessary in

a controlled manner. Clearly this is a huge task and requires formalised methods for assessing and judging the scale of the problem on a slope by slope basis.

This is mainly achieved through use of Geoguide 5 (GEO, 1995b). This guide sets out the factors to record during inspections of slopes. In particular, details of maintenance needs, for example the clearing of drains or repair of surface protection, are identified. Recommendations go to the slope owner who then will employ a contractor to carry out the works.

If there is evidence of more serious distress, such as tension cracks, then engineering works may be instigated which might include trimming back, the construction of buttress walls, dowelling or local drainage. Such measures are termed Preventive Maintenance Works. Where there are concerns that more deeper-seated failure might occur, then recommendations will be made for more major engineering works, i.e. upgrading works.

THE LANDSLIDE PREVENTIVE MEASURES PROJECT

Upgrading works on slopes have been underway since the establishment of GCO in 1977 and indeed previously on a site by site manner.

Currently there is a systematic programme for upgrading. In February 1995, the GEO received increased resources to commence a 5-year Accelerated Landslip Preventive Measures (LPM) Project.

The target is to complete the investigation and the necessary upgrading works on as many substandard slopes and retaining walls in the 1977/78 Catalogue of Slopes as possible over the five years commencing 1 April 1995. The acceleration of the LPM Programme was originally arranged as a 5-year Project to end in March 2000. However, as part of the Government long-term strategy for upgrading slopes and retaining walls, the GEO are now extending the Project for another 10 years beyond the year 2000. This 10-year extended LPM Project aims to complete the upgrading works for another 2,500 substandard government features and safety screening studies for another 3,000 private features by the year 2010.

These studies are mostly carried out by consultants. Contracts are let by competitive bidding. Typically a contract will comprise the assessment and upgrading, as necessary, of 40 to 60 slopes over a period of about 3 years.

The works require careful desk study initially and reconnaissance of each feature to judge whether the slope seems below standard (i.e. Factor of Safety below 1.2 to 1.4 depending on perceived consequence). It is also necessary to make a decision whether extensive ground investigation (drilling, testing, etc.) is needed. These decisions are not trivial and rely for a large part on the experience of the inspecting engineers. There is a move to ensure that all inspecting engineers are well qualified. This generally requires Chartered status (Membership of the Hong Kong Institute of Engineers or equivalent) together with at least one year's experience in Hong Kong.

Many of the deeper-seated failures in Hong Kong are the result of adverse geological conditions, often leading to concentrations of groundwater (Hencher et al. 1984). The recognition of such conditions requires skilled engineering geologists. A recent example is the Ching Cheung Road Landslide of 1997 (Halcrow Asia Partnership, 1998)

UPGRADING OPTIONS

There is a move towards the use of "prescriptive measures" for upgrading slopes. Generally for weak, decomposed rock masses, the main options are drainage, buttressing and reinforcement by the use of soil nails. These measures are used judgmentally where the slope geology and hydrogeology are thought to be relatively simple so that detailed ground investigation is unnecessary.

Where the slope is more complex, then standard ground investigation techniques are used to develop ground models so that slope stability analysis can be carried out.

Consultants must demonstrate their competence and experience (on an

individual basis) in using software, formally to Government.

Most analyses are carried out using limit equilibrium software such as SLOPE/W but it is expected that time-stepping software such as FLAC and UDEC may become more used as the science develops to recognise the gradual and progressive development of failures. It will also be necessary to derive some means of checking stability other than by a limit equilibrium factor of safety that is both acceptable and standardised.

RECENT INITIATIVES

Recent initiatives in Hong Kong include:

(1) Formal Quantitative Risk Studies of both natural and cut slopes

(2) Investigation of landslides in an 'integrated' way - in particular in looking at small events as possible precursors of larger and more general distress

(3) Improved Safety – a current study is reviewing safe working practices and techniques for the formation of rock slopes, and

(4) Trying to improve the look of slopes – an attempt to integrate slopes into their background. This requires a careful balance between visual appearance and maintaining safety standards and avoiding excessive maintenance requirements.

The first two of these initiatives have been underway for about two years. Quantitative risk studies have been conducted for man made slopes and are currently being completed for boulder fall hazards. The next major study, which has recently commenced is a site-specific study of the risk from failures in natural terrain.

The 'integrated approach to landslides' is an initiative which stemmed from comments by expert reviewers following a serious failure of a retaining wall in 1994 (Morgenstern, 1994). This extensive study is due to be completed by 2001.

CONCLUSIONS

Hong Kong has severe problems with landslides. These are the consequence of adverse natural conditions such as deeply weathered rocks and intense rainfall, combined with severe pressures on useable land space.

A history of landslide disasters, especially sine the Second World War caused death and disruption and led to the establishment of a control system run by a dedicated Control Office within Government, staffed by well-qualified and experienced individuals.

A system of standardisation, routine checking and programmed upgrading has been established and has led to major and demonstrable improvements in safety.

This has been accompanied by the publication of numerous guidelines and practice notes relating to all aspects of slope stability.

New initiatives are underway to improve the system and these will continue to make Hong Kong a vibrant place of work for engineering geologists and geotechnical engineers and Hong Kong to be at the forefront of managing slope safety.

REFERENCES

Brand, E.W. (1985) Landslides in Hong Kong. Eight Southeast Asian Geotechnical Conference, pp.1-15.

Eves, G.W. (1913) The Canton-Kowloon railway: British section (with discussion). M. Proc. Inst. C.E., Vol.192, pp 190-246.

GCO (1979) Geotechnical Manual for Slopes. (First edition). Hong Kong Government Printer, 242 p. Second edition (1984) Geotechnical Control Office, 295p.

GEO (1995b) Layman's Guide to Slope Maintenance. Geotechnical Engineering Office, Hong Kong, 56p. (In English and Chinese).

GEO (1995b) Geoguide 5. Guide to Slope Maintenance. Geotechnical Engineering Office, Hong Kong, 92p.

Halcrow Asia Partnership (1998) Report on the Ching Cheung Road Landslide of 3 August 1997. Findings of the Landslide Investigation (in press).

Hencher S.R., Massey, J.B. & Brand, E.W. (1984) Application of back analysis to some Hong Kong landslides. Proceedings of the 4th International Symposium on Landslides, Toronto 1, pp. 631-638

Lumb, P. (1975) Slope Failures in Hong Kong. Q. Jl. Eng. Geol., Vol. 8, pp. 31-65.

Morgenstern, N.R. (1994) Report on the Kwun Lung Lau Landslide of 23 July 1994. Vol.1, Causes of the Landslide and Adequacy of Slope Stability Practice in Hong Kong. , Hong Kong Government, 21p (in English and Chinese).

Premchitt, J., Brand, E.W. & Chan, P.Y.M. (1994) Rain-induced Landslides in Hong Kong, 1972-1992. Asia Engineer, June, pp.43-51.

Tam, A. (1997) The GEO comes of age: 20 years of Promoting Safety. Asia Engineer, September, p.10-12.