GEOTECHNICAL CHALLENGES IN SLOPE ENGINEERING OF INFRASTRUCTURES

Gue See-Sew[1] & Cheah Siew-Wai[2]

ABSTRACT

Slopes within infrastructures sometimes slide and cause damage and inconvenience to the public. Some of these landslides have claimed lives. Landslides include newly completed slopes, such as the recent failure at Putrajaya as well as old slopes, such as the collapse of the rock slope of the PLUS Expressway at Bukit Lanjan (2003), which was completed more than ten years ago.

The most notorious one was the collapse of a slope with rubble walls bringing down the Tower 1 Apartment of Highland Towers and killing 48 people on 11 Dec 1993. The towers were built in 1978.

A review of the causes of landslides indicates that most of the landslides are man-made slopes and are mainly due to design deficiency (Gue & Tan 2006). This keynote also discusses some of the recent and older failures, the causes of failures, and outlines some suggestions to mitigate future occurrence.

Keywords: Slope Engineering, Infrastructure, Research & Development (R&D), Culture

1. INTRODUCTION

With the increased developments that have encroached into the hilly areas over the past two decades, Malaysia experiences frequent landslides with a number of major slope failures which cause damage and inconvenience to the public. These landslides include newly completed slopes, such as the recent failure at Putrajaya in 2007 as well as old slopes, such as the collapse of the rock slope of the PLUS Expressway at Bukit Lanjan (2003), which was completed more than ten years ago. Some of these landslides have claimed lives. The notorious collapse of Tower 1 apartment of Highland Towers claimed 48 lives in 1993.

Climate conditions in Malaysia are characterized by relatively uniform temperature and pressure, high humidity and particularly abundant rainfall with annual rainfall intensity over 2500mm. Most of the landslides in two monsoon seasons of Malaysia are induced by the high rainfalls and more than 80% of landslides were caused by man-made factors, mainly design and construction errors. (Gue & Tan 2006)

Many will still remember the collapse of the Highland Tower on 11 Dec 1993. Since then, there have been other major landslides resulting in fatalities and severe losses and destruction of property. A brief discussion of these major landslides and their causes is presented here. This key note also outlines some suggestions to mitigate future occurrence.

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[1] CEO, G&P Professionals Sdn Bhd & Managing Director of G&P Geotechnics Sdn Bhd Kuala Lumpur, Malaysia
[2] Associate, G&P Geotechnics Sdn Bhd, Kuala Lumpur, Malaysia

2. MAJOR LANDSLIDES IN MALAYSIA

Among the major landslides occurring in the past two decades, the most notorious landslide was the collapse of a slope with rubble walls, bringing down Tower 1 Apartment of Highland Towers and killing 48 people on 11 Dec 1993. The towers were built in 1978.

Major landslides occurring within infrastructure seldom result in loss of lives compared to those occurring in residential areas. However, major landslides that occurred within infrastructures have resulted in great economic loss to the public and business due to disruption to the transportation network and property damage.

The following table summarises some of the major landslides with their consequences: -

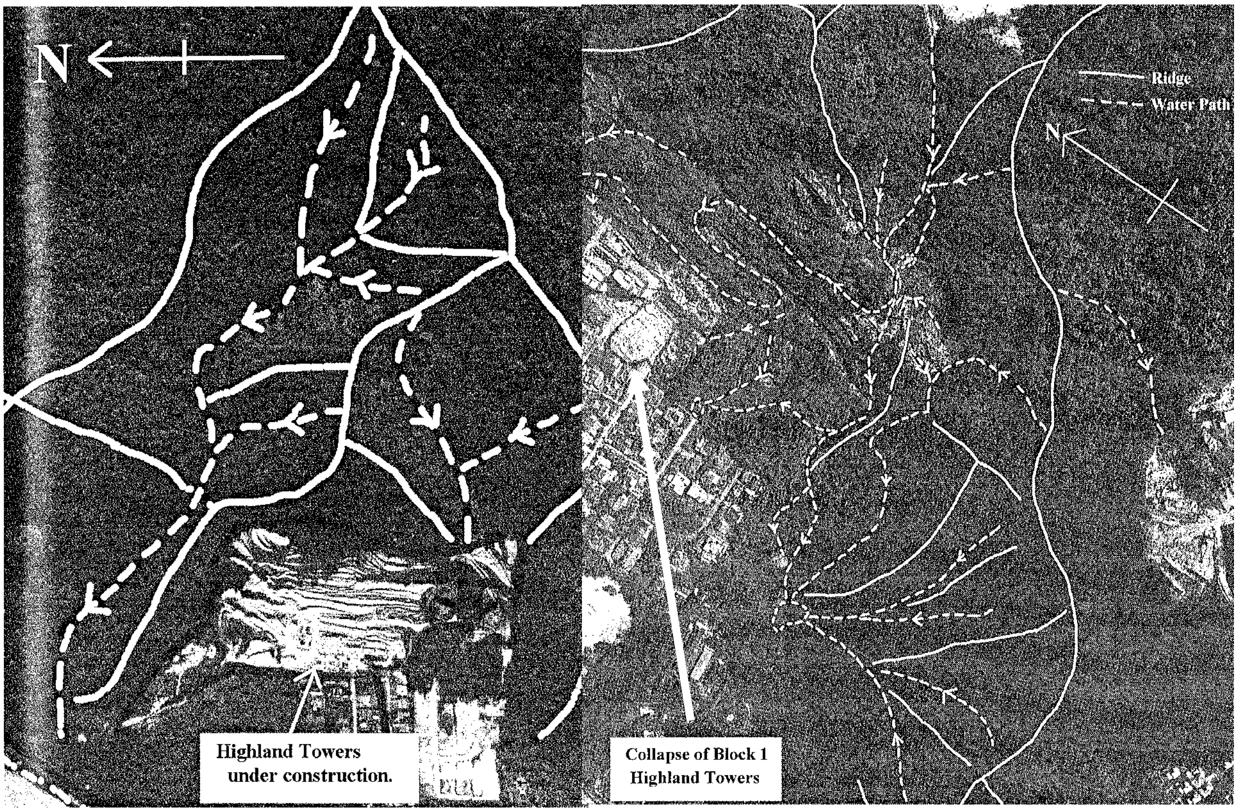
DATE OF OCCURENCE	LANDSLIDE LOCATION (NAME)	CATEGORY	FATALITY (NOS)	DISRUPTION TO TRANSPORTATION NETWORK
11 Dec 1993	Highland Tower	Residential	48	No
20 Nov 2002	Taman Hillview	Residential	8	No
26 Oct 2003	Bukit Lanjan	Highway	-	Yes
12 Oct 2004	Gua Tempurung	Highway	1	Yes
23 Mar 2007	Putrajaya	Public Amenities	-	No
13 Nov 2007	Pulau Banding	Public Amenities	-	No

Table 1: Major Landslides with their Consequences in Malaysia
(After Abdullah et al. 2007)

2.1 Collapse of Tower 1 of Highland Towers Apartment, 1993

The Highland Towers Condominium is located in the district of Hulu Kelang, Selangor. Highland Towers consisted of three blocks 12 storey high apartments named simply Block 1, 2 and 3 respectively. It was constructed between 1975 and 1978. Block 1 was completed and occupied in 1979. Tower 1 therefore collapsed 14 years after completion.

Figure 1 shows the water path before and after the completion of the Highland Tower Apartments. In the course of the Highland Towers development, the stream was diverted by means of a pipe culvert to flow northwards across the hill slope directly behind Highland Towers. The approved drainage system on the hill slope behind Highland Towers was never completed. Figure 1 shows the water path before and after the completion of Highland Towers.



Aerial Photo 1975 (Before Completion) Aerial Photo 1993 (After Completion)

Figure 1: Water Path Before and After Completion of the Highland Towers Apartments

On Saturday, 11 Dec 1993, at about 1.30p.m., after 10 days of continuous rainfall, Block 1 collapsed and killed 48 people. The cumulative daily rainfall intensity measured from 1st to 10th December 1993 recorded at JPS Ampang was 177.5mm and the measured maximum daily rainfall intensity was 59.5mm. It was not exceptional rainfall as compared to previous measured rainfall intensity.

An investigation was carried out by experts and specialists assembled by Majlis Perbandaran Ampang Jaya (MPAJ) and was published in a report titled “Report on the Inquiry Committee in the Collapse of Block 1 and The Stability of Blocks 2 and 3 Highland Towers Condominium, Hulu Klang Selangor Darul Ehsan” in 1994. The report concluded that the most probable cause of the collapse of the tower was the buckling and shearing of the rail piles foundation induced by the movement of the soil. The movement of the soil was the consequence of retrogressive landslides behind the building of Block 1.

The landslide was triggered by inadequate drainage on the hillslope that had aggravated the surface runoff (MPAJ 1994). Slope and rubble walls behind and in front of Block 1 were also found to be improperly designed with an overall Factor of Safety of less than 1. Figure 2 shows the sequence of retrogressive failures that took place, causing large soil movement and piling up behind Block 1 and causing an increase in lateral pressure to the foundation of the building and the rubble wall in front of the Block until it collapsed and was followed by the toppling of the apartment. Figure 3 shows the collapse of Block 1 of the Highland Tower Apartments.

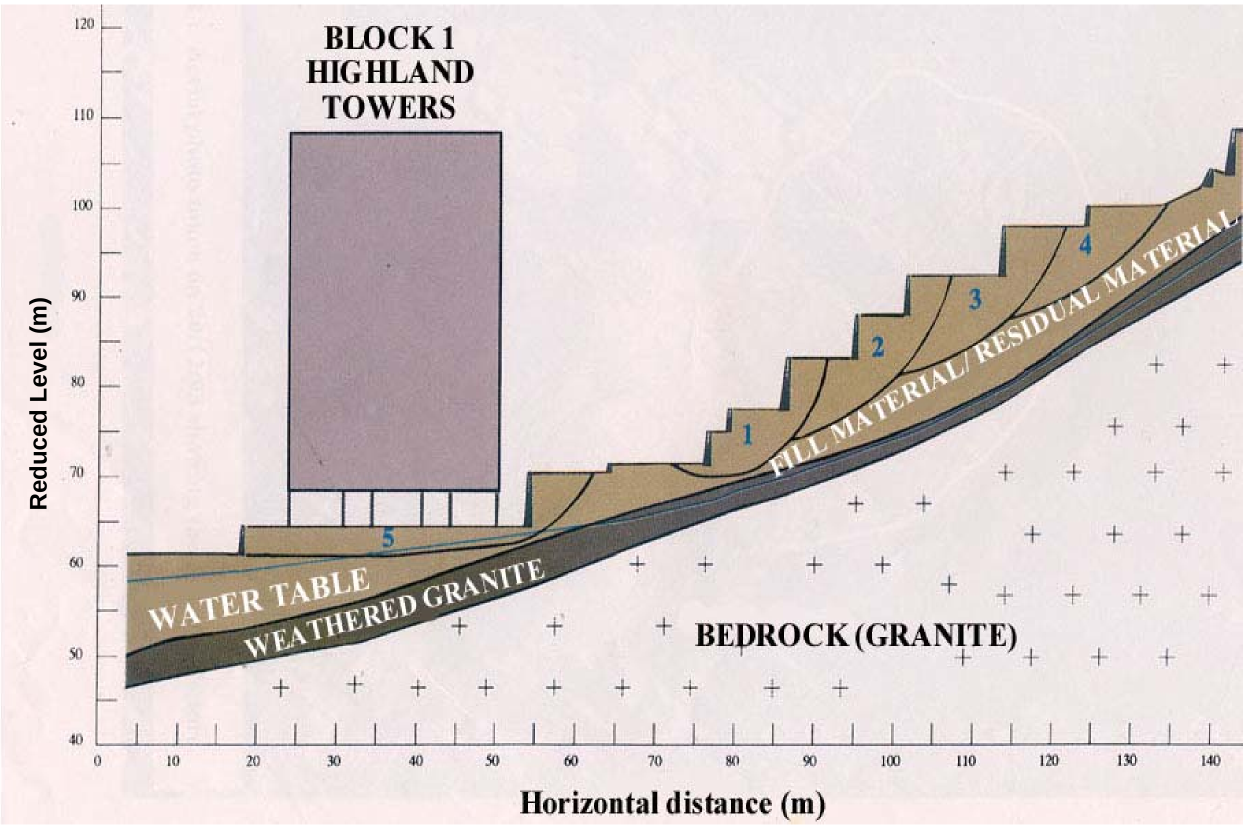


Figure 2: Illustration of Retrogressive Slope Failure Sequence (after Gue & Tan 2002)

Figure 3: Collapse of Block 1 of Highland Towers Apartments, 1993

2.2 Collapsed Bungalow at Taman Hillview in Ampang, 2003

The collapse of a double storey bungalow at Taman Hillview in Ampang (Figure 4) occurred on 20 Nov 2002 and claimed 8 lives. The cause of landslide at Taman Hillview was similar to the Highland Towers tragedy, where failure of a rubble wall again triggered a landslide. The Factor of Safety of the rubble wall in the Highland Towers was found to be less than 1.0 even without considering any presence of geological features such as relic joints etc and water tables. In fact, the rubble wall is part of the series rubble walls behind Highland Towers.

Figure 4: Collapsed Bungalow at Taman Hillview in Ampang, 2003

2.3 Rock Slope Failure at Bukit Lanjan, 2003

On 26 Nov 2003, a massive rock slope failure occurred at Bukit Lanjan Interchange which is part of the New Klang Valley Expressway (Mohd. Asbi et al. 2007). The failure occurred immediately after a period of heavy rainfall. The substantial large volume of rock debris (approx. 35,000m^3) that came to rest on the expressway blocked the expressway completely and forced the entire stretch of the expressway to be closed for 6 months for rehabilitation works (Figure 5). Immediately after the failure, the Highway Concessionaire commissioned site investigations that included surveys, geological mapping, deep boreholes and laboratory tests to assess the likely causes of failure and also to provide geotechnical information required to design for rehabilitation of the failed slope. From the site investigation results, it was inferred that the rock slope failure was a complex wedge type failure. The wedge was formed by two discontinuities that daylighted out of the slope and the third discontinuity acted as a release plane. It was also demonstrated that for the failure to occur there was a requirement for water pressure to be acting on the potentially unstable wedge. Figure 5 shows the elevation and plan view of the failed rock slope.

Figure 5: Rock Slope Failure at Bukit Lanjan, 2003 (newspaper cutting, New Straits Times)

2.4 Debris Flow at KM302 of PLUS North-South Expressway Near Gua Tempurung, 2004

Two lanes for southbound traffic bridge of KM302, North–South Expressway near Gua Tempurung were closed for three months for rehabilitation works as the result of a debris flow that occurred on 12 Oct 2004. Tonnes of earth, boulders and trees went crashing down the hill slope in this incident, as illustrated in Figure 6. Three beams of the bridge were damaged and had to be replaced. This incident also caused one casualty, public and economic losses and a great inconvenience to the public.

Figure 6: Debris Flow at KM 302 of PLUS Expressway, 2004
(newspaper cutting, Nanyang Siang Pau)

2.5 Slope Failure at Putrajaya, 2007

On 22nd March 2007, a massive slope failure occurred at Precinct 9, Putrajaya which twenty-three vehicles were buried in this landslide and forced about 1,000 residents to vacate their homes at 4.30am. This slope failure involved a 50-metre high hill with a man-made slope about 45 degrees which was located about 10 metres from the 15-storey apartment. It had been raining heavily in Putrajaya since the evening of 21 March 2007 till the early morning of 22 March 2007 before the slope failure happened. Figure 7 shows the collapsed slope with buried vehicles.

Figure 7: Slope Failure at Precinct 9, Putrajaya, 2007

2.6 Collapse of Tourism Complex in Pulau Banding, 2007

Before the collapse of the Tourism Complex at Pulau Banding, Perak on 13th November 2007, the complex was sitting on a hill slope with its toe near to the edge of the lake, Tasik Temenggor.

The slope extended down into the lake where the water level fluctuates to about 4 meters without toe protection in the area of fluctuation. The building was completed in 2004. The 15-room resort was not occupied, as defects such as cracks were found in the buildings. It was reported that a few months before the failure, a few piles beneath the columns of the building were found exposed and deflected. On 10th November 2007, part of the building collapsed, followed by a total collapse of the whole building on 13th November 2007.

Figure 8: Collapse of Tourism Complex in Pulau Banding, 2007 (The Star, 15 Nov 2007)

3. WHY LANDSLIDES: FACTORS ATTRIBUTED TO LANDSLIDES

A study of the causes of landslides such as design errors, construction errors, design and construction errors, geological features and maintenance had been carried out by Gue & Tan (2006) based on 49 investigation cases of primarily large landslides on residual soils. The results of the study are shown in Table 2.

CAUSES OF LANDSLIDES	NUMBER OF CASES	PERCENTAGE (%)
Design Errors	29	60
Construction Errors	4	8
Design and Construction Errors	10	20
Geological Features	3	6
Maintenance	3	6
Total	49	100

Table 2: Causes of Landslides (after Gue & Tan, 2006)

The results of the study indicate that 60% of the failures are due to inadequacy in design alone. The inadequacy in design is generally the result of a lack of understanding and appreciation of the subsoil conditions and geotechnical issues. Failures due to construction errors alone either of workmanship, materials and/or lack of supervision contributed to 8% of the total cases of landslides. About 20% of the landslides investigated are caused by a combination of design and construction errors. For landslides in residual soil slopes, the landslides caused by geological features only account for 6% which is same as the percentage contributed by a lack of maintenance.

3.1 Geological Features

Landslides due to geological features contributed to about 6% of the total failures investigated. However, it should be recognised that these geological features, such as discontinuities in residual soils, especially sedimentary formations, are not usually detectable during the design stage even with extensive subsurface investigation (boreholes, geophysical methods) by an experienced engineering geologist or engineer who carries out geological mapping at the site prior to cutting. Most of these geological features can only be detected after exposing the slopes during excavation. In view of this, it is best to carry out confirmatory geological slope mapping of the exposed slopes after excavation, by an experienced engineering geologist or geotechnical engineer to detect any geological discontinuities that may contribute to potential failure mechanisms, namely planar sliding, anticline sliding, active-passive wedges, etc. Figures 9 and 10 show the discontinuities found during excavation which were otherwise almost impossible to detect.

By understanding that geological discontinuities could not be fully addressed during the design stage, design engineers should make conservative assumptions about the soil/rock parameters and also the groundwater profile to ensure adequacy in design and should only carry out adjustments on site after geological slope re-mapping and re-analysis of the slopes. On the contrary, when optimistic assumptions are made and the results obtained during construction on sites that are less favourable then expensive options such as retaining walls or slope strengthening using soil nails are required due to space and boundary constraints. Thus the safety of slopes is often compromised due to unbudgeted strengthening and additional protection works being needed.

Figure 9: Block Failure of Sedimentary Formation (After Liew S.S. 2005)

Figure 10: Inconsistent Weathering Profile (After Liew S.S. 2005)

3.2 Design and Construction Errors

The majority of these failures investigated by Gue & Tan (2006) were avoidable if extra care was taken and input from engineers with relevant experience in geotechnical engineering was sought from planning to construction. Many of the landslides which were caused by design errors reported above were due to the following:-

1) The abuse of the prescriptive method on the slope for cut or fill slopes without proper geotechnical analyses and assessment. It is very common in Malaysia to find many cut slopes formed for residual soils that are 1V:1H (which means one vertical: one horizontal = 45 degrees angle). Based on literature published on residual soils and the authors' own experience of residual soils, it is not likely, or impossible, for residual soils to have the effective parameters (c', ϕ') to maintain the stability of the slopes even without water table and geological features unless it is not a soil slope but a rock slope. The authors' own experiences indicates that the ϕ' values of residual soils generally ranges from 29^o to 36^o and mainly depend on the particle size distribution of the materials. Therefore, if proper analysis of the slopes' stability was carried out with correct soil parameters, most of these 45^o gradient slopes would not have a sufficient Factor of Safety (FOS) recommended against slip failure in the long term, even with some effective cohesion. In summary, engineers should not only follow the slope gradients (e.g. 1V: 1H) that have been done previously, without proper geotechnical analysis and design.
2) Subsurface investigation (S.I.) and laboratory tests were not carried out to obtain representative soil parameters, subsoil and groundwater profiles for design and analysis of slopes. Therefore, the analysis and design carried out are not representative of the actual site conditions, and are thus unsafe.
3) A lack of good understanding of fundamental soil mechanics, so that the most critical condition of cut slopes is in the long term (in the "Drained Condition"). Therefore, it is necessary to adopt effective shear strength parameters for the "Drained Analysis" of the cut slopes in residual soils instead of undrained shear strength (s_u or c_u).

For landslides that were caused by construction errors alone or combined with design, the common construction errors are as follows:-

1) Tipping or dumping of loose fill down the slopes to form a filled platform or filled slope. This is the most rampant construction error for earthworks construction in Malaysia. Contractors carrying out the filling works on slopes will find it most “convenient” and “easy” to dump or tip soil down the slopes to form the fill. The condition is worsened by not removing the vegetation on the slopes, causing the bio-degradable materials to be trapped beneath the dumped fill, forming a potential slip plane with the bio-degradable materials (vegetation). The uncompacted fill slopes, having a very low Factor of Safety, will likely fail in the long term.
2) Errors in the construction method, such as forming cut slopes by excavating slopes from the bottom (undermining) instead of the correct practice of cutting from the top downwards. This wrong practice will trigger landslides or induce potential shear planes extending beyond the proposed cut slope profile.
3) Over-excavation of cut slopes. Contractors unintentionally over-excavate cut slopes and then try to fill back the excavated materials to reform the slope to the required gradient. The uncompacted loose materials will eventually slip down.

The way to prevent these bad construction practices is to have proper full-time supervision by members of the design consultant together with reliable and responsible earthwork contractors having clear approved method statements for construction. Failure of slopes and retaining walls can also take place if the temporary works (e.g. temporary excavation) are not properly designed and constructed.

3.3 Maintenance

Poorly maintained slopes can lead to slope failure. These may include amongst others, damaged/cracked drains, inadequate surface erosion control and clogged drains. The common problems of landslides caused by a lack of maintenance are blockage of drains for surface run-off, and erosion. Blockage of drains will cause large volumes of water to gush down a slope causing erosion to the slope and the formation of gullies. These gullies will further deteriorate into big scars on the slopes and will finally lead to landslides.

Figure 11 shows the formation of rills and gullies and Figure 12 shows localized landslips caused by erosion which will propagate with time into landslides if erosion control is ignored. If proper maintenance is carried out, then all these small defects would have been rectified and landslides caused by erosion would be prevented.

Figure 11: Formation of Rills and Gullies (after Gue & Tan 2004)

Figure 12: Localized landslips (after Gue & Tan 2004)

4. GOOD DESIGN AND CONSTRUCTION PRACTICES FOR SLOPE ENGINEERING

4.1 Planning, Analysis and Design of Slopes

Desk Study
Desk study includes reviewing of geological maps, memoirs, topographic maps and aerial photographs of the site and adjacent areas so that the engineers are aware of the geology of the site, geomorphology features, previous and present land use, current development, construction activities, problem areas like previous slope failure, etc.

Site Reconnaissance
Site reconnaissance is required to confirm the information acquired from the desk study and also to obtain additional information from the site. For hillsite development, it is also very important to locate and study the landslip features to identify previous landslides or collapses that can act as indicators of the stability of the existing slopes.

Subsurface Investigation
Subsurface investigation (SI) should be properly planned to obtain representative subsurface condition of the whole slope such as general depth of soft soil, hard stratum, depth of bedrock, geological weak zones, clay seams or layers, and the groundwater regime. The planning of exploratory boreholes should take into consideration the slope profile instead of following a general grid pattern. A minimum of three (3) boreholes per cross-section (one on slope crest, one at mid-slope and one at slope toe) is recommended so as to obtain representative subsurface conditions of the whole slope.

Analysis and Design of slopes
For the design of the slopes, correct information on soil properties, the groundwater regime, the geology of the site, selection and methodology for analysis are important factors that require the special attention of the design engineer. A detailed analysis of soil slopes can be found in Tan & Chow (2004) and Gue & Tan (2000).

For the selection of Factor of Safety (FOS) against a slope failure, the recommendation by Geotechnical Manual for Slopes (GCO, 1991) of Hong Kong with minor modifications to suit local conditions is normally selected with consideration of two main factors, namely, Risk-to-life or Consequence to life (e.g. casualties) and Economic Risk or Consequence (e.g. damage to property or services). Further details on selection of FOS can be found in Gue & Tan (2004).

Design of Cut and Fill Slopes
The vertical interval of slopes between intermediate berm is usually about 5m to 6m in Malaysia. GCO (1991) recommends that the vertical interval of slopes should not be more than 7.5m. The berms must be at least 1.5m wide for easy maintenance. The purpose of berms with drains is to reduce the volume and velocity of runoff on the slope surface and the consequent reduction of erosion potential and infiltration. The adopted slope gradient should depend on the results of analysis and design based on moderately conservative strength parameters and representative groundwater levels.

For fill slopes before the placing of fill, the vegetation, topsoil and any other unsuitable material should be properly removed. The foundation should also be benched to key the fill into an existing slope. A free-draining layer conforming to the filter criteria is normally required between the fill and natural ground to eliminate the possibility of high pore pressures from developing and causing slope instability, especially when there is an existing surface or intermittent streams and depressions. Sufficient numbers of discharge drains should be placed to collect the water in the filter layer and discharge it outside the limits of the fill and away from the slopes.

Surface Protection and Drainage

Surface drainage and protection are necessary to maintain the stability of the designed slopes through reduction of infiltration and erosion caused by heavy rain, especially during monsoon seasons. Runoffs from both the slopes and the catchment areas upslope should be effectively cut off, collected and led to convenient points of discharge away from the slopes. Details on surface protection and drainage can be found in Gue & Tan (2004).

Catchment Study

Catchment study is rarely carried out for the provision of surface drainage capacity to carry the runoffs in current slope engineering practice. Under-provision of surface and subsurface drainages can lead to infiltration and spillage of the surface runoffs to the slopes, cause saturation of slopes, surface erosions to the slopes and can result in slope deterioration with time.

Fill Slopes Over Depressions or Valleys

Depressions or valleys are the preferred water path of natural surface runoffs. Streams or intermittent streams are usually formed at these depressions and valleys, especially during heavy rain. In the meantime, intermittent streams at depressions or valleys will also transport sediments from upstream and deposit these sediments at the depression or valley and form a layer of soft or loose material and debris.

For slopes which are formed by filling over a depression or valley, the possibility of having saturation of slopes and developing slip planes through the pre-existence of weak soft or loose layers with debris is high.

Therefore, extra care should be exercised on the fill slopes over depressions or valleys by adopting the following measures to mitigate occurrence of slope failure: -

1) To provide adequate surface drainage by calculating the capacity required based on catchment study to reduce infiltration of surface runoffs to the slopes.
2) Subsurface drainages should be adequately provided to drain out water from a slope to avoid saturation of the slope and rising of the groundwater level. Increases in ground water levels will reduce the FOS of the slope.
3) To replace shallow weak materials by compacted good fill material during the filling works to enhance the slope stability FOS.

Slopes Next to Water Courses

For slopes next to water courses such as river bank slopes, beaches, pond side slopes, etc, the slope should be robustly designed by considering the probable critical conditions such as saturated slope with rapid drawn-down conditions, scouring of slope toe due to flow and wave actions, etc. Properly designed riprap or other protection measures are needed over the tidal range.

4.2 Construction Controls

Supervision and Coordination
The supervising personnel should have sufficient knowledge and experience in geotechnical engineering to identify any irregularities of the subsurface conditions (e.g. soil types, surface drainage, groundwater, weak planes such as clay seams etc.) that might be different from those envisaged and adopted in the design. Close coordination and communication between design engineer(s) in the office and supervising engineer(s) are necessary so that modification of the design to suit the change of site conditions could be carried out when needed. This should be carried out effectively during construction to prevent failure and un-necessary remedial works during the service life of the project. Site staff should keep detailed records of the progress and the conditions encountered when carrying out the work in particular if irregularities like clay seams, significant seepage of groundwater are observed. Sufficient photographs of the site before, during and after construction should be taken. These photographs should be supplemented by information such as dates, weather conditions or irregularities of the subsoil conditions observed during excavation.

Filling of Slopes
Whenever possible, construction programmes should be arranged such that fill is placed during the dry season, when the moisture content of the fill can be controlled more easily. When filling, tipping should not be allowed and all fill should be placed in layers not exceeding 300mm to 450mm thick depending on the type of compacting plant used (unless compaction trails proved that thicker loose thickness is achievable) in loose form per layer and uniformly compacted in near-horizontal layers to achieve the required degree of compaction before the next layer is applied. The degree of compaction for fill to be placed on slopes is usually at least 90% to 95% of British Standard maximum dry density (Standard Proctor) depending on the height of the slope and the strength required.

Cutting of Slopes
Cutting of slopes is usually carried out from top-down followed by works like drains and turfing. When carrying out excavation of the cut slopes, care must be taken to avoid overcutting and loosening of the finished surface which may lead to severe surface erosion. Minor trimming should be carried out either with light machinery or by hand as appropriate. It is also a good practice to construct first the interceptor drains or berm drains with proper permanent or temporary outlets and suitable dissipators before bulk excavation is carried out or before continuing to excavate the next bench.

Surface Protection of Slopes
For all exposed slopes, slope protection such as turfing or hydroseeding should be carried out within a short period (not more than 14 days and 7 days during the dry and wet seasons respectively) after the bulk excavation or filling for each berm. All cut slopes should be graded to form suitable horizontal groves (not vertical groves) using suitable motor graders before hydroseeding. This is to prevent gullies from forming on the cut slopes by running water before the full growth of the vegetation, and also to enhance the growth of vegetation.

4.3 Maintenance of Slopes

Guideline for Slope Maintenance
A good guideline from GEO of Hong Kong such as “Geoguide 5 – Guide to Slope Maintenance” (2003) for engineers and the “Layman’s Guide to Slope Maintenance” which is suitable for the laymen should be referred to.

Geoguide-5 (2003) recommends maintenance inspections be sub-divided into three categories:

(A) Routine Maintenance Inspections, which can be carried out adequately by any responsible person with no professional geotechnical knowledge (layman).
(B) Engineer Inspections for Maintenance, which should be carried out by a professionally-qualified and experienced geotechnical engineer.
(C) Regular Monitoring of Special Measures, which should be carried out by a firm with special expertise in the particular type of monitoring service required. Such monitoring is only necessary where the long term stability of the slope or retaining wall relies on specific measures which are liable to become less effective or deteriorate with time.

Frequency of Maintenance Inspections
Since Malaysia has at least two monsoon seasons, Routine Maintenance Inspections (RTI) by a layman should be carried out a minimum of twice a year for slopes with negligible or low risk-to-life. For slopes with high risk-to-life, more frequent RTI is required (once a month). In addition, it is good practice to inspect all the drainage channels to clear any blockage by siltation or vegetation growth and repair all cracked drains before the monsoon. Inspection should also be carried out after every heavy rainstorm.

Category B Engineer Inspections for Maintenance, should be taken to prevent slope failure when the Routine Maintenance Inspection by laymen observed something unusual or abnormal, such as the occurrence of cracks, settling ground, bulging or distorting of walls or settlement of the crest platform. Geoguide-5 (2003) recommends as an absolute minimum that an Engineer Inspection for Maintenance should be conducted once every five years or more as requested by those who carry out the Routine Maintenance Inspections. More frequent inspections may be desirable for slopes and retaining walls in the high risk-to-life category.

5. SUGGESTIONS FOR IMPROVEMENT OF THE ENGINEERING AND MANAGEMENT OF SLOPES

5.1 Practitioners and Professionals in Slope Engineering

The institution of Engineers, Malaysia (IEM), under its own initiative, formed a taskforce in 1999 to formulate policies and procedures for mitigating the risk of landslides in hilly terrain developments. IEM (2000) produced a report entitled, “The policies and procedures for mitigating the risk of landslide on hill-site development” with the aim of providing uniform, consistent, and effective policies and procedures for consideration and implementation by the Government of Malaysia. However, the recommendations by IEM were not immediately accepted and acted on by the Government (C.H. Abdullah et al. 2007).

Practitioners and professionals that involve in slope engineering works should practice ethically and professionally and should only practice in the area of their expertise to ensure the safety of the design and to mitigate the risk of landslides.

Stakeholders such as engineering universities and colleges, the Association of Consulting Engineers Malaysia (ACEM) and the IEM should work together to develop a series of structured training modules on slope engineering so as to inculcate better understanding of the practitioners so that the public could benefit.

Apart from having structured training modules, all practitioners should also think another step ahead on how to further improve the current slope engineering practices through Research and Development (R&D) to enhance safety, speed of construction and economical aspects. It is important to equip practitioners with R&D skills to improve construction industry's competitiveness and to prepare ourselves for globalisation.

A successful example by Hong Kong Geotechnical Engineering Office (GEO) on suggesting a new cost-effective and eco-friendly method of natural slope stabilisation through R&D (Campbell et al. 2005) is discussed in the following section.

In 2003, the Hong Kong GEO completed a planting trial involving the use of native small tree and shrub species on steep slopes. Based on this, guidelines were promulgated on the selection of suitable vegetation species for man-made slopes. Trials were also initiated on repairing natural terrain landslide scars by means of predominantly native vegetation species (Figure 13). The interim findings are documented by Campbell et al. (2005).

(a) Landslide scar prior to (left) and during (right) installation of bioengineering measures

(b) Landslide scar during (left) and after (right) installation of bioengineering measures

Figure 13: Use of Bioengineering Measures for Repair of Natural Terrain Landslides (after Wong & Ho 2006)

5.2 Slope Management in the Public Sector (Abdullah et al. 2007)

The first to document on guidelines in hilly areas development was the Urban and Rural Planning Department in 1997. The guidelines addressed the issues of planning and development in highlands, on slopes, natural waterways, and water catchment areas. In June 2002, the Geology and Minerals Department of Malaysia produced guidelines on hillsite development. The guidelines considered the angle of the natural slopes and geology of the area. The areas were then classified into 4 categories which were termed as Class l, ll, lll and lV. Class l is the least severe in terms of terrain grading whereby slope angles are less than 15^o. Class lV was the highest risk, where, absolutely no development will be allowed in this area.

Also in June 2002, the National Disaster Management Committee in the Prime Minister's Department directed Jabatan Kerja Raya (JKR) to form a Working Group on Landslide Study with the objectives of identifying areas with high landslide risks and coming up with mitigative measures. The Working Group was officially inaugurated on August 14, 2002 and subsequently 4 subcommittees were formed, namely (Abdullah et al. 2007):

- Sub-committee for Forensic Investigation of landslides
- Sub-committee for Disaster Management during landslides
- Sub-committee for Co-ordination and Information Sharing
- Sub-committee for Research Coordination.

The first task given to the committee was to investigate the Taman Hillview landslide that killed eight (8) people at the end of 2002. The overall mandate given to JKR during this time was not very successfully implemented because the Slope Engineering Unit was then placed under the Road Maintenance Division, where it had to compete for attention and resources within the division.

The Slope Engineering Branch (CKC) was established as a branch within the JKR in February 2004 with the aim of managing and monitoring of slopes throughout the country. CKC has 6 units that deal with slope matters. They are the Slope Safety Unit that coordinates and controls the budget for the slope repair works; the Slope Management Unit that collects spatial and non spatial data and produce hazard maps for slopes; the IT and Documentation Unit whose job is to archive and disseminate slope data and information through the website and by archiving; the Research and Development Unit whose function includes research, initiating cooperation with universities (local and abroad) and conducting National Slope Master Plan studies; the Forensic Unit,responsible for landslide investigation and preparing standards and guidelines for slope design, and finally the Quality, Training and Public Awareness Unit is responsible for training personnel in JKR and creating public awareness (Abdullah et al. 2007).

Apart from the above, there are also numerous guidelines and regulations available from the following government authorities and associations related to slope management: -

a) Department of Environment (DOE)
b) Geology and Mineral Department (JMG)
c) Majlis Perbandaran Ampang Jaya and other local authorities such as Penang Local Council etc.
d) Ministry of Housing and Local Governments (MHLG)
e) Urban and Rural Planning Department (JPBD)
f) The Institution of Engineers Malaysia (IEM)

Some of these guidelines and regulations are unclear and do not add value to safety, enhance slope stability and protection, environmental friendliness and sustainability of the slope engineering projects. These guidelines and regulations should be harmonized and improved further by developing unified guidelines for good practices in the planning, design, construction, supervision, maintenance and monitoring of slope engineering projects, as well as ensuring the safety, environmental friendliness and sustainability of these projects.

5.3 National Slope Master Plan (NSMP)

In view of the slope failure occurrences in recent years, the Malaysian Government instructed JKR to carry out the NSMP study in May 2004 to be completed by March 2008. The goal of this study is to provide detailed elements of a comprehensive and effective national policy, strategy and action plan for reducing losses from landslides on slopes nationwide including activities at the national, state and local levels, in both the public and private sectors (Abdullah et al. 2007).

The NSMP consisted of 10 key objectives which were translated into 10 components of the study. The components of the NSMP and the summary of their objectives are as follows:

ii. Policies and institutional framework - improve policies and institutional frameworks
iii. Hazard mapping and assessments – develop a plan for mapping and assessing landslide hazards and also develop standards and guidelines for landslide hazard mapping
iv. Early warning and real-time monitoring system- to develop a national landslide hazard monitoring, prediction and early warning system
v. Loss assessment – assess the current data on landslide losses and develop a national plan for compilation, maintenance and evaluation of data from landslides
vi. Information collection, interpretation, dissemination, and archiving – evaluate the state-of-the-art technologies and methodologies for the dissemination and archiving of technical information
vii. Training - develop training programs for personnel involved in landslides
viii. Public awareness and education – evaluate and develop education programs related to the predictive understanding of landslides
ix. Loss reduction measures – evaluate and develop effective planning, design, construction and maintenance with a view to landslide hazard reduction
x. Emergency preparedness, response and recovery – develop a national plan for a coordinated landslide rapid response capability.
xi. Research and development - develop a predictive understanding of landslide processes, thresholds and triggering mechanisms

The NSMP is to be implemented in 3 phases: the first phase is called the short term which would cover the first 5 years; the second phase is known as the medium term i.e. the period of implementation between 5 and 10 years; and final phase is known as the long term, which is the period of implementation of 10 to 15 years and beyond.

5.4 Undergraduates in Slope Engineering

Apart from improving the understanding of practitioners and policy implementation by the government on slope engineering and management, emphasis should also be given to how to improve undergraduates' understanding on slope engineering fundamentals, which is currently lacking, and this is one of the most important components to improve slope engineering.

Consequently, universities and colleges should review and update the undergraduate syllabus from time to time with the assistance of active experienced practitioners to ensure graduates possess enough fundamentals to suit industry needs.

Besides, structured modules of lecture notes on slope engineering and management should be developed and updated regularly by pooling resources from a group of universities, colleges and passionate practitioners to ease the workload of the lecturers so that the quality of the lecture notes is assured.

Lecturers should also obtain more exposure on slope engineering with the help of practitioners and getting them to give lectures related to mitigation and prevention of slope failures.

6. CONCLUSION

This keynote presents a brief review on six major landslides in Malaysia that includes old and new slope failures. Most of the landslides were induced by high rainfall and 80% of the landslides were caused by man-made factors (design errors and construction errors). Some good design and construction practices were put forward for slope engineering on planning, analysis and design aspects, construction control aspects and slope maintenance aspects. Finally, this keynote also discussed some suggestions on improvement for practitioners, undergraduates, public sector and implementation of government policy. Practitioners should be equipped with R&D skills to improve construction industry's competitiveness and be prepared for globalisation.

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