CHAPTER 7

Guidelines for development on hill-sites

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In Malaysia, there has been a tremendous increase in construction of residential buildings on hill-sites over the last 15 years especially due to depleting flat land and other influencing factors like beautiful scenery, fresh air, exclusiveness, etc. Often hill-site development is related to landslides, and safety of buildings on hill-sites is often a topic of discussion among engineers and the public. The truth is hill-site development can be safe with proper planning, design, construction and maintenance. This chapter presents brief guidelines on the engineering aspects of hill-site development. A simplified classification of landslide risk for hill-site development and recommendations by The Institution of Engineers, Malaysia (IEM) will also be discussed in this chapter together with the current legislation related to hill-site development in Malaysia.

7.1 INTRODUCTION

Safety of buildings and slopes on hill-sites is often a topic of discussion among engineers and the public. The discussions intensify each time a landslide is highlighted by media and this usually happens during the monsoon seasons. The collapse of Block 1 of Highland Towers in 1993, landslides at Bukit Antarabangsa in 1999, and the recent tragic landslide at Taman Hillview in November 2002 have worried the public particularly those who are staying on a hill-site or planning to purchase a unit on one.

Hill-site development is safe with proper planning, design, construction and maintenance. Engineers with good engineering expertise on soil/rock slopes and foundation designs are usually engaged to design for a hill-site development to safeguard the safety of the public from landslide hazards.

This chapter summarises some of the statute related to hill-site development and presents brief guidelines on the engineering aspects of hill-site development for general engineers.

7.2 POSITION PAPER ON MITIGATING THE RISK OF LANDSLIDE ON HILL-SITE DEVELOPMENT

With the recent awareness of the difficulty and risks involved in building on hill-sites, a more systematic control of hill-site developments is taking shape through the public and private sectors. One is the position paper titled 'Mitigating the Risk of Landslide on Hill-Site Development' (IEM 2000) prepared by The Institution of Engineers, Malaysia.

In the IEM position paper, it is proposed that the slopes for hill-site developments be classified into three classes and the necessary requirements are as follows:

- *Class 1 Development (Low Risk)*: Existing Legislation Procedures can still be applied.
- *Class 2 Development (Medium Risk)*: Submission of geotechnical report prepared by professional engineer to the authority is mandatory. The taskforce viewed a professional engineer for hill-site development as those with the relevant expertise and experience in analysis, design and supervision of construction of the slopes, retaining structures and foundations on hill-site.
- *Class 3 Development (Higher Risk)*: Other than submission of geotechnical report, the developer shall also engage an 'Accredited Checker' (AC) in the consulting team. In the original proposal by the taskforce, the AC shall have at least 10 years relevant experience on hill-site development and have published at least five (5) technical papers on geotechnical works in local or international conferences, seminars or journals.

The general risk classification is based on the geometry of the slopes such as height and angle for simplicity of implementation by non-technical personnel in our local authorities, although under actual conditions are many other factors that also affect the stability of the slopes such as geological features, engineering properties of the soil/rock, groundwater regime, etc. In order to facilitate the implementation of the classification, simple geometry has been selected as the basis for risk classification. Table 7.1 summarizes the details of the classification and Figure 7.1 shows the geometries of slopes referred for classification. (IEM 2000a, Gue & Tan 2002).

From the review of several case histories of landslides in Malaysia, IEM (2000a) summarises the causes of the failures as follows:

- Design - inadequate subsurface investigation and lack of understanding of analysis and design.
- Construction - lack of quality assurance and quality control by contractors.
- Site supervision and maintenance - lack of proper site supervision by consulting engineers during construction and lack of maintenance after construction.
- Communication - lack of communication amongst various parties during construction.

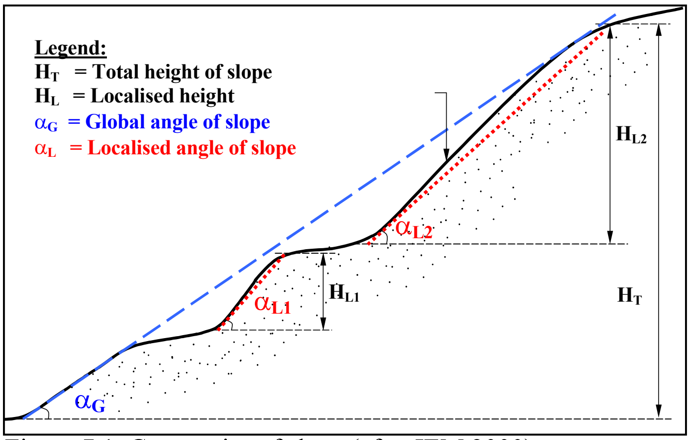

Figure 7.1. Geometries of slope (after IEM 2000).

The IEM position paper also proposes that a new federal department called 'Hill-Site Engineering Agency' be formed under the Ministry of Housing and Local Government to assist local authorities in respect to hill-site development. The Agency is to assist local authorities to regulate and approve all hill-site developments. The Agency could engage or outsource, whenever necessary, a panel of consultants to assist and expedite implementation. For existing hill-site development, the Agency should advise the local government to issue 'Dangerous Hill-Side Order' to owners of doubtful and unstable slopes so that proper remedial and maintenance works can be carried out to stabilize unstable slopes and prevent loss of lives and properties.

7.3 STATUTE RELATED TO HILL-SITE DEVELOPMENT IN MALAYSIA

Definition of Hill-Site in Malaysia

There is no legal definition of Hill-Site development. Some agencies have proposed various classification systems to suit their own usage. The most common ones are based on altitude and/or slope gradient of the original topography before development. According to the Ministry of Housing and Local Governments of Malaysia (KPKT 1997), hill-sites will be classified as high risk if the lands have natural or original gradient of the slopes of 25 degrees and steeper.

In the EPU (2002) report prepared by WWF, it was stated that a consistent classification of highlands should be adopted throughout the country. Hence it gives the proposed definition based on altitude as follows:

- 0 m - 150 m = Lowland
- 150 m - 300 m = Hill Land
- 300 m - 1000 m = Highland
- Above 1000 m = Mountain

Table 7.1. Classification of risk of landslide on hill-site development. (after IEM, 2000)

Class	Description
1 (Low risk)	For slopes either natural or man made, in the site or adjacent to the site not belonging to Class 2 or Class 3.
2 (Medium risk)	For slopes either natural or man made, in the site or adjacent to the site where : ○ 6 m $\leq H_T \leq$ 15 m and $\alpha_G \geq 27^o$ or ○ 6 m $\leq H_T \leq$ 15 m and $\alpha_L \geq 30^o$ with $H_L \geq$ 3 m or ○ $H_T \leq$ 6 m and $\alpha_L \geq 34^o$ with $H_L \geq$ 3 m or ○ $H_T \geq$ 15 m and $19^o \leq \alpha_G \leq 27^o$ or $27^o \leq \alpha_L \leq 30^o$ with $H_L \geq$ 3 m
3 (Higher risk)	Excluding bungalow (detached unit) not higher than 2-storey. For slopes either natural or man made, in the site or adjacent to the site where : ○ $H_T \geq$ 15 m and $\alpha_G \geq 27^o$ or ○ $H_T \geq$ 15 m and $\alpha_L \geq 30^o$ ○ with $H_L \geq$ 3 m

H_T	=	Total height of slopes
	=	Total height of natural slopes & man made slopes at site and immediately adjacent to the site which has potential influence on the site. It is the difference between the Lowest Level and the Highest Level at the site including adjacent site.
H_L	=	Height of Localised Slope which Angle of Slope, α_L is measured.
α_G	=	Global Angle of Slopes (Slopes contributing to H_T).
α_L	=	Localise Angle of Slopes either single and multiple height intervals.

Planning Stage

In the planning stage, Section 22 of The Town & Country Planning Act 1976 as amended in 2001 has widened the statutory requirements in granting planning approval or development order (DO). This section allows local authorities to regulate hill-site developments (defined as hill tops or hill slopes in the Act) by imposing a list of conditions to ensure sustainability, environmentally friendly and of course, public safety. The Act also states that planning approval may be subjected to certain conditions, namely the prohibition of damage to the land, natural topography and landscape, prohibition of the removal or alteration of any natural features of the land and, the prohibition of the felling of certain trees.

In the stage of planning permission, many local authorities also require earthwork and building plans to be submitted together with the application of DO. Recently, the State of Selangor and Penang have imposed the requirements of a Geotechnical Report as well as an Independent Geotechnical Report submitted by separate geotechnical engineers for areas which local authority is of the opinion that the proposed development site falls under the category of high risk.

Section 70 of The Street, Drainage & Building Act (Act133) 1974 (amendments 1994) also gives local authorities the power to impose the additional condition. Under this Act, local authorities can give written directions to the person submitting a plan and specification in respect of compliance with 'This or Other Act' which would include compliance with the Town & Country Act, Land Conservation Act and Environmental Legislation.

On the environmental aspects, The Environmental Quality Act 1974 gives the Minister the power to order and prescribe conditions on any activity which may have significant environmental impact. The following two prescribed activities under The Environment Quality (Prescribed Activities) (EIA) Order 1987 are relevant to hill-site development:

- Conversion of hill forest land to other land-use covering an area of 50 hectares or more (Paragraph 6: Forestry)
- Hillstation resort or hotel development covering an area of 50 hectares or more (Paragraph 17:Resort and Recreational Development)

Environmental Impact Assessment (EIA) Report should be carried out according to prescribed guidelines, particularly in relation to assessment of the impact or likely impact of such development on the environment and proposed measures to prevent, reduce or control the adverse impact on the environment are being incorporated (534A of EQA).

In some states, The Land Conservation Act 1960 has been applied to prescribe certain areas as hill-land by notification in gazette (S.3). For example lands in Penang that are generally above 1,000 ft (300 m) have been prescribed as hill land and therefore development is not allowed (S.6). The technical definition for the gazette is not provided and the classification is unclear and merely based on altitude.

Design and Construction Stage

Section 70 of The Street, Drainage & Building Act (Act133) 1974 (amendments 1994), requires submission of infrastructure and building plans before construction is allowed. Earthwork precedes building construction and it is a common practice to get infrastructure plans including earthwork be approved first while preparation for actual building plans are in progress. This allows the developer to reduce the holding time and save on cost.

The earthwork plans should also include detailed mitigation plans to control the adverse impact on the environment especially erosion, siltation and additional runoff due to the proposed site clearance.

On the safety of earthworks or slope stability aspects, earthwork plans should clearly indicate the cut and fill slopes with the design slope gradients and surface and subsurface drainage details, retaining systems and strengthening measures such as soil nails, rock bolts and etc, if required.

The design of slopes has to consider not only the safety of the slopes within the development site but also within the vicinity which may foreseeably affect the proposed building, if the slope fails. This 'Duties At Common Law' has been reaffirmed by the decision of the High Court and Court of Appeal in the Highland Towers case.

Duties of care to the neighbours in particular those located downslope such that their acts or omissions do not destabilise their neighbour's properties.

7.4 PLANNING, ANALYSIS AND DESIGN FOR HILL-SITE DEVELOPMENT

Planning of Hill-Site Development

The planning of hill-site development can be divided into four major sections as follows:

- Desk Study
- Site Reconnaissance
- Subsurface Investigation
- Planning of Layout

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 hill-site development, it is also very important to locate and study the landslip features to identify previous landslides or collapses that can act as an indicator of the stability of the existing slopes.

Subsurface investigation
Subsurface investigation (S.I.) for hill-site development should be properly planned to obtain representative subsurface condition of the whole site such as general depth of soft soil, hard stratum, depth of bedrock, geological weak zones, clay seams or layers, and groundwater regime. The planning of exploratory boreholes shall take into consideration the terrain instead of following a general grid pattern. Usually S.I. can be carried out in two or more stages. Preliminary S.I. usually consists of boreholes and sometimes also includes geophysical survey for a larger area with varying thickness of overburdened subsoil.

The general information on the subsurface profile and properties will be useful when planning the cut and fill and formation of the platform because the depths of hard stratum and bedrock will have major influence on the cost and construction time for earthworks.

Once the preliminary layout of the hill-site development is confirmed, the detailed S.I. should be carried out to obtain the necessary information for detailed geotechnical designs. In the detailed S.I., field tests can be carried out at the following locations:

- Areas of major cut and fill
- Retaining walls
- Buildings or structures with heavy loading

For details on the planning of subsurface investigation and interpretation of test results for geotechnical design, reference can be made to Gue & Tan (2000a) and Gue (1995).

Planning of the layout for roads network and platforms
Different from normal flat ground development, the planning of platform and roads network for hill-site development shall be geotechnical engineering driven with close coordination among developers, planners, architects, and civil & structural engineers. With this, a terrain friendly (less disturbance to the existing vegetated slopes), safe, ease of construction and cost effective development can be achieved. The planning of platform layout for hill-site development shall try to suit the natural contour and minimise cut and fill. Although retaining walls or soil nailing are generally more costly than normal earthwork solution, with proper planning, the use of these retaining systems at critical areas will be effective to reduce significant earthworks that may be more expensive as shown in Figure 7.2.

Buildings on slopes
It is a good practice to construct buildings with extended columns above the stable slopes instead of filling a platform on slopes as shown in Figure 7.3. This is to reduce the load acting on the slopes that could reduce the stability of slopes.

If a flat platform is preferred, then it is very important to orientate the building layout to minimise potential differential settlement especially if buildings are on filled ground. This can be achieved by arranging the longitudinal axis of the buildings parallel to the contour lines of the original topography, in which the building is underlain by a fill of more uniform thickness and therefore with less differential settlement. Figure 7.4 shows two different arrangements of buildings on a filled ground. The designer if possible shall refrain from arranging a long building perpendicular to the contour. Care should be taken to eliminate excessive long term settlement.

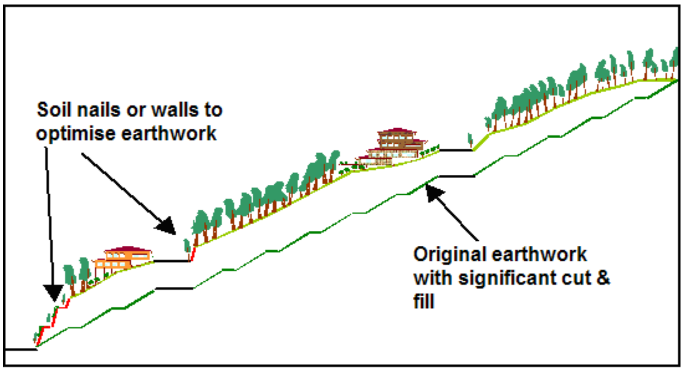

Figure 7.2. Method to optimise earthworks.

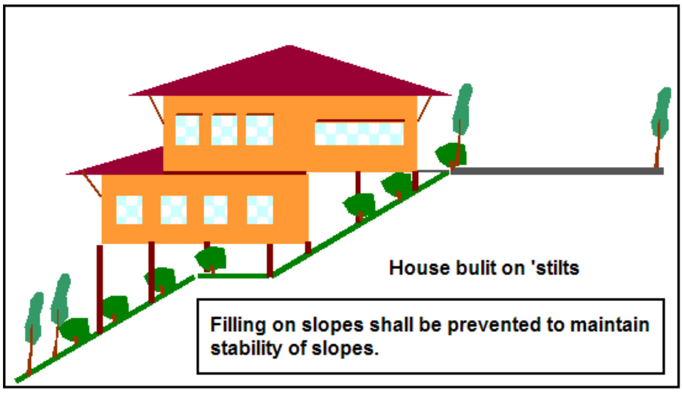

Figure 7.3. Typical building on cut slopes.

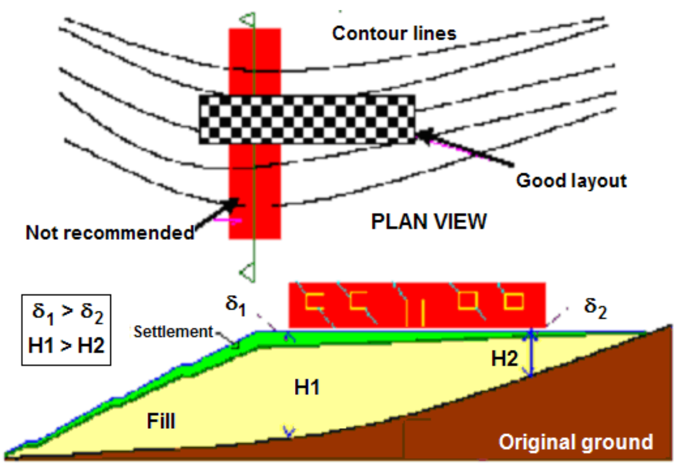

Figure 7.4. Different layout of building on filled ground.

When piles are used to support buildings on a fill, the design engineer should evaluate negative skin friction (down drag) acting on the piles if the ground is going to settle with time. Slip coating of the piles with bitumen coating or surcharging of the fill to eliminate future settlement are options to eliminate the negative skin friction. However, the slip coating option is more complex and costly. Other more cost effective options include the use of temporary surcharging, floating piles system and rearrangement of layout to reduce differential settlement.

Analysis and Design of Slopes

Although local geology and rainfall characteristics differ in different countries, generally the phenomenon of slope failure occurs in much the same way throughout the world with the fundamental causes not differing greatly with geological and geographical locations. Therefore, the same methods of assessment, analysis, design and also remedial measures can be applied. The only difference is that in tropical areas, the climate is both hot and wet causing deep weathering of the parent rocks and the slopes are of weaker materials.

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

Factor of Safety for Slopes

For hill-site development in Malaysia, the Factor of Safety (FOS) against slope failure recommended by Geotechnical Manual for Slopes (GCO 1991) of Hong Kong is usually adopted with minor modifications to suit local conditions. When selecting the FOS to be adopted in the stability analysis, the two main factors to be considered are:

(a) Risk-to-life or consequence to life (e.g. casualties)
(b) Economic risk or consequence (e.g. damage to properties or services)

There are three levels of risk in each factor (negligible, low and high) as defined in detail by GCO (1991). The engineer has to use his judgement when deciding the seriousness of the consequence for both loss of life and economic loss. For guidance, reference can be made to Tables 7.2 and 7.3 that list the typical examples of slope failures in each risk-to-life and economic risk categories respectively after GCO (1991).

Generally the slopes are divided into three categories namely:

- New Slopes
- Existing Slopes
- Natural Slopes

For new slopes, the recommended FOS for slopes with groundwater conditions resulting from a ten-year return period, rainfall or representative groundwater conditions are listed in Table 7.4 for different levels of risk. In addition, slopes of high risk-to-life category should have FOS of 1.1 for the predicted worst groundwater conditions using moderately conservative strength parameters (characteristics values).

Table 7.2. Typical examples of slope failures in each risk-to-Life category (modified from GCO 1991).

Examples of failure affecting the following:	Risk-to-life
1. Country parks and lightly used open-air recreation areas.	Negligible
2. Roads with low traffic density.	Negligible
3. Storage compounds (non-dangerous goods).	Negligible
4. Densely used open spaces and recreational facilities (e.g. sitting-out areas, playgrounds, car parks).	Low
5. Roads with high vehicular or pedestrian traffic density.	Low
6. Public waiting areas (e.g. railway platforms, bus stops, petrol station).	Low
7. Occupied buildings (e.g. residential, educational, commercial, industrial).	High
8. Buildings storing dangerous goods.	High

Table 7.3. Typical examples of slope failures in each economic risk category (modified from GCO 1991).

Examples of failure affecting the following:	Risk-to-life
1. Country parks.	Negligible
2. Rural, feeder, district distributor and local distributor roads which are not sole accesses.	Negligible
3. Open-air car parks.	Negligible
4. Rural or primary distributor roads which are not sole accesses.	Low
5. Essential services which could cause loss of that service for a temporary period (e.g. power, water and gas mains).	Low
6. Rural or urban trunk roads or roads of strategic importance.	High
7. Essential services, which could cause loss of that service for an extended period.	High
8. Buildings, which could cause excessive structural damage.	High

Table 7.4. Recommended factor of safety for new slopes.

Economic risk	Risk-to-life: Negligible	Low	High
Negligible	>1.0	1.2	1.4
Low	1.2	1.2	1.4
High	1.4	1.4	1.4

Note:
1. The FOS above is based on Ten-Year Return Period Rainfall or Representative Groundwater Conditions.
2. A slope in the high risk-to-life category should have a FOS of 1.1 for the predicted worst groundwater conditions.
3. The FOS listed are recommended values. Higher or lower FOS must be warranted in particular situations in respect to both risk-to-life and economic risk.

An existing slope should be analyzed to check for its stability and to determine the extent of any remedial or preventive works required. If the engineer has the opportunity to examine the geology and subsoil conditions of the slope closely and can obtain more realistic information on the groundwater, the FOS for existing slopes recommended in Table 7.5 may be used. Otherwise, if substantial modification to the existing slopes is required, the recommended FOS in Table 7.4 shall be adopted.

Table 7.5. Recommended FOS for existing slopes.

FOS against loss of life for a ten-year return period rainfall		
Negligible	Low	High
>1.0	1.1	1.2

Note :
1. These FOS are minimum values recommended only where rigorous geological and geotechnical studies have been carried out, where the slope has been standing for considerable time, and where the loading conditions, the ground water regime and the basic form of the modified slope remain substantially the same as those of the existing slope.
2. Should the back-analysis approach be adopted for the design of remedial or preventive works, it may be assumed that the existing slope had a minimum FOS of 1.0 for the worst known loading and groundwater conditions.
3. For a failed or distressed slope, the causes of the failure or distress must be specifically identified and taken into account in the design of the remedial works.

It is very important to be aware that not all natural slopes are safe. It is very common for natural slopes to fail during a monsoon though there may not be any activity like clearing of trees or development around it. Therefore the stability of the natural slopes in or adjacent to the site should be evaluated. Usually it is not advisable to disturb the natural slopes and vegetation just to achieve marginal improvement in stability unless the slope does not have adequate FOS. It is important not to locate buildings on areas that could be affected by landslide of natural slopes, otherwise the recommended FOS in Table 7.4 need to be used for natural slopes.

Design of Cut Slopes

The vertical interval of slopes between intermediate berms is usually about 5 m to 6 m in Malaysia. GCO (1991) recommends that the vertical interval of slopes should not be more than 7.5 m. The typical slope gradient is normally 1V:1.75H to 1V:1.5H depending on the results of analysis and design based on moderately conservative strength parameters and representative groundwater level. The berms must be at least 1.5 m 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. Cut slope should be designed to the recommended FOS in Table 7.2 taking into considerations representative geotechnical parameters, geological features (e.g. clay seams) and the groundwater regime.

Design of Fill Slopes

As in the case of cut slopes, berms of 1.5 m wide at 5 m to 6 m vertical slope interval are commonly used for fill slopes in Malaysia. Usually the fill slope is at one vertical to two horizontal angles (1V:2H) depending on the subsoil conditions and the material used for filling.

Before 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. 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 stream or creek. 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. Runoff from both the slopes and the catchment area upslope should be effectively cut off, collected and led to convenient points of discharge away from slopes.

When designing surface drainage on steep slopes, it is important to make sure the drains have sufficient capacity to carry the runoff. General guidelines for design of permanent surface drainage is based upon a hundred-year return period rainfall, and temporary drainage is based upon a ten-year return period.

For proper slope drainage, runoff should be channelled by the most direct route away from vulnerable areas of the slope, particularly runoff from behind the top of the slope. Cast-in-situ reinforced concrete berm drains instead of precast drain should be constructed at all the berms. The berm drains should be suitably reinforced to prevent them from cracking. Cracked berm drains will induce water seeping into the slopes thus reducing the factor of safety of slopes against slip failure.

For large slopes, several stepped channels (e.g. cascading drains) should be employed instead of concentrating into one or two channels only. Since the flow in stepped channels is turbulent, sufficient freeboard must be allowed for splashing and aeration, or energy breakers could be provided. Special attention should also be given to the design of the junctions (e.g. catchpit or sump) of channels due to inevitable turbulence, splashing and vulnerability to blockage by debris.

Surface protection should be provided to slopes formed in materials susceptible to rapid surface erosion or to weakening by infiltration. The most common surface protection used in Malaysia is close turfing or hydro-seeding (slope vegetation). Establishment of vegetation on a slope is governed by several factors such as steepness and material composition of the slopes and weather. The steeper the slope, the greater the effort required to establish vegetation. Generally cut slopes can be regarded as relatively infertile and appropriate fertilisers should be added at the time of planting. If turfing is carried out in the dry season, frequent watering is required to enable the growth of the grass on slopes.

If slope vegetation cannot be carried out or is not suitable for the slope, rigid protection measures would be required. The most common rigid protection measures used in Malaysia is sprayed concrete (shotcrete and gunite) reinforced with BRC and with proper drainage weepholes.

7.5 CONSTRUCTION CONTROL

It is very important for the consultant to properly supervise the construction of a hill-site development. The personnel supervising hill-site development especially on the formation of cut and fill slopes, should have sufficient knowledge and experience in geotechnical engineering to identify any irregularities of the subsurface condition (e.g. soil types, surface drainage, groundwater, weak plane such as clay seam etc.) that might be different from that envisaged and adopted in the design. Close coordination and communication between design engineer(s) in the office and supervising engineer(s) are necessary to ensure modification of the design to suit the change of site condition. This should be carried out effectively during construction to prevent failure and unnecessary 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 and 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 like date, weather conditions or irregularities of the subsoil conditions observed during excavation.

Whenever possible, construction programmes should be arranged such that the 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 300 mm to 450 mm thick depending on the type of compacting plants used (unless compaction trails prove to be thicker, loose thickness is achievable) in loose form per layer and uniformly compacted in near-horizontal layer to achieve the required degree of compaction before the next layer is applied. The degree of compaction for the 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 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 first construct 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.

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 a suitable motor grader 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.

7.6 MAINTENANCE OF SLOPES

Although lack of maintenance of slopes and retaining walls are not a direct cause of failure, failure to maintain slopes, particularly after erosion may propagate and trigger landslides. Therefore regular inspection and maintenance of the slopes are necessary.

Awareness alone is not sufficient; engineers and personnel involved in slope maintenance should also know how to carry out their working properly, they need a set of standards of good practice slope maintenance to follow. A good guideline from GEO (1995) of Hong Kong for engineers and GEO (1996) for layman should be referred.

Geoguide-5 (1995) 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.

Since Malaysia has at least two monsoon seasons, Routine Maintenance Inspections (RTI) by layman should be carried out at least 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 a 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 Inspection for Maintenance should be undertaken to prevent slope failure when the Routine Maintenance Inspection by layman observed something unusual or abnormal, such as occurrence of cracks, settling ground, bulges or distortions or wall or settlement of the crest platform. Geoguide-5 (1995) 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.

Slope maintenance is also an important factor. Poorly maintained slopes can lead to slope failure. These may include, amongst others, damaged/cracked drains, inadequate surface erosion control and clogged drains. Eventually, erosion of the slopes allow the formation of rills and gullies (Figure 7.5) or may cause localised landslips (Figure 7.6) which will may propagate with time into landslides if erosion control is ignored.

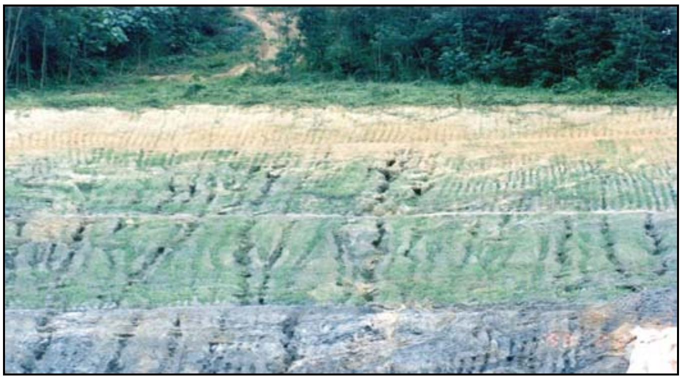

Figure 7.5. Rills and gullies on slopes.

Figure 7.6. Localised slip failures and erosions on slopes.

7.7 CONCLUSION

For safe hill-site development, geotechnical input by the engineers with relevant geotechnical experience during planning, design, construction and maintenance is necessary.

It is also important for the consultant to send personnel with knowledge on geotechnical engineering to supervise hill-site construction so that any irregularities of the subsoil condition from that adopted in the design can be identified and rectified. 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 site condition can be carried out effectively during construction to prevent failure and unnecessary remedial works in the future.

Finally, even with correct design and proper construction, lack of maintenance of slopes and retaining walls can also trigger landslides. Owners and engineers should regularly inspect and maintain their slopes.

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