ASM Inaugural Lecture 2008

Landslides :





How, Why and the Way Forward

Gue See Sew, F.A.Sc.

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Ir Dr Gue See Sew, FASc

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Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

Gue, See Sew, 1953–
Landslides: how, why and the way forward / Gue See Sew.
Bibliography: p. 31
ISBN 978-983-9445-36-7
1. Landslide hazard analysis—Malaysia. 2. Landslides—Malaysia.
1. Title.
551.30709595

Landslides:
How, Why and the Way Forward



Ir Dr Gue See Sew, F.A.Sc.

Ir Dr Gue See Sew, F.A.Sc. was born in Melaka on 3 May 1953. He had his early education in Wen Hua Primary School and Catholic High School, Malacca. He graduated with a Diploma in Civil Engineering from Universiti Teknologi Malaysia in 1976. He later obtained a First Class (Honours) Degree from University of Strathclyde, UK in 1979 with a scholarship from the Federal Government. In 1981, he won the prestigious Kuok Foundation Post-graduate Scholarship and completed his doctorate at Oxford University in 2½ years. He returned to the Public Works Department Malaysia in 1984.

His working experience includes the Public Works Department, Malaysia as a Bridge Design Engineer (1979–1981) and later as Geotechnical Engineer (1984 – 1990). He joined Percon Corporation Sdn Bhd as Head of the Research and Development Department (1990–1992) and SSP Geotechnics Sdn Bhd as the Managing Director (1992–1999).

Since 1999, Dr Gue See Sew has been the Managing Director of G&P Geotechnics Sdn Bhd, a geotechnical consulting firm and in 2003 he was also appointed as the Chief Executive Officer of G&P Professionals Sdn Bhd, a one-stop engineering specialist service centre.

He is the current International Chairman of the Co-ordinating Committee of APEC Engineer (2001 to 2005, 2007 to 2009) and was elected as Fellow of Academy of Sciences, Malaysia on 28 April 2008. He was President of the Institution of Engineers, Malaysia (IEM) (2001 to 2003) and Head Commissioner of ASEAN Engineers Register (AER) (2003–May 2007).

Dr Gue is active in engineering education and research and has been appointed by twelve local universities in various capacities; from Adjunct Professor to member of the Advisory Panel. He is also a panel member for prestigious scholarship awards of Kuok Foundation, Gamuda and LITRAK since 2002.

He has contributed significantly to the engineering profession, especially in the area of geotechnical design, and has created a structured R&D culture in private engineering consultancy services.

Dr Gue has led G&P and his previous companies in providing numerous creative and innovative engineering designs in improving quality, cost and time savings, and has won ACEM awards listed below:

1. A Silver Award of Merit (2006) for Bandar Botanic Development, Bukit Tinggi, Klang
2. An Award of Commendation (2002) for the alternative design of Palm Oil Mill over soft marine deposits in Riau, Indonesia
3. An Award of Merit (1998) for the alternative design of Bistari Condominiums.

Dr Gue was honoured with an Honorary Doctorate in Science (2006) from his alma mater, the University of Strathclyde, Glasgow, Scotland. In 2006, he was awarded The Construction Professional of the Year Award at the Malaysian Construction Industry Excellence Awards, the ASEAN Outstanding Engineering Award at the Conference of ASEAN Federation of Engineering Organisations 2007 and The Most Supportive Member for Recruitment of Corporate Members to the Institution of Engineers, Malaysia 2008. He was also awarded the Melaka State Award, Darjah Seri Melaka (D.S.M) by the Yang Di-Pertua in 2001.

He has published 94 technical papers related to geotechnical engineering in various conferences and seminars including a number of keynote addresses, theme lectures and special lectures. These papers can be found in: <http://www.gnpgeo.com.my>.

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Landslides: How, Why and the Way Forward

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Abstract

The safety of buildings on hillsites is often a topic of discussion among engineers and the public especially after a landslide. Landslide occurrence is more frequent during monsoons. Media coverage after a landslide often includes hypotheses and suggestions to prevent recurrence. Some of these are quite factual while other suggestions and comments are hasty and misleading. This lecture aims to explain with examples about how and why landslides occur. It also outlines some suggestions for landslide mitigation and improvement of slope engineering and management for stakeholders. For example, Universities should strengthen the fundamentals of slope engineering in undergraduate education; practitioners should continuously improve on slope engineering and management through continuing structured training and should make further initiatives in research and development. In addition, developing a National Slope Master Plan for compressive action is needed for a total solution.

1.0 INTRODUCTION

Malaysia experiences frequent landslides with a number of major slope failures with high casualties and economic losses. These are associated with the increased concentration of developments on steep terrain and close proximity to slopes in recent years.

The most notorious example was the collapse of the Block 1 apartment of Highland Towers in 1993, where 48 lives were lost. This notorious landslide had aroused concern among government agencies and stakeholders on the safety of buildings on hillsites.

Climate conditions in Malaysia are characterized by relatively consistent temperature and pressure, high humidity and particularly abundant rainfall with annual rainfall intensity of over 2500 mm. Most of the landslides in Malaysia

are triggered by the high rainfall and more than 80% of landslides were caused by man-made factors mainly related to design and construction errors (Gue & Tan 2006).

Media coverage after a landslide often includes hypotheses and suggestions to prevent recurrence. Some of these are quite factual while other suggestions and comments are hasty and misleading. This lecture aims to explain in simple terms with examples about how and why landslides occur. It also outlines some suggestions for landslide mitigation and improvement of slope engineering and management for stakeholders. For example, Universities should strengthen the fundamentals of slope engineering in undergraduate education, practitioners should continuously improve on slope engineering and management through continuing structured training and should make further initiatives in research and development. In addition, developing a National Slope Master Plan (NSMP) for compressive action is needed for a total solution.

2.0 MAJOR LANDSLIDES

Among the major landslides that occurred in the past two decades, the most notorious 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.

Table 1 summarises the fatalities suffered in the major landslides according to categories of residential area and infrastructure.

TABLE 1. MAJOR LANDSLIDES

Year of occurence	Landslide location (Name)	Category	Fasalities
11 Dec. 1993	Block 1 of Highland Tower, Malaysia	Residential	48
20 Nov. 2002	Taman Hillview, Malaysia	Residential	8
26 Oct. 2003	Bukit Lanjan, Malaysia	Infrastructure (Highway)	0
12 Oct. 2004	Gua Tempurung, Malaysia	Infrastructure (Highway)	1
23 Mar. 2007	Putrajaya, Malaysia	Infrastructure (Public amenities)	0
13 Nov. 2007	Pulau Banding, Malaysia	Infrastructure (Public amenities)	0

2.1 Collapse of Block 1 of the Highland Towers, 1993

The Highland Towers are located in the district of Hulu Kelang, Selangor. Highland Towers consisted of three blocks of 12 storey high apartments named simply Blocks 1, 2 and 3, respectively. It was constructed between 1975 and 1978. Block 1 was occupied in 1979 and collapsed 15 years after its completion.

In the Highland Towers development, an existing 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.

On Saturday, 11 Dec. 1993, at about 1.30 p.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 177.5 mm and the measured maximum daily rainfall intensity was 59.5 mm. It was not an 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, 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 pile foundation induced by the movement of the soil. The movement of the soil was the consequence of retrogressive landslides behind the Block 1. *Figure 1* shows the extent of the failure.

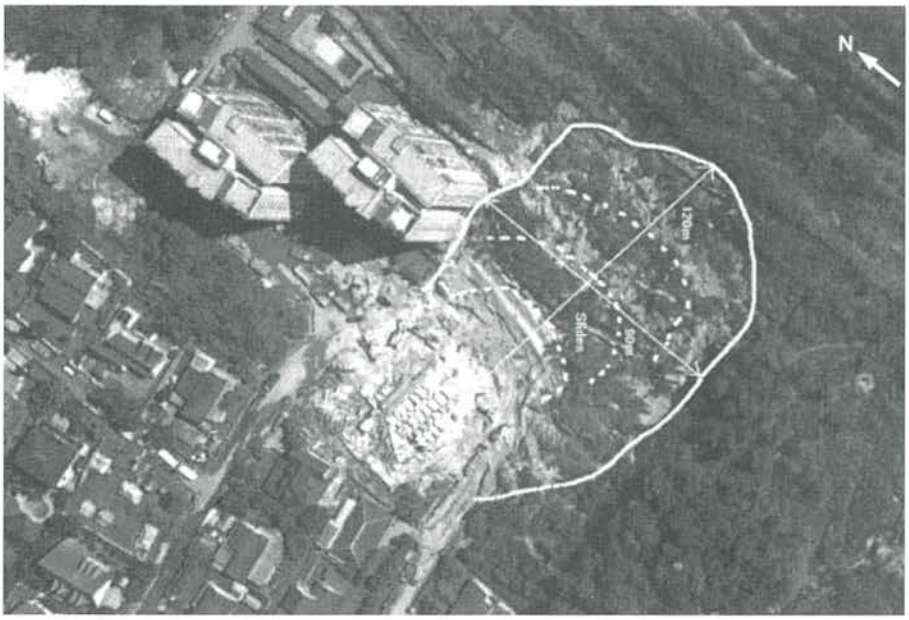


Figure1. Extent of the failure.

(Source: MPAJ 1994)

The landslide was triggered by inadequate drainage on the hillslope that aggravated the surface runoff (MPAJ 1994). Slope and rubble walls behind and in front of Block 1 were also found to be unengineered 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 to pile up behind Block 1, increasing the lateral pressure to the foundation of the building and the rubble wall in front of Block 1 until it collapsed and toppled. *Figure 3* shows the collapse of Block 1 of the Highland Towers Apartments.

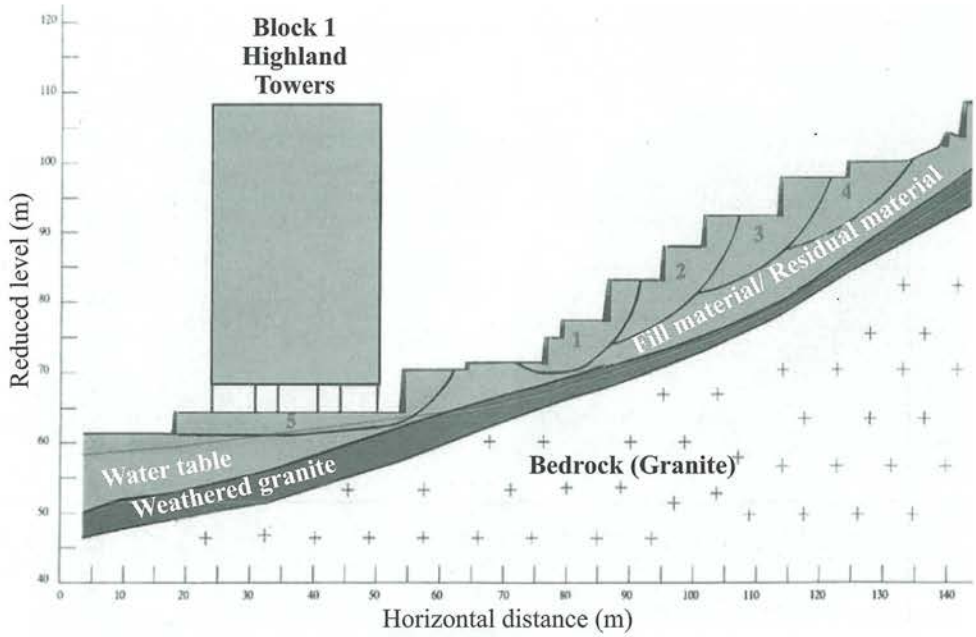


Figure 2. Illustration of retrogressive slope failure sequence.
(Source: MPAJ 1994)

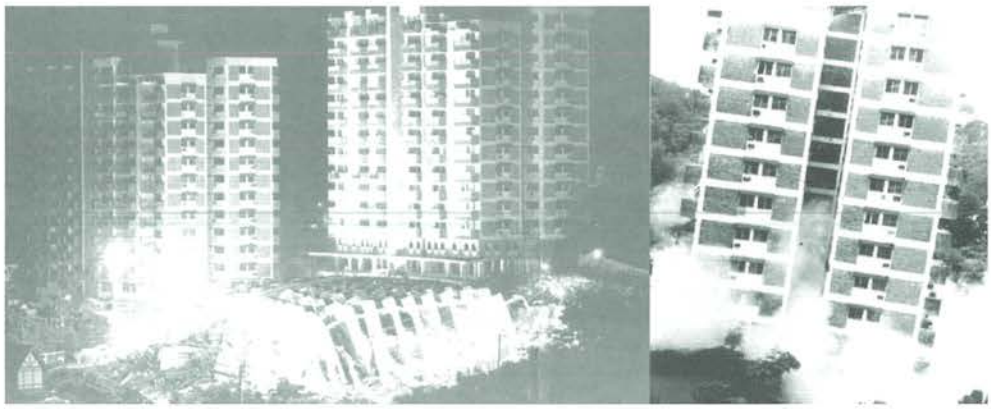


Figure 3. Collapse of Block 1 of Highland Towers Apartments, 1993.

2.2 Collapsed Bungalow at Taman Hillview in Ampang, 2002

The collapse of a double storey bungalow at Taman Hillview in Ampang *(Figure 4)* occurred on 20 Nov. 2002 and claimed eight lives. The bungalow was built on a relatively flat ground but it was adjacent to the slope of the abandoned Highland Towers site. The cause of landslide at Taman Hillview was similar to that of the Highland Towers tragedy, where failure of a rubble wall together with the rain water triggered the landslide. The Factor of Safety of the rubble wall in Highland Towers was found to be less than 1.0 even without considering any presence of geological features such as relic joints etc. and the water table. In fact, the rubble wall is part of the series of rubble walls behind Highland Towers.



Figure 4. Collapsed bungalow at Taman Hillview in Ampang, 2002.

3.0 HOW AND WHY LANDSLIDES OCCUR

3.1 Anatomy of Landslides

Figure 5 shows a typical slope consisting of (i) ground profile with some vegetation, (ii) ground water table, (iii) partially saturated soil above ground water table, (iv) saturated soil below the ground water table and (v) weathered and/or competent rock.

In the analysis of slope stability to determine whether a slope is safe, potential slip surfaces *(Figure 6)* are postulated on the slope's cross-section. These slip surfaces

are analysed in terms of the total driving and resisting forces. The factor of safety (FOS) is determined from the ratio of resisting forces to driving forces. The lowest FOS is the critical stability of the slope.

The FOS, also known as Safety Factor, is used to provide a design margin over the theoretical design capacity to allow for uncertainties in the design process. The threshold value of FOS for slope stability is 1.0, Therefore, theoretically, FOS of 1 or less indicates slope failure.

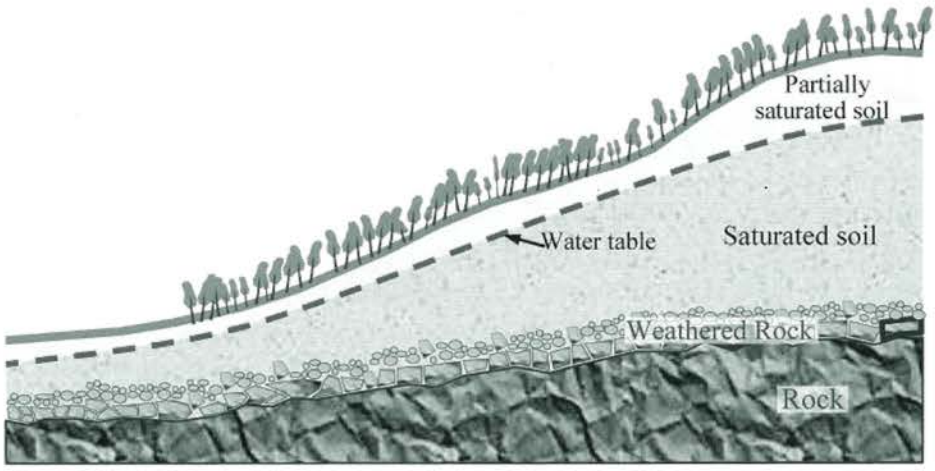


Figure 5. Anatomy of a typical slope.
(Source: Gue & Fong 2003)

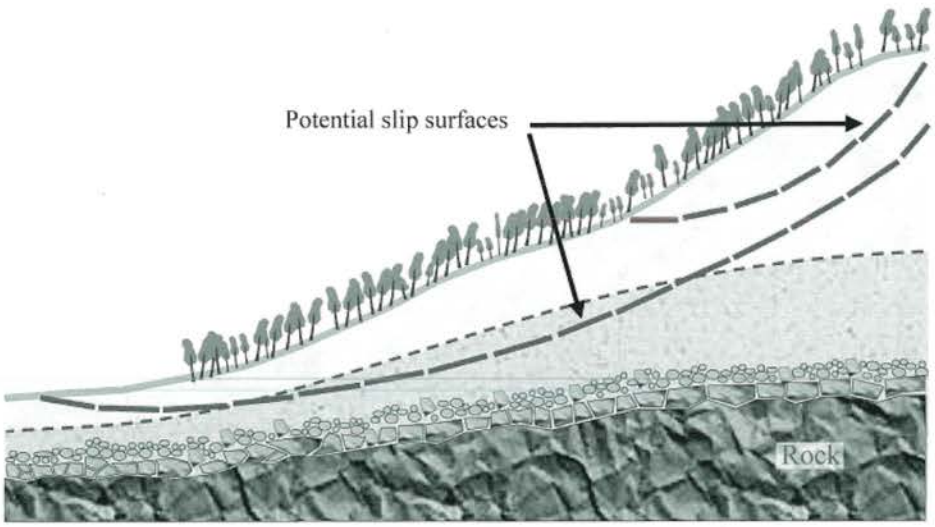


Figure 6. Potential slip surfaces.
(Source: Gue & Fong 2003)

With the above features of a typical slope, the following introduces several simplified fundamental concepts of slope stability. The first concept is friction. Friction is generated between two bodies or surfaces when the bodies or surfaces are moving against each other as shown in *Figure 7*. From the illustration, there is a normal force *(N)* causing the two bodies or surfaces to come into contact, a driving force *(T)* and frictional resistance *(F)*. Two important events arise: (1) If *T* increases, *F* also increases until a limit in which the two bodies will slide against each other; (2) As *N* increases, *F* increases as well. *F* is a function of soil properties and the weight of the two bodies in contact.

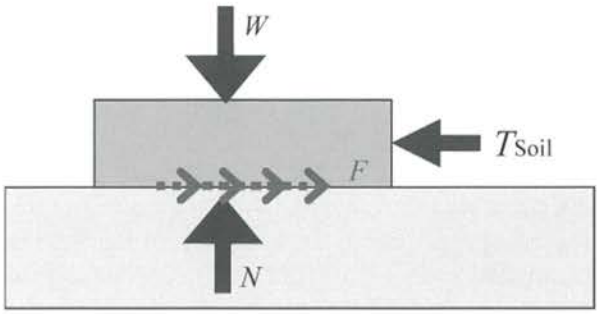


Figure 7. Concept of friction.

(Source: Gue & Fong 2003)

In slope stability, the main properties of soil for slope analysis are soil unit weight (γ), apparent cohesion (c') and friction angle (ϕ). By relating to the earlier concept of friction on slope stability, the forces *N* and *T* can be replaced by the force components in slope; *N* is analogous to the self weight of the soil, *F* is the shear resistance at the potential slip surface and *T* is the driving force caused by soil self weight and/or surcharge *(Figure 8)*. The governing equation for the resistance of the potential slip surface to shearing is based on the Mohr-Coulomb equation:

$$\tau = (\sigma_n - u) \tan(\phi') + c' \quad (1)$$

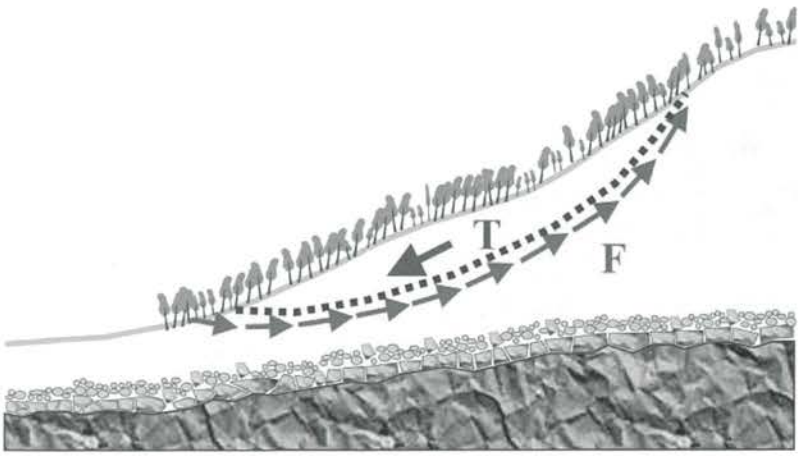


Figure 8. Friction concept in slope.

(Source: Gue & Fong 2003)

From the equation, τ is shear stress, σ_n is the normal vertical stress, u is the pore water pressure, ϕ' and c' are the friction angle and apparent cohesion of soil, respectively. Therefore, in a slope stability analysis, a slope is unstable when the summation of shear forces or resistance along the potential slip surface is less than the driving forces.

The second concept is the role of water pressure in slope stability analysis. In soil, water pressure exists if the soil is below the ground water table (saturated soil).

The main effect of water pressure on a sliding plane is the reduction of normal pressure or forces on soil particles at contact. Thus the shear stress is reduced and correspondingly the shear resistance is also reduced.

The third concept is suction. Suction occurs in partially saturated soils where water is drawn out of the voids between soil particles mainly through evaporation. This creates a vacuum effect that pulls the soil particles together, this increases normal pressure or forces on the soil particles, thereby increasing the shear resistance. However, the suction effect in slope is temporary and is easily diminished when water re-enters the voids (for example, infiltration during prolonged rainfall).

3.2 Factors Attributed to Landslides

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

TABLE 2. CAUSES OF LANDSLIDES

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

(Source: Gue & Fong 2003)

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

3.2.1 *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 (e.g. 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. Therefore, it is better 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 are almost impossible to detect by subsurface investigation.

Since geological discontinuities could not be fully addressed during the design stage, design engineers should make conservative assumptions for the soil/rock parameters and also the groundwater profile to ensure adequacy in design. Besides that, they should only carry out adjustments on site after geological slope re-mapping and re-analysis of the cut slopes. When optimistic assumptions were made during the design stage and the results obtained during construction on sites that were less favourable, 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 may be compromised due to unbudgeted strengthening and additional protection works being needed.



Figure 9. Block failure of sedimentary formation.
(Source: Liew 2005)



Figure 10. Discontinuities of cut rock slope.
(Source: Nur & Yew 2005)

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

1. The abuses of the prescriptive method on the slopes for cut or fill slopes without proper geotechnical analyses and assessments. It is common in Malaysia to find many cut slopes formed for residual soils that are 1V:1H (which means one vertical: one horizontal i.e. 45 degrees angle). Based on literature published on residual soils and the author's own experience in residual soils, it is unlikely, or even impossible, for residual soils to have the effective parameters (c', ϕ') to maintain the stability of high slopes even without water table and geological features, unless it is not a rock slope. The author's own experience indicates that the ϕ' values of residual soils are generally in the range of 29° to 36° and mainly depend on the particle size distribution of the materials. Therefore, if proper analyses of the slope stability were carried out with correct soil parameters, most of these 45° gradient slopes will not have a sufficient FOS recommended against slip failure in the long term, even with some effective cohesion. In summary, engineers should not prescribe slope gradients (e.g. 1V: 1H) without proper geotechnical investigation, 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, analyses and designs carried out were not representative of the actual site conditions, and thus were unsafe.

3. A lack of good understanding of fundamental soil mechanics, such as the most critical long-term condition of cut slopes i.e. the 'Drained Condition'. Therefore, it is necessary to adopt effective shear strength parameters for the 'Drained Analysis' for 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 errors, the reasons are as follows:

1. Tipping or dumping of loose fill down the slopes to form a filled platform or filled slope which is against the normal specification for earthworks. 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 slope to form fill slopes. 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, are likely to 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 to the bottom. This wrong practice triggers landslides or induces 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 eventually slip down.

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

3.2.3 *Maintenance.* Poorly maintained slopes can lead to slope failure. These include damaged/cracked drains, inadequate surface erosion control and clogged drains. The common problems of landslides caused by lack of maintenance are clogged drains. Clogged drains often cause large volume of water to gush down the slope, eroding it and later the formation of gullies will happen. These gullies then further deteriorate and this finally leads to landslides.

Figure 11 shows the formation of rills and gullies and *Figure 12* shows localized landslips caused by erosion which propagated with time into landslides when control was ignored. If proper maintenance was carried out, then these small defects would have been rectified and landslides caused by erosion would have been prevented.



Figure 11. Formation of rills and gullies.
(Source: Gue & Tan 2004)



Figure 12. Localized landslips.
(Source: Gue & Tan 2004)

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3.3 Abuse of the Prescriptive Method

The abuse of the prescriptive method by engineers on the selection of slope gradient (slope angle) to be adopted for cut or fill slopes have been quite commonplace in Malaysia. In these cases, the slope gradient was specified without proper geotechnical analyses and calculations. It is common in Malaysia to find many residual soil cut slopes that are 1V:1H (which means one vertical: one horizontal i.e. a 45° angle).

The proposed gradient of 1V:1H was borrowed from obsolete methods for slopes along roads adopted in the early sixties and seventies in Malaysia. This obsolete method does not warrant an adequate FOS against failure required for slopes with high risks to life (to take care of public safety) and high risks of economic loss. The FOS against slope failure recommended for high risk-to-life and high economic risk is 1.4. In addition, previous slopes along roads are commonly with low height, either one to two berms height (less than 10 m) and therefore the impact of landslides is less severe. There are incidents indicating that the abuses of the prescriptive method are also extended to retaining walls and soil nailed slopes. This is of major concern for the safety of the public as the consequences of failure of high walls or high soil nailed slopes are much more severe.

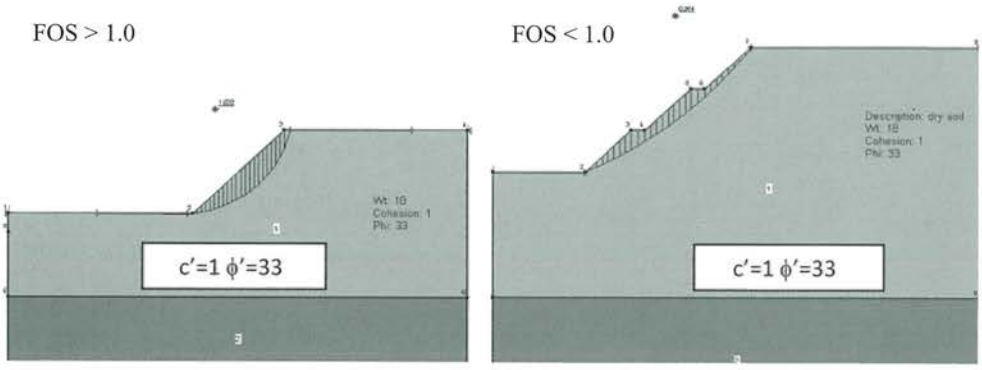


Figure 13. Insufficient factor of safety (FOS) for 1v:1h (45 degree) slope based on moderately conservative soil parameters and ground water profile.

(Source: Gue & Tan 2007)

In order to show the danger of specifying unsafe slope gradients, a simple stability analysis for typical cut slopes and also soil nailed slope using soil strength parameters that are common for residual soils was conducted. *Figure 13* shows the typical cut slope in residual soil with a slope gradient of 1V:1H (45 degree), based on a soil strength of $c' = 1$ kPa and $\phi' = 33o$ which is a typical value for residual soils in Malaysia. The FOS obtained is 1.0 (imminent failure) even without groundwater and geological features. However, if the soil has a higher shear strength (c'–ϕ'), then the FOS will increase and vice versa if the shear strength is lower. Design engineers must be aware that every slope should be designed based on the representative soil

strength parameters, ground water levels, unit weight and correct geometry instead of relying on bad past experience using the prescriptive method. Although there are many cut slopes in Malaysia that are 45° and have not failed, these slopes are either assisted by suction (which is not reliable in the long term) or they are weathered rocks (class II to III) with high effective shear strength. Understanding fundamental soil mechanics is necessary when designing slopes to prevent failures.

Figure 14 shows the typical soil nailed slopes in residual soil with a slope gradient of 4V:1H, based on a soil strength of $c' = 1$ kPa and $\phi' = 33°$. For all four analyses, the length of the soil nails adopted is 9 m. The FOS of a single berm soil nailed slope (5 m high) with and without groundwater is higher than required at 1.4. However when the height of the slopes increases to three (3) berms, the FOS reduces to 1.2 and 1.1, respectively for the dry slopes and the slopes with groundwater. It is obvious that as the height of the slope increases, the length of the nails should be increased and should be at closer spacing to improve the FOS. However, it is still common in Malaysia to find the opposite. Liew & Liong (2006) highlighted two cases of soil nailed slope failures and Chow & Tan (2006) presented design methodologies for proper design of soil nails. In summary, it is dangerous and irresponsible to abuse the prescriptive method and not carry out proper design for slopes, either reinforced or unreinforced.

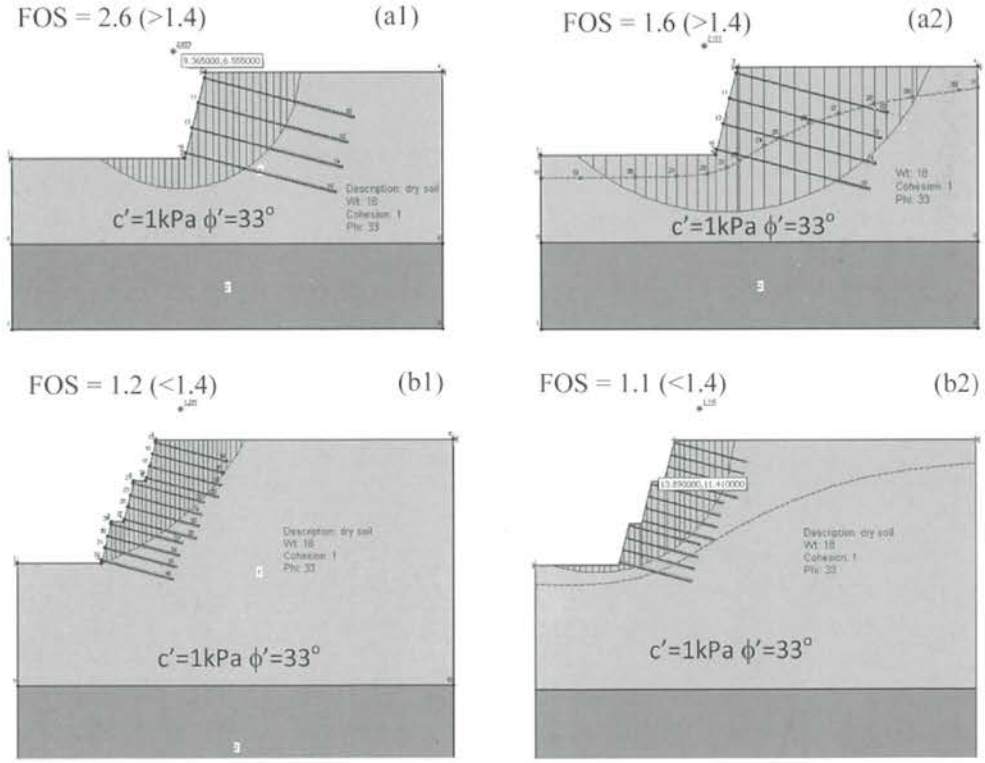


Figure 14. FOS obtained for soil nailed slopes with 9 m length nails.
(Source: Gue & Tan 2007)

Another example of errors in design or construction is adopting a design for other configurations without further analysis. *Figure 15* shows common errors that have occurred in Malaysia. *Figure 15 a* shows a rubble wall which is properly designed with adequate FOS against bearing capacity, sliding, overturning and also slip failure. However due to the site conditions, the retained height was increased on site. The wall was constructed wrongly following the original drawings without changing the base width (*W*) despite the height (h2) having increased. Therefore, the higher adopted wall is not safe and could fail. *Figure 16* shows a picture of the Taman Hillview failure site and *Figure 17* shows a close up view of the unsafe and unengineered rubble wall after failure.

The prescriptive method could only be useful if applied properly and if it complies with all the following conditions:

a) Proper analysis and design is previously carried out for similar slope configurations and geometry, and
b) Same geological formation, and
c) Same subsoil conditions especially soil properties, and
d) Same groundwater conditions and for slopes of low risk to life and economic loss.

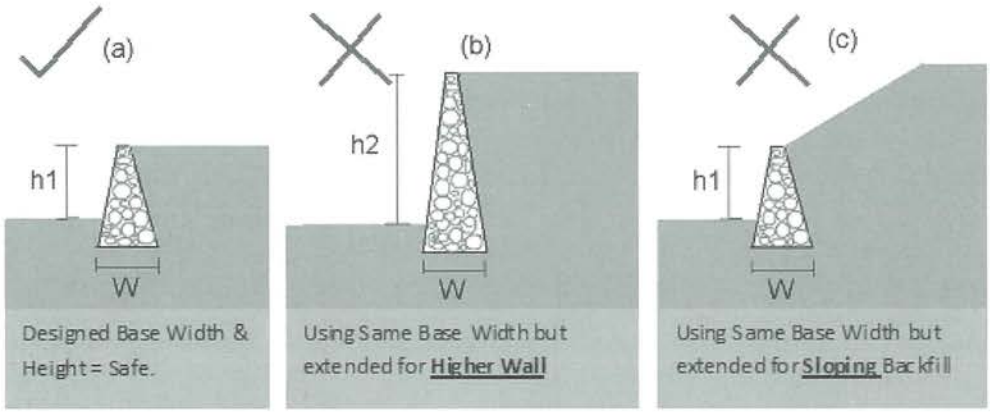


Figure 15. Example of design errors for rubble walls.

(Source: Gue & Tan 2007)

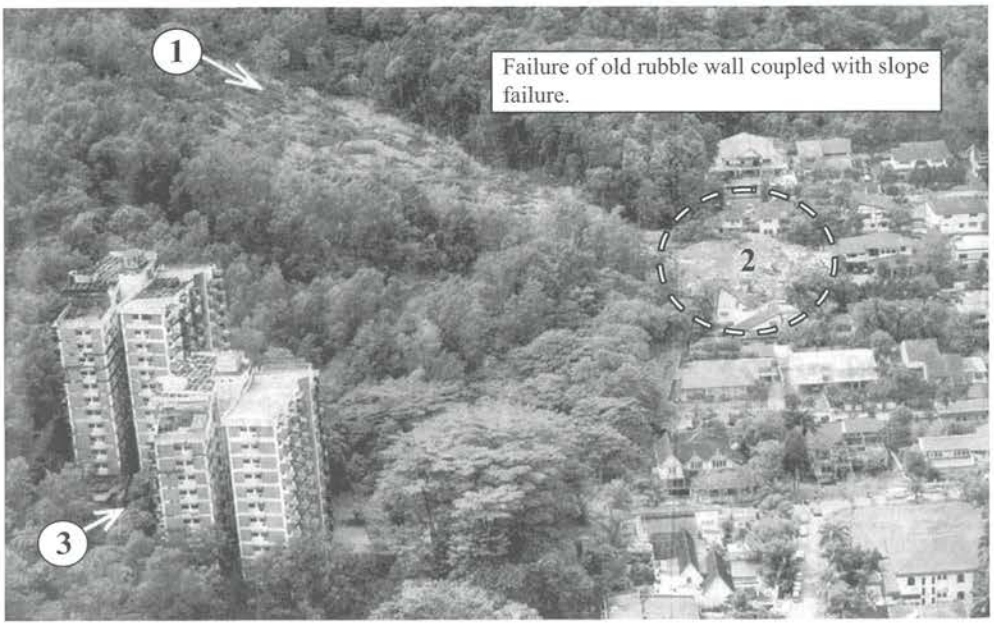


Figure 16. Wall and slope failures at Taman Hillview (2002): (1) Location of unsafe rubble wall that failed (2) Location of collapsed bungalow (3) Remaining two blocks of Highland Tower that collapsed in 1993.



Figure 17. Close up view of collapsed rubble wall at Taman Hillview failure site.

4.0 FURTHER IMPROVEMENTS TO SLOPE MANAGEMENT

The majority of the landslides as discussed in Section 4.0 were avoidable if extra care was taken and input from engineers with relevant experience in geotechnical engineering was utilised from planning to construction.

Hence, it is crucial to improve the current practice of slope management and engineering to avoid recurrence of failures. *Figure 18* summarises the identified key areas where improvement and initiatives are needed in slope management and engineering.

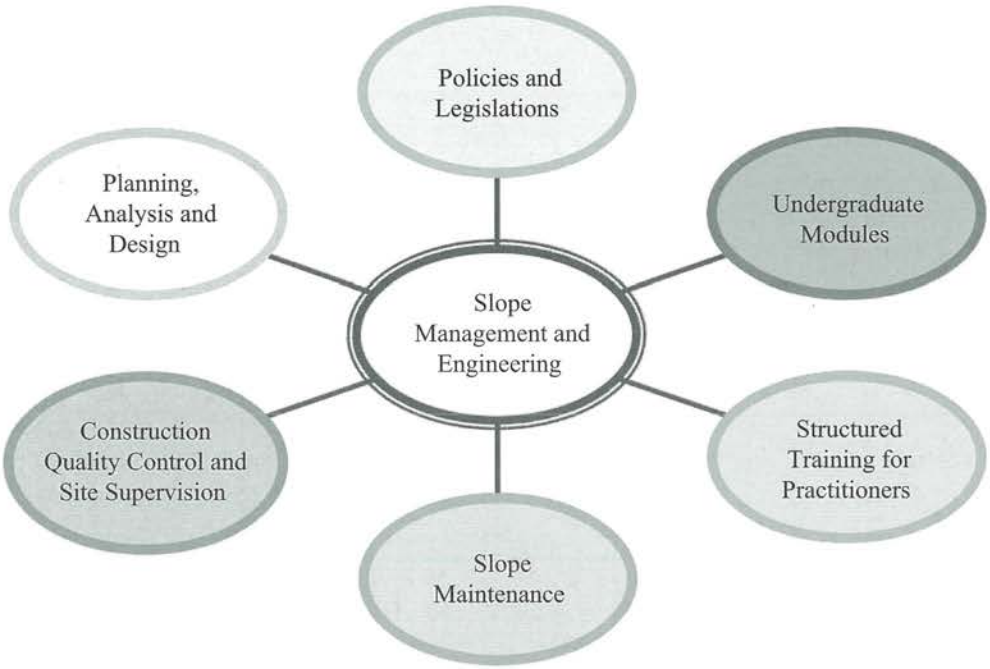


Figure 18. Key areas for improvement in slope management and engineering.

4.1 Policies and Legislation

The first authority to document hillsite development guidelines 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 (Abdullah *et al.* 2007). In June 2002, the Minerals and GeoScience Department Malaysia produced guidelines on hillsite development. The guidelines considered the angle of natural slopes, type of terrain, type of activity, severity of erosion and extent of vegetation. Terrain could be classified into four categories termed as Classes I, II, III and IV. Class I is the least severe in terms of terrain grading whereby slope

angles are less than 15°. Class IV is for slopes with an angle of more than 35° and is classified as the highest risk, where no development is allowed.

Apart from this, there are also numerous other guidelines and regulations related to slope management from the following government and private agencies:

a) Department of Environment (DOE)
b) Minerals and GeoScience Department (JMG)
c) Majlis Perbandaran Ampang Jaya (MPAJ)
d) Ministry of Housing and Local Governments (MHLG)
e) Urban and Rural Planning Department (JPBD)
f) The Institution of Engineers Malaysia (IEM)
g) Kumpulan Ikram Sdn Bhd (IKRAM)

However, some of these guidelines and regulations are unclear and do not add value in terms of safety enhancement, slope stability and protection, environmental friendliness and sustainability of engineering projects. These guidelines and regulations should be harmonized and improved by developing unified guidelines for good practices in planning, designing, construction, site supervision, maintenance and monitoring of engineered slopes. 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 hillsite development. IEM (2000) produced a report titled, *The Policies and Procedures for Mitigating the Risk of Landslide on Hillsite Developments* with the aim of providing uniform, consistent, and effective policies and procedures for consideration and implementation by the Government of Malaysia. However, the recommendations proposed by IEM were not immediately accepted and acted on by the Government—the main stakeholder. The two recommendations implemented by the government of Malaysia after the collapse of the bungalow at Taman Hillview are as follows:

1. The establishment of a centralised agency for slope management and engineering under the Ministry of Housing and Local Government. However, Malaysian Government appointed Public Works Department (PWD) to set up the centralised agency called Slope Engineering Branch of PWD; and
2. The introduction of accredited checkers for geotechnical and structural works for hillsite development by The Board of Engineers, Malaysia.

Consequently, the current legal and regulatory framework should be reviewed and enhanced, including policies and legislation on landslide risk reduction management, mechanisms and processes in ensuring legal accountability, mechanisms for effective implementation, enforcement etc. In the aspect of development planning, the relevant policy should cut across development in both urban and rural areas for housing, infrastructure, agricultural, forestry, mining, etc. Procedures and guidelines

on planning and implementation should incorporate an effective risk assessment and mitigation system with attention to possible environmental impact, mitigation, enhancement and sustainability. The Malaysian legal framework can be enhanced by emulating certain provisions in the legal and regulatory framework for development planning used by Hong Kong (Chan 2007), Italy (Casale & Margottini 1999), etc. For areas where field mapping has been done and hazard maps are available, these should be used to evaluate the level of inherent hazard on site and appropriate approval procedure may be implemented. As the Slope Engineering Branch of PWD has already started with ground mapping to produce hazard maps at sensitive areas like Ulu Klang, usage of such hazard maps should be incorporated into the current system of development approval and enforcement.

The main stakeholders involved in the harmonisation and standardisation of policies and legislation are illustrated in *Figure 19*. Participation from these stakeholders is very important for the success of developing comprehensive policies and regulations for subsequent implementation.

In order to achieve improvements in landslide mitigation and risk reduction, success at the implementation stage is vital. Two different stages of implementation are identified and they are the preparedness stage and mitigation stage. In the preparedness stage, the appropriate laws and regulations, implementation and enforcement policies and guidelines for development planning, training schemes for stakeholders and promotion schemes for community awareness should be geared towards effective landslide mitigation and risk reduction management.



Figure 19. Formation and Implementation of a National Slope Master Plan.
(Source: Gue et al. 2008)

In the mitigation stage, significant resource allocation from the main stakeholders is essential as it consists of planning and enforcement of good practices in new development, retrofitting of existing high risk areas, research and development and exploring advancement in technology and methodology. A similar approach has been adopted in Hong Kong where landslide mitigation and risk reduction have been incorporated into two components, first in planning control of new developments, and subsequently in retrofitting existing slopes at risk (Chan 2007). *Figure 20* illustrates the success of Hong Kong's Geotechnical Engineering Office (GEO) in reducing the risk of landslide. Such policies have contributed significantly to landslide mitigation and risk reduction in Hong Kong with tremendous success. Furthermore, the entire implementation procedure should be entrenched with a 'check and review' or audit benchmarking system for continuous policy refinement. With that, the formulated template of a National Slope Master Plan may become a flagship programme, serving as a blueprint for a structured and systematic implementation plan.

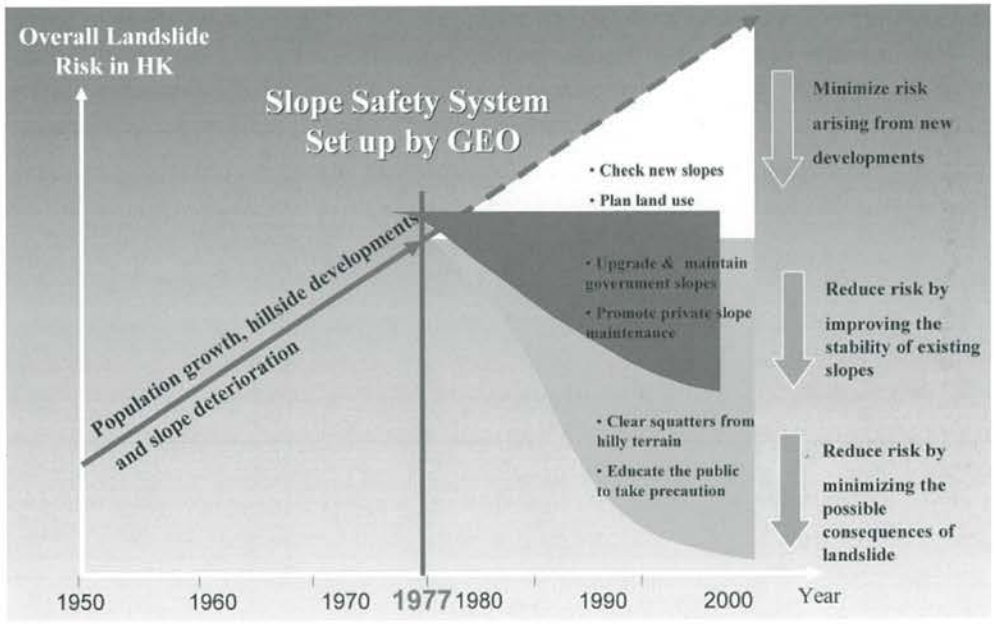


Figure 20. Landslide Risk Reduction Strategy.

(Source: Malone, 2007)

4.2 Planning, Analysis and Design of Slopes

4.2.1 *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 developments, construction activities, problem areas such as previous slope failures, etc.

4.2.2 *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 a hillsite development, it is also very important to locate and study the existing landslip features that can act as indicators of the stability of the site.

4.2.3 *Subsurface investigation.* Subsurface Investigation (SI) should be properly planned to obtain representative subsurface conditions of the whole slope such as the profiles of soils, and bedrock, geological weak zones, clay seams or layers, and the groundwater profile. The planning of exploratory boreholes should take into consideration the slope profile instead of following a general grid pattern. A minimum of three boreholes per cross-section (one on slope crest, one at mid-slope and one at slope toe) is recommended to obtain representative subsurface conditions of the whole slope. In addition, the design engineer must attempt to identify clay seams with the potential of inducing a perch water profile. This could be done by superimposing the classification of subsoil in proportion on the cross-section of a slope, as shown in *Figure 21* to examine its influence on the stability of a slope.

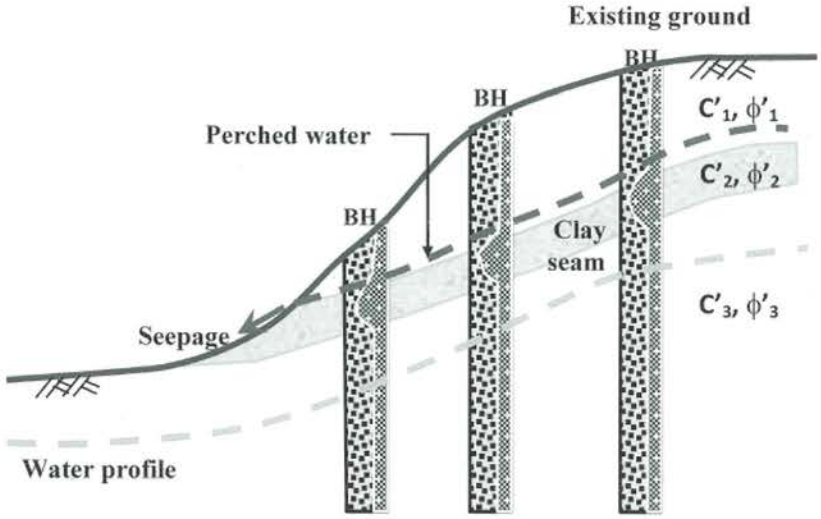


Figure 21. Potential clay seam on slope.

(Source: Gue et al. 2008)

4.2.4 *Analysis and design of slopes.* The design of slopes should use correct information on soil properties, groundwater profile, site geology, selection and methodology for analysis, which 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).

Selection of FOS against a slope failure should follow the recommendations of the *Geotechnical Manual for Slopes* (GEO 2000) of Hong Kong, with minor modifications

to suit local conditions, which are 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 the selection of FOS can be found in Gue & Tan (2004).

4.2.5 *Design of cut and fill slopes.* The vertical interval of slopes between intermediate berms is usually 6 m in Malaysia. GEO (2000) recommends that the vertical interval of slopes should not be more than 7.5 m. 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. The adopted slope gradient should depend on the results of analyses and design based on moderately conservative strength parameters and representative groundwater profiles.

For fill slopes, the vegetation, topsoil and any other unsuitable materials should be properly removed before placing the fill. 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 developing and causing slope instability, especially when there are existing intermittent streams and depressions. Sufficient numbers of discharge drains should also be placed to collect the water in the filter layer and discharge it outside the limits of the fill and away from the slope.

4.2.6 *Surface protection and drainage.* Surface drainage and protection are necessary to maintain the stability of 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 above the slope should be effectively cut off, collected and led to convenient safe points of discharge away from the slopes. Details of surface protection and drainage can be found in Gue & Tan (2004).

4.2.7 *Catchment study.* Catchment study should be carried out for the provision of surface drainage capacity. Under-provision of surface and subsurface drainages can lead to infiltration and spillage of the surface runoffs to slopes, causing surface erosion and resulting in slope deterioration over time which may trigger landslides.

4.2.8 *Fill slope over depressions and valleys.* Depressions and valleys are the preferred water path of natural surface runoff. Streams or intermittent streams are usually formed at depressions and valleys, especially during heavy rain. Intermittent streams at depressions or valleys 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 saturation of slopes and slip planes through the pre-existence of weak, soft or loose layers with debris is high.

Therefore, extra care should be taken on the fill slopes over depressions or valleys by adopting the following measures to mitigate the risk of landslides:

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

4.2.9 *Slopes next to water courses.* Slopes adjacent to water courses such as river banks, beaches, pond side, etc., should be robustly designed for the probable critical conditions such as saturated slopes with rapid drawn-down conditions, scouring of slope toes due to flow and wave actions, etc. Thus, properly designed riprap or other protection measures are needed over the fluctuating water levels.

4.3 Construction Control and Site Supervision

4.3.1 *Site supervision and co-ordination.* Supervising personnel should have sufficient knowledge and experience in geotechnical engineering to identify any irregularities in the subsurface conditions (e.g. soil types, surface drainage, groundwater, weak planes such as clay seams etc.) that may 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 unnecessary remedial works during the service life of the slopes. 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 or 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.

4.3.2 *Construction control via contractual measures.* There should be contractual provisions in protecting the environment against inappropriate ground disturbance by earthwork contractors for both temporary and permanent earthworks. Such legal provision should be included in the relevant Earthworks Specification. An extract from a sample Specification for Earthworks is shown in *Appendix A*, in which clause 12.7 specifies the Engineer's requirements on temporary works (see *Appendix A1*), clauses 24.3 and 24.4 specify protection of borrow pit (see *Appendix A2*), Clauses 33.5 specifies turfing and Clause 33.21 penalties imposed for non-compliance (see *Appendix A3*).

Furthermore, contractors are required to quote for temporary slope protection works so that the Engineer's specifications for temporary protection are not compromised. Contractors should be penalised for not providing the required precautionary measures during the course of works, especially on the protection of borrow pits. The control of temporary works should also be included in the construction drawings. In addition, the construction drawings should also include the appropriate construction sequence for cut and fill slopes, as shown in *Appendices B1* and *B2*, respectively.

In the event that a borrow pit is used, the engineers should ensure it is cut to a gentle and stable gradient to allow for appropriate discharge of surface run-off. Meanwhile, slopes should be closed turfed to minimise soil erosion and washing away of fine particles which may cause slope instability. The above requirements should be highlighted to the contractor through the specifications.

Whenever possible, construction works should be arranged such that fill is placed during the dry season, when the moisture content of the fill can be better controlled. 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 plant used (unless compaction trials 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.

4.3.3 *Cutting of slopes.* Cutting of slopes is carried out from the top to the bottom, followed by works such as drainage and closed turfing. When carrying out excavation of 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 with light machinery. 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.

4.3.4 *Surface protection of slopes.* For all exposed soil slopes, protection such as closed turfing or hydroseeding should be carried out within a short period. The period should be limited to 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 horizontal grooves (not vertical grooves as shown in *Figure 11*) using suitable motor graders before hydroseeding. *Figures 22* and *23* illustrate examples of the horizontal groves formed using suitable motor graders. This is to



Figure 22. Horizontal groves during cutting.

(Source: Gue & Tan, 2002)

from forming on the cut slopes by running water before the full growth of the vegetation, and also to enhance the growth of vegetation.



Figure 23. Vegetation growth on completed slope with horizontal groves.

(Source: Gue & Tan, 2002)

4.4 Slope Maintenance

4.4.1 *Guidelines for slope maintenance.* A good reference for engineers is *Geoguide 5 — Guide to Slope Maintenance (2003)* from GEO of Hong Kong and for laymen, the *Layman's Guide to Slope Maintenance.*

Geoguide-5 (2003) recommends that 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.

4.4.2 *Frequency of maintenance inspections.* Since Malaysia has at least two monsoon seasons, Routine Maintenance Inspections (RMI) by a 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 RMI 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 Inspections for Maintenance, should be taken to prevent slope failure when the Routine Maintenance Inspection by laymen observes 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 an Engineer Inspection for Maintenance to be conducted at a minimum of once every five years and more frequently if 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. Such regimes of regular maintenance inspection should be made known to all property owners and be enforced by the relevant authorities. The regulator may then implement the appropriate orders (in accordance with the available legal/regulatory framework) if the property owners refuse to carry out their duty diligently.

4.5 Undergraduate Training

Apart from improving the policies and legislation for implementation by the government on slope engineering and management, emphasis should also be given to improve undergraduates' understanding of slope engineering fundamentals. This is currently lacking, and is one of the most important elements in improving slope engineering.

As such, the proposed strategy is to develop training modules for undergraduate curricula and course notes for engineering undergraduates. The training modules should cover adequate fundamentals of slope engineering, which include planning of subsurface investigation works, compiling and interpreting soil parameters and water profiles from the subsurface investigation works, followed by analysis, design, specifications, site supervision, construction control, monitoring and maintenance.

Government and private universities should review and update the undergraduate modules on slope engineering from time to time with the assistance of active and experienced practitioners to ensure graduates possess enough fundamentals to meet industry needs. The regular updates may be further improved by pooling resources from a group of universities and passionate practitioners to ease the workload of the lecturers so that the contents and quality of the lecture modules are not compromised. Knowledge sharing between lecturers and practitioners can also be achieved through workshops and forums to share experiences on landslide mitigation and risk reduction.

4.6 Structured Training Modules for Practitioners

As engineers are professionals involved in specifying the required landslide mitigations measures, providing structured training to practitioners would be the best way to improve slope engineering practices. Such training should also serve as a reminder to practitioners and professionals who are involved in slope engineering works to practice ethically and professionally. They should be reminded to only practice in the area of their expertise to ensure public safety. Therefore, continuing professional development scheme implemented by the Board of Engineers Malaysia should be enforced to ensure practising engineers continue updating themselves. Furthermore, collaboration and working partnership should be established between professional bodies like The Institution of Engineers, Malaysia, technical agencies, academia, federal, state and local governments and private industry. Structured training programmes for professionals and sub-professionals with certification and accreditation systems should also be implemented to update and improve the capacity and competency of stakeholders involved in slope engineering and management.

Training of different stakeholders, gathering of comments on conflicts and weaknesses of existing guidelines or procedures can facilitate standardisation or harmonisation of practices/procedures and formulation of relevant guidelines related to slope engineering and management. With appropriate and sufficient training together with the adoption of best practices and technology, landslides can be mitigated.

4.7 Research and Development

Apart from structured training modules, all practitioners can take another step ahead with research and development (R&D) to enhance safety, environmental protection and sustainability, speed of construction and economical aspects related to slope engineering and management.

Among others, R&D on a simplified laboratory test to derive soil properties would be a top priority. It is particularly useful in establishing a framework of relationships between friction angle and soil classification. In addition, efforts could also be channelled to correlate soil friction angle against percentage of fines. By understanding the inversely proportional relationship, practitioners may be able to appreciate the change in material behaviour and its sensitivity towards material particle size distribution. However, the above proposed R&D topics would not be achievable without high quality sampling and testing techniques. Therefore, these are the challenges to the current slope engineering industry waiting to be tackled by practitioners and academic.

As slope stability analyses are heavily dependent on the accuracy of groundwater profile estimation, the behaviour of groundwater fluctuation during dry and wet seasons should be evaluated through research and development. Such understanding of ground water fluctuation for countries with tropical weather like Malaysia would be highly beneficial as terrestrial rainfall is known to be highly unpredictable. The knowledge of groundwater fluctuation can help formulate design procedures for subsoil drainage systems, such as horizontal drains and their spacing.

5.0 SUMMARY AND CONCLUSIONS

With the increased developments that have encroached into the hilly areas and the occurrence of landslides over the past two decades, safety of buildings on hillsites against landslides is a crucial issue among engineers and the public.

The most notorious example was the collapse of apartment Block 1 of Highland Towers and that took 48 lives in 1993. This notorious landslide had aroused concern of the government agencies and stakeholders on the safety of buildings on hillsites.

80% of the landslides were directly due to design and construction deficiencies. This excludes construction errors and lack of maintenance at 8% and 6%, respectively.

Landslides are avoidable if extra care is taken and input from engineers with relevant experience in geotechnical engineering is engaged from planning through to construction. It is crucial to improve the current practice of slope management and engineering to mitigate landslides.

Among the way forward, this includes enhancements and improvements to the following:

i) Policies and legislation
ii) Planning, analysis and design of slopes
iii) Construction control and site supervision
iv) Slope maintenance
v) Undergraduate training
vi) Structured training modules for practitioners; and
vii) Research and development.

ACKNOWLEDGEMENT

The author would like to express gratitude to Ir Cheah Siew Wai of G&P Geotechnics Sdn Bhd for assisting in the preparation of this lecture.

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APPENDIX A1. EXTRACTION FROM THE SPECIFICATION FOR EARTHWORKS (CLAUSES 12.0: TEMPORARY WORKS)

12.0 TEMPORARY WORKS

12.1 The Contractor shall allow in the tender for the cost of providing the necessary design, statutory submission, construction, testing and monitoring of all temporary works, including the subsequent removal of all recoverable temporary structures, for the satisfactory completion of the earthworks. He shall be responsible for the overall adequacy and safety of all temporary works. All temporary works shall comply with requirements of BS 5975.

12.2 Temporary works means all planning and works carried out by the Contractor to
the Consultant complying with all specifications, drawings and workscope. This
and laboratory tests, temporary tracks, excavation, filling, proper cover and protect
of works, necessary temporary drainage, pumping of water, emergency contingenc
strengthening measures, methodology and method statement of all works, and etc.

12.3 The scope of temporary construction shall include but not limited to:

(a) Life safety measures such as hoardings, barricades, nettings, signboards, etc.

(b) Ground improvement and/or ground water cut off systems using jet grout piling,

(c) Ground water recharging systems, surface and groundwater drainage system usi

(d) All other measures necessary for the safe performance of the temporary work
strengthening, adapting, modifying, re positioning, taking down and re-fixing from

12.4 Temporary works shall be the sole responsibilities of the Contractor. S.O.'s approval
on all temporary works shall not relieve the Contractor's sole responsibilities to e
engineering practice, and Contractor's own time and cost to rectify any defects, non
possible long term instability/failure and serviceability problems of the temporary w

12.5 The Contractor shall employ a Professional Engineer to design and supervise the con
copy of the design calculations and construction drawings for the temporary works shall be mad
to the S.O. for the purpose of record.

12.6 The Contractor shall make all necessary statutory submissions in connection with hi
orary works, and secure from the local Authority the required clearances and the statutory permit to commence work
all comply with the requirements of the local Regulations governing his design and construction of the temporary
s, including any statutory requirements that may be imposed from time to time during the tenure of the contract.

12.7 All temporary works especially but not limited to tem
rary accesses and temporary earthworks (temporary cut or temporary fill) shall not cause failure and shall not induce instability or serviceability problems in the long term. All temporary cut and fill by Contractor that will be left behind after completion of permanent works shall have the same Factor of Safety on stability and Serviceability conditions as permanent works. These temporary works by Contractor shall also comply with all requirements, specifications, drawings and workscope applicable for similar type of permanent works (e.g. slope angle, compaction of fill, surface drainage, retaining structures, strengthening measures if necessary, etc).

12.8 Temporary works by the Contractor that in the opinion of the S.O. will cause instability or serviceability problems (either short term or long term) in any way, the S.O. will order remedial works to be provided immediately at the Contractor's own expense with not additional performance time. Such instruction will not relieve the Contractor of his sole responsibility for the temporary works. The remedial works carry out shall comply to all requirements, specifications, drawings and workscope of similar type of permanent works (e.g. cut, fill, retaining walls, strengthening works, etc).

12.7 All **temporary works** especially but not limited to temporary accesses and temporary earthworks (temporary cut or temporary fill) shall not cause failure and shall not induce instability or serviceability problems in the long term. All temporary cut and fill by Contractor that will be left behind after completion of permanent works shall have the **same Factor of Safety on stability and Serviceability conditions as permanent works.** These temporary works by Contractor shall also comply with all requirements, specifications, drawings and workscope applicable for similar type of permanent works (e.g. slope angle, compaction of fill, surface drainage, retaining structures, strengthening measures if necessary, etc).

APPENDIX A2. EXTRACTION FROM THE SPECIFICATION FOR EARTHWORKS (CLAUSES 24.0: PROTECTION OF BORROW PIT)

24.2 Fill materials for use in forming fill platforms shall be the suitable material obtained from excavation in cuttings. Where the quantity of such materials is inadequate, the Contractor shall obtain suitable materials from the designated borrow pits or from his own borrow pits which have been approved by the S.O.

Borrow Pit

24.3 The Contractor shall be responsible for locating borrow pits. Designated borrow pits shown on the Drawings only indicate to the Contractor potential areas for borrow. Whether the Contractor obtains materials from the designated or his own borrow pit, it shall be his responsibility to ascertain the suitability of the pit with respect to the quantity and quality of the materials, which shall be subject to the approval of the S.O. The Contractor shall pay all necessary fees, taxes or royalties to the appropriate authorities and observe all relevant regulations. The Contractor shall keep the borrow pits free from ponding water and the excavation neat and tidy and shall carry out necessary erosion and environmental protection measures following the agreed method statement or as instructed by the S.O.

24.4 The contractor shall submit method statement on cutting or filling and turfing at the borrow pit or dump site for approval of the S.O.. After cutting or dumping, all the slopes shall be formed to a stable gradient and close turfed or protected by other approved surface protection method. Provision of drainage, siltation pond and preventive measures of pollution shall also be included in the method statement.

Soft Spots

24.5 Where any undue movements due to the presence of soft und[illegible] at the bottom of the fill, it shall be excavated to such depth and o[illegible] spoil. The resulting excavation shall be backfilled with suitable mater[illegible] exceeding 225mm thick and compacted as described above, or with compac[illegible]

24.6 The Contractor shall allow for settlement or displacement of fill over soft [illegible] with necessary compaction.

Filling under Floors, Aprons, beside Pilecaps and Trenches etc.

24.7 Filling shall be provided and laid under floors, aprons, etc. where requi[illegible] hereinbefore, deposited in loose lifts not exceeding 150mm loose thickne[illegible] rammed and compacted. No Generally, clay shall be used for filling under [illegible] At areas where compaction is practically difficult due to space constraint, [illegible] can be used for backfilling with the approval from the S.O.

25.0 FILL MATERIALS

25.1 In general, fill material shall be well graded suitable fill material unless [illegible] hazardous fill shall not be used at any location or part of the site, includin[illegible] tender for the cost of laboratory tests to determine the optimum moisture c[illegible] commencement of filling operations.

25.2 The safety of workmen, ease of placement and compaction are primary c[illegible] narrow, confined spaces. Under these conditions, only granular soil will be [illegible] take this requirement into

Borrow Pit

24.3 The Contractor shall be responsible for locating borrow pits. Designated borrow pits shown on the Drawings only indicate to the Contractor potential areas for borrow. Whether the Contractor obtains materials from the designated or his own borrow pit, it shall be his responsibility to ascertain the suitability of the pit with respect to the quantity and quality of the materials, which shall be subject to the approval of the S.O. The Contractor shall pay all necessary fees, taxes or royalties to the appropriate authorities and observe all relevant regulations. The Contractor shall keep the borrow pits free from ponding water and the excavation neat and tidy and shall carry out necessary erosion and environmental protection measures following the agreed method statement or as instructed by the S.O.

24.4 The contractor shall submit method statement on cutting or filling and turfing at the borrow pit or dump site for approval of the S.O.. After cutting or dumping, all the slopes shall be formed to a stable gradient and close turfed or protected by other approved surface protection method. Provision of drainage, siltation pond and preventive measures of pollution shall also be included in the method statement.

APPENDIX A3. EXTRACTION FROM THE SPECIFICATION FOR EARTHWORKS (CLAUSES 33.0: PROTECTIVE VEGETATION FOR EROSION CONTROL AND PENALTY FOR NON-COMPLIANCE).

33.0 PROTECTIVE VEGETATION FOR EROSION CONTROL

33.1 If specified in the drawings, directed by the Engineer or required to be used by the C
the following sections shall be adhered to unless otherwise directed by the Engineer

33.2 If due to unforeseen circumstances turfing or hydroseeding cannot be carried out
temporary protection/cover (eg. plastic sheets or equivalent) shall be laid on expose

Topsoil

33.3 Topsoil stockpiled for the Works shall be spread and lightly compacted to an even thi
in areas to be turfed and/ or seded.

33.4 Topsoil stockpiled for the Works in accordance with Sub-Sections 2.1.1
an even thickness of 50 mm as directed by the S.O. in areas to be t
direct for tree planting and other purposes.

Turfing

33.5 Turfing shall be carried out within seven (7) days after formation of the final slope profile as shown in the Drawings and/or where directed by the Engineer. Otherwise Engineer reserves the right to engage external party to carry out the work and deduct the additional cost incurred accordingly from the contract. The type of turf shall be as indicated in the Drawings or other alternative type as approved by the Engineer and shall be free of lallang and essentially free of weeds.

33.6 Turf shall be obtained in unbroken sods with a substantial amount of topsoil and shall be approximately 250mmx250mm in size and 100mm thick, from an approved source, and shall be placed in position as soon as practical after cutting.

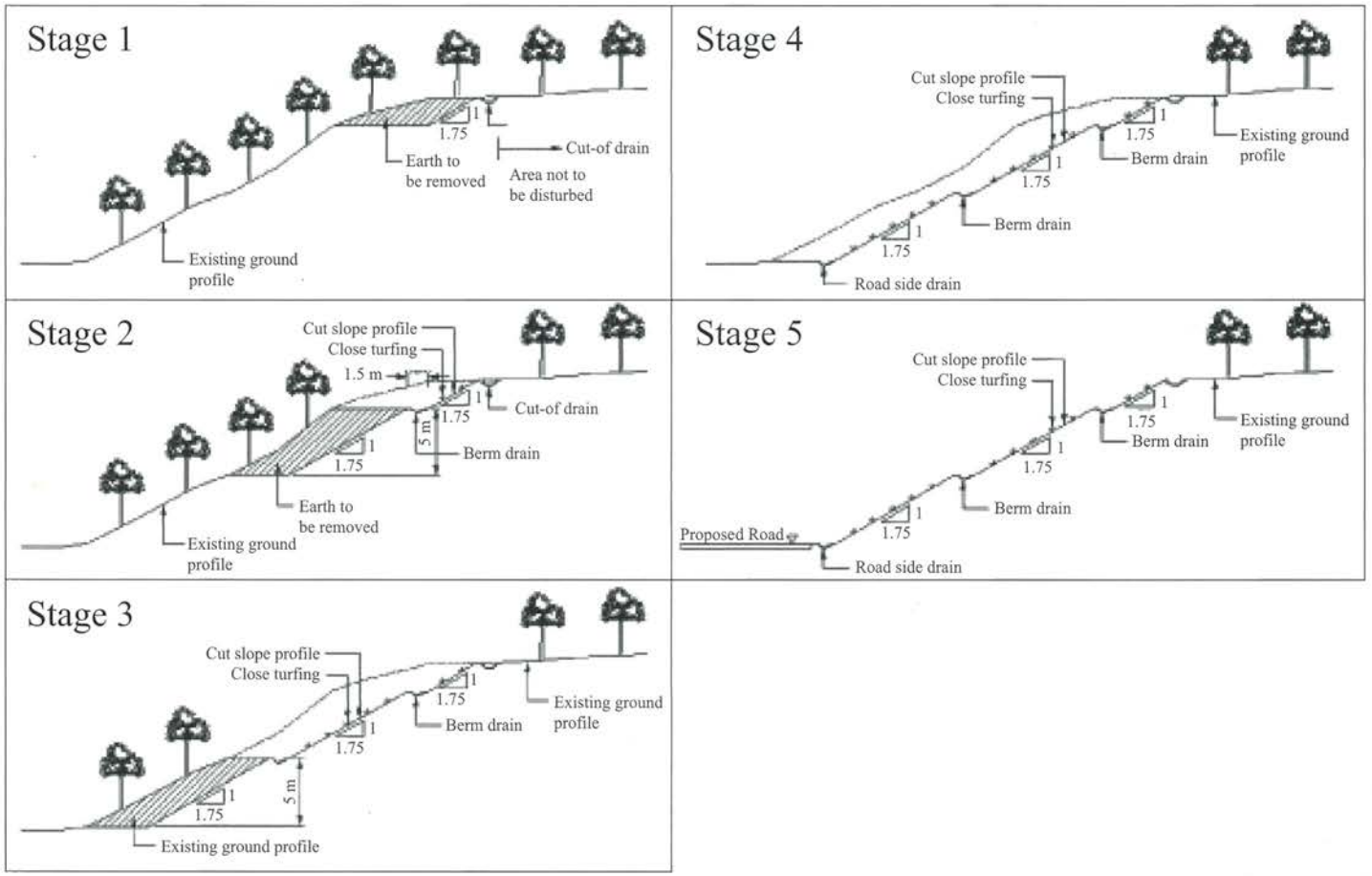
33.7 Turf sods shall be stacked and watered when they cannot be laid immediately after cutting. The surfaces to be turfed shall be trimmed and thoroughly wetted. The turf shall then be carefully laid to form a complete and uniform cover as shown on the Drawings. Turf laid on slopes steeper than 1 (vertical) : 3 (horizontal) shall be pegged down with bamboo stakes approximately 250mm

33.5 Turfing shall be carried out within seven (7) days after formation of the final slope profile as shown in the Drawings and/or where directed by the Engineer. Otherwise, the Engineer reserves the right to engage external party to carry out the work and deduct the additional cost incurred accordingly from the contract. The type of turf shall be as indicated in the Drawings or other alternative type as approved by the Engineer and shall be free of lallang and essentially free of weeds.

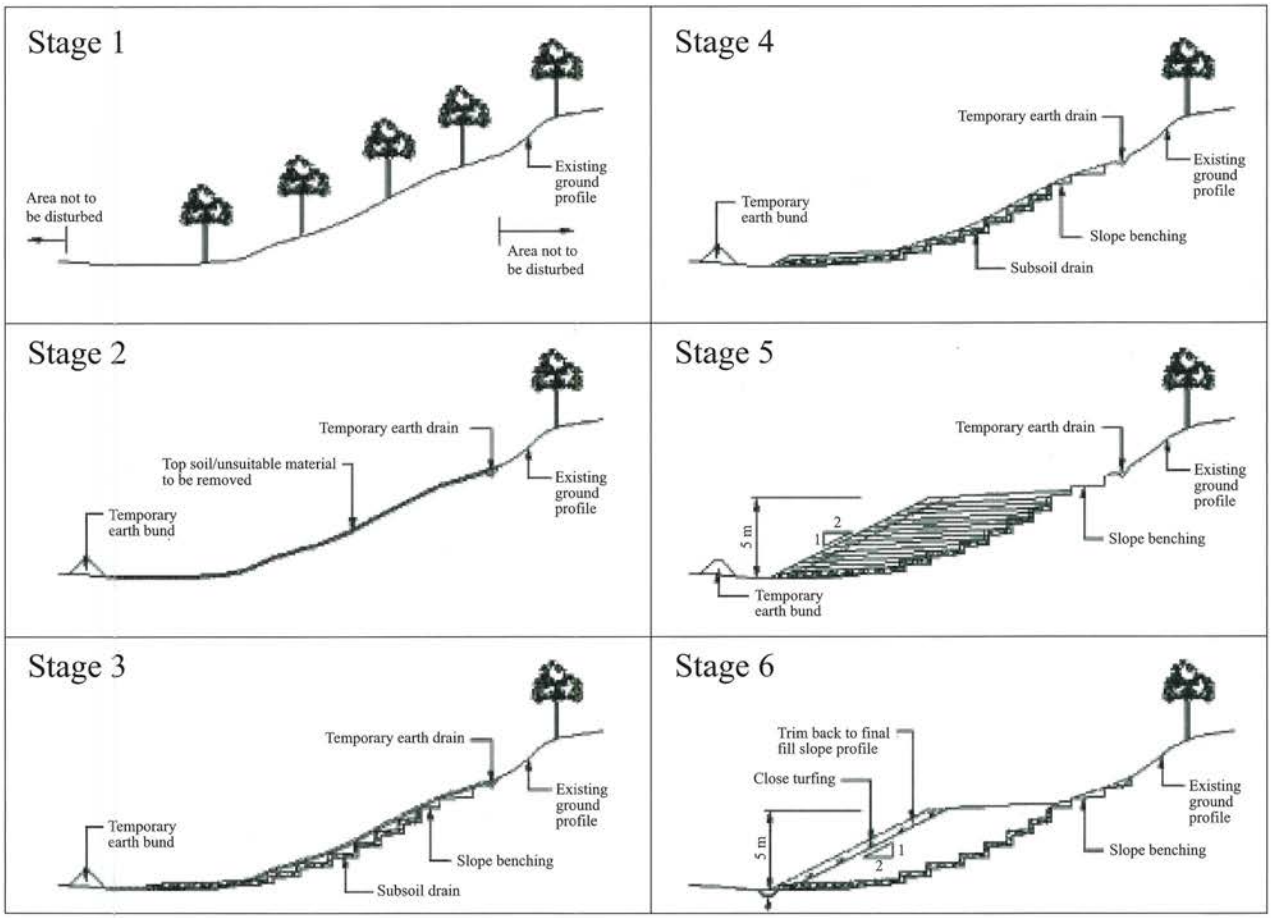
Penalty

33.21 The Contractor who fails to implement the Works as per above Sub-sections 2.2.8.1, 2.2.8.2 and 2.2.8.3 shall bear the time and cost of turfing/hydroseeding works carried out by others under the direction of the S.O.

APPENDIX B1. SAMPLE CONSTRUCTION DRAWING ON CONSTRUCTION SEQUENCE FOR CUT SLOPES.



APPENDIX B2. SAMPLE CONSTRUCTION DRAWING ON CONSTRUCTION SEQUENCE FOR FILL SLOPES.



Pusat Informasi & Perpustakaan
Akademi Saint Malaysia

Academy of Sciences Malaysia

Establishment

The Academy of Sciences Malaysia was established under the *Academy of Sciences Act 1994* which came into force on 1 February 1995. It was officially inaugurated by the former Prime Minister, YABhg Tun Dr Mahathir Mohamad on 8 September 1995.

Mission

To pursue, encourage and enhance excellence in the fields of science, engineering and technology, for the development of the nation and benefit of mankind.

Management

The Academy is governed by a Council consisting of 16 members. Various Working Committees and Task Forces are charged with developing strategies, plans and programmes in line with the Academy's objectives and functions.

Secretariat

The administration of the Academy is carried out by a Secretariat comprising the Executive Director, 27 officers and 12 supporting staff.

Activities

Within the framework of its given mission, the Academy organizes its activities based on the following thrust areas:

- Providing advice to the Government on matters of national importance related to science, engineering and technology
- Fostering a culture of excellence in science, engineering and technology in Malaysia
- Assisting in upgrading the technological capability and competency of Malaysian industries
- Promoting public awareness on the importance of science, engineering and technology in everyday life
- Facilitating and co-ordinating international collaboration and co-operation; and
- Enhancing scientific publications.

Membership

The Academy has 176 Fellows and four Honorary Fellows — YABhg Tun Dr Mahathir Mohamad, YABhg Tun Abdullah Ahmad Badawi, Nobel Laureate Professor Ahmed H. Zewail and YABhg Tun Ahmad Sarji Abdul Hamid. Out of the 176 Fellows, 41 are Foundation Fellows and 135 Elected Fellows. The Fellows of the Academy are elected from among eminent Malaysian scientists, engineers and technologists in the fields of medical and health sciences , engineering and computer sciences, biological, agriculture and environmental sciences, mathematical and physical sciences, chemical sciences as well as science and technology development and industry.

Fellows of the Academy are entitled to be distinguished by the title 'Fellow of the Academy of Sciences Malaysia' and to use the designatory letters F.A.Sc. after their names.

From amongst the Fellows, Senior Fellows are appointed based on recommendation by a Special Panel appointed by the Honorable Minister of Science, Technology and Innovation. Appointment as Senior Fellows is a recognition given to Fellows who have made outstanding contributions to science, engineering and technology, nationally and internationally. The Senior Fellow of the Academy will be addressed as 'Academician'. To date, the Academy has 13 Senior Fellows.

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ISBN 978-983-9445-36-7
9 789839 445367