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JUDUL: ANALYSIS OF SLOPE FAILURE AT MARAN HIGHWAY USING SLOPE/W SOFTWARE

SESI PENGAJIAN: 2009/2010

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Date: **16 NOVEMBER 2009**

ANALYSIS OF SLOPE FAILURE AT MARAN HIGHWAY USING SLOPE/W SOFTWARE

ANNAS ROBANI BIN AMINUDIN

A report submitted in partial fulfillment of the requirements for the award of the degree of achieving Bachelor of Civil Engineering

Faculty of Civil & Earth Resources
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NOVEMBER 2009

I declare that this project report entitled "*Analysis of Slope Failure a Maran Highway using slope/W software*" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date: **16 NOVEMBER 2009**

Dedication…

“…. to whom I love and those who love me**….”**

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ABSTRACT

Analysis towards certain slope at Malaysia is important due to many tragedy occurred effect by the slope failure. The purpose of this study is to analyze the slope stability at KM 99 and 101, Maran Highway that carried out by using computer simulation software, slope/ W by Geoslope. The analysis is divided into four (4) different case, which is natural slope condition, protection of slope using slope benching, ground anchor and soil nail method. The computation for the factor of safety is required and from the result achieved; then the proposed slope protection is applied to improve ground stability. The data (Soil Investigation report) collected from the IKRAM Sdn. Bhd. is important to gather the parameter needed for analysis. The output of this study using Morgenstern and Price's method establishes the FOS value for natural condition of the slope is below the minimum requirement for safe slope which is 0.796. Presence of excess pore water pressure beneath the slope ground layer through rainfall affected the ground stability of the slope. Thus, slope protection must be installed to improve the stability. The result after applying the protection shows the increased in stability; and the highest FOS value is achieved by soil nailing method with 1.591 and followed by anchoring and benching method with 1.229 and 1.164. After safety and economical criteria are considered, soil nailing method is chosen. The immense friction between the soils nails and soil layer produce an additional grip and hold the slope from easily slide.

ABSTRAK

Analisis terhadap cerun tertentu di Malaysia adalah penting disebabkan oleh banyak tragedi telah berlaku kesan daripada kegagalan cerun. Tujuan kajian ini ialah untuk menganalisis kestabilan cerun di KM 99 and 101, Lebuhraya Maran yang dilaksanakan dengan menggunakan perisian simulasi komputer, ‘slope/ W’ daripada Geoslope. Analisis ini dibahagikan kepada empat (4) kes yang berbeza, iaitu keadaan semulajadi cerun, perlindungan cerun menggunakan kaedah cerun bertingkat, sauh tanah dan paku tanah. Pengiraan faktor keselamatan adalah diperlukan dan daripada hasil yang telah dicapai; kemudian perlindungan cerun yang dicadangkan dipasang untuk membaiki kestabilan tanah. Data (laporan penyiasatan tanah) telah dikumpul daripada IKRAM Sdn. Bhd. adalah penting untuk menghimpun parameter yang diperlukan untuk analisis. Hasilan daripada kajian ini dengan menggunakan kaedah Morgenstern and Price’s membuktikan nilai FOS untuk keadaan semulajadi cerun itu ialah di bawah keperluan minima untuk cerun selamat iaitu 0.796. Kehadiran lebihan tekanan air di bawah lapisan tanah cerun melalui air hujan memberi kesan pada kestabilan tanah cerun. Demikian, perlindungan cerun mesti dipasang untuk membaiki kestabilan. Hasil selepas mengenakan perlindungan menunjukkan peningkatan dalam kestabilan; dan nilai FOS tertinggi telah dicapai oleh kaedah memaku tanah dengan 1.591 dan diikuti oleh kaedah menyauh dan meneres dengan 1.229 dan 1.164. Selepas kritera keselamatan dan ekonomikal dititikberatkan, kaedah memaku tanah telah dipilih. Geseran yang sangat besar antara paku-paku tanah dan lapisan tanah menghasilkan lebihan cengkaman dan memegang cerun tersebut daripada tergelincir dengan mudah.

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LIST OF SYMBOLS

σ	-	normal stress
σ'	-	effective stress
u	-	pore water pressure
S	-	total shear strength
S'	-	drained shear strength
c	-	total cohesion soil
c'	-	effective cohesion
σ_n	-	total normal stress
Φ	-	total angle of internal friction
ϕ'	-	angle of internal friction in terms of effective stress
τ	-	shear stress
FOS	-	factor of safety
γ	-	unit weight

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CHAPTER 1

INTRODUCTION

1.1 Overview

Malaysia has undergone a rapid infrastructure development for the past decade due to the population growth. Many buildings and houses have to be built even at the risky area such as hilly or mountainous region. In order to cope with the population exceeding, civil engineers have to come out with the project at the mountainous region. As a consequence, slope stability issues have been the main threat in construction industry affect by the nature topography of Malaysia.

Lately, we were surprised with a tragic landslide at Bukit Antarabangsa on December 2008 that has lead to the great loss in property and life. This is not the first occasion ours country experienced the landslide failure. The collapse of Block 1 of Highland Tower in 1994, slope failure at Taman Hillview in November 2002 and followed by the landslide at Bukit Lanjan in 2003 had prompted our government and public to concern about the stability of slope and the risk involve in such circumstance.

As stated by Samjwal (2006), landslide is defined as the movement of a mass of rock, debris or earth down the slope, when the shear stress exceeds the shear strength of the material. Thus, detailed study to provide the appropriate analysis of slope stability is needed in order to minimize the disaster tragedies from being repeated.

According to Hamdan *et al* (2007), another risky location that may have high possibility of slope failure is at the expressways or highways which have been experiencing deep excavation. The civil engineers must therefore give serious considerations before any construction or development is carried out to ensure the designed slope remain stable. The slope stability analysis is generally carried out at the beginning, and sometimes throughout the life of projects during planning, design, construction, improvement, rehabilitation, and maintenance. Engineers, geologists, contractors, and maintenance workers may take part or involve in this process.

There are several factors that contributed to the slope failure, but they are more likely to occur in certain season if triggered by weather events. For example rainfall has been the biggest contributor to landslide. As addition, our country receives annual rainfall about 2000 to 3000 mm per year. The existence of excess water through rainfall will penetrate into the ground and makes the slope become active. Not just decreasing the overall strength of slope failure, the excess water penetration plus the already groundwater will increase the water pressure in the ground and activate seepage flow in the soil. Seepage reduces the stability of the slope by making it easier to slide between each other. An increase of moisture content in soil will reduces the soil shear strength and thus decreases slope safety (Akmal, 2006).

1.2 Objective

The objectives that we have to achieve at the end of this research are:

i. To produce slope stability analysis for Maran Highway slope using slope/W software.
ii. To propose a method to improve ground stability at Maran Highway slope.

1.3 Scope of study

The study is focused on the use of the slope/W software (by GEO-SLOPE) to analyze the probability of failure of a slope. The minimum factor of safety will be computed or calculated by the software using the several parameters and values from the soil investigation reports data. The data consists of soil investigation report is gathered from the Kump. IKRAM Sdn. Bhd. (IKRAM) for the case study area. Maran Highway has been selected as a case study which is located at the middle of Pahang Darul Makmur state. The location of Maran is shown in Figure 1.1.

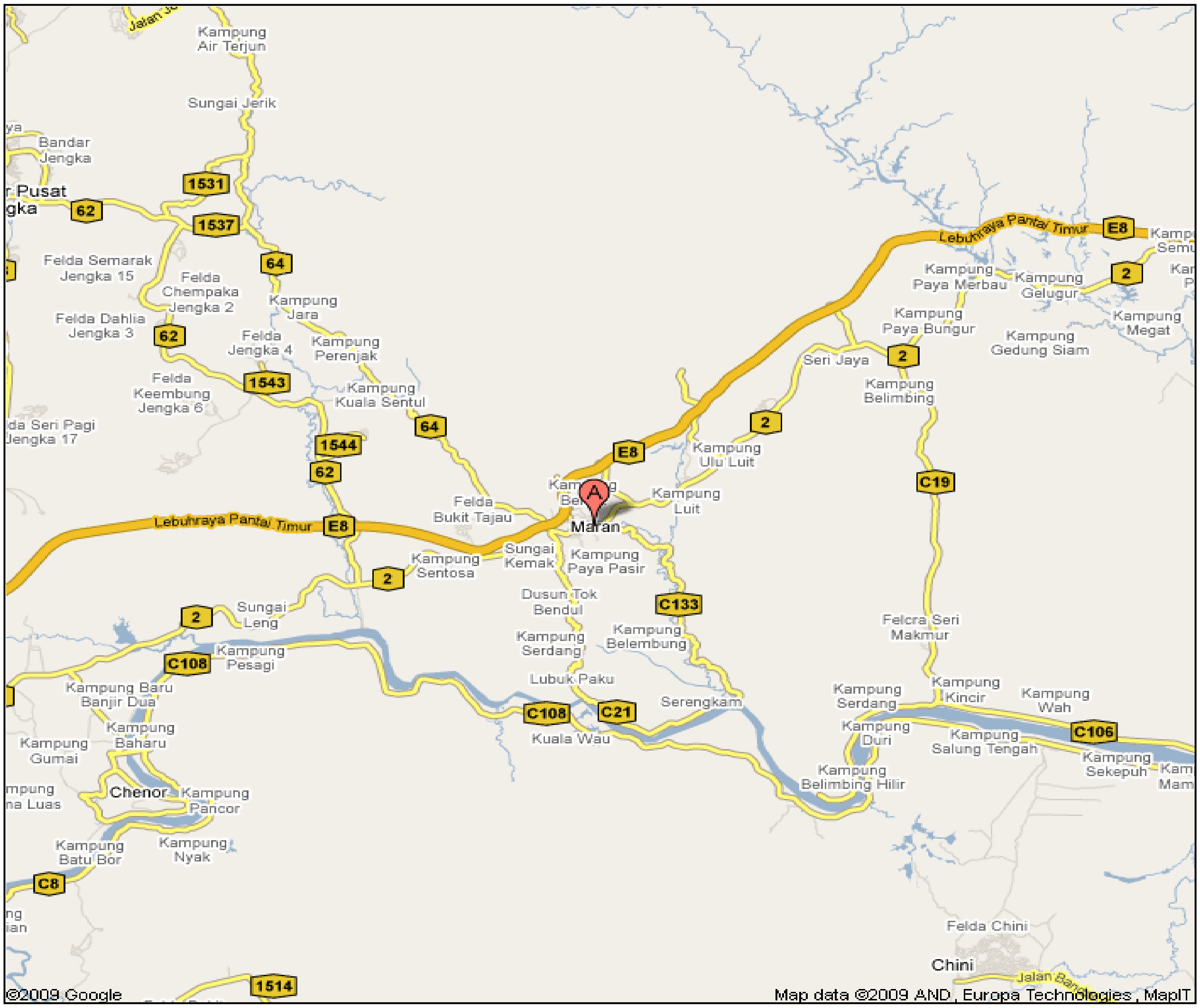

Figure 1.1: Location of Maran (www.googlemaps.com)

1.4 Importance of study

The understanding towards geotechnical engineering especially in slope stability can help civil engineers and geologists when entering the field site. Civil engineers must able to understand and analyze the stability of slope in order to provide the better construction industry in future without harmful. Slope stability analyses and stabilization require an understanding and evaluation of the processes that govern the behavior of slopes. Fail to deal with the slope behavior will leads to the serious matter. Better understanding of the slope including the degree of slope-cut, the type of soil and even the factor that can affect the soil strength is required to offer the suitable analysis so the engineer can counter the slope failure problem.

1.5 Problem statement

Slope stability is a challenging task for the civil engineer to solve it. Analysis of slope stability is carried out to minimize the occurrences of slope failure or landslide. Slope along the highway which have been experiencing deep excavations are very vulnerable to slope failure and thus landslide. Thus, the initial soil investigation has to be done properly in order to achieve the actual soil condition for the certain place where we want to start construction. The slope stability analysis has to be mentioned strictly because it will determine whether the slope is safe to live in. The data we collected from IKRAM Sdn. Bhd. (IKRAM)) can be used in calculating the factor of safety using the appropriate software.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The developments in soil and rock mechanics have triggered the evolution of slope stability analyses in geotechnical engineering. Our concern about certain matters regarding to slope failure must be slimmed out by a proper or best slope analysis to avoid it from happen frequently. Refer to Das (2007), an exposed ground surface that stands at an angle with the horizontal is called unrestrained slope. Slopes occurrences can be categorized in two major: naturally or engineered by humans. Slope stability problems have been faced throughout history when men and women or nature has disrupted the frail balance of natural soil slopes.

The first outward sign of slope instability is usually a tension crack in the ground behind the crest of the slope, sometimes accompanied by slumping of the soil in front of the crack (Felix, 2003). The rate of failure is generally fairly slow, developing over a period of hours to days. For the front part of this chapter, review about investigation of slope instability including classification systems that available and factors contributing to instability will be discussed.

However, the constructions at hilly region (cut and fill) have to be carried out in order to satisfy the human demand or needed due to the short of space. Thus, the need to understand analytical methods, investigate tools, and stabilization methods to solve slope stability problems must be achieved. Able to reach the high understanding of slope stabilization method can guaranteed the stability of slope itself.

An understanding of geology, hydrology, and soil properties is central to applying slope stability principles properly. Analyses must be based upon a model that accurately represents site subsurface conditions, ground behavior, and applied load. Judgment regarding acceptable risk or factors of safety must be made to assess the result of analyses.

Slope failures are usually precipitated by a variation in conditions, such a change in rainfall, drainage, loading or surface stability due to plant removal. Some changes may occur immediately after the construction, or it will take several or even decade of years to slowly occurs, or they may imposed suddenly at any possible time.

In the analysis of both cut and built slopes it is necessary to consider both immediate and long-term stability condition. It is also necessary to consider whether failure is likely along a newly created slip surface, or along the pre-existing one, since the difference between the peak and residual shear strength in some soils may be considerable (Roy, 2001).

2.2 History of slope analysis development

The deterministic analysis of slope stability basically involves the calculation of factor of safety for trial slip surfaces and the search for a slip surface with the minimum or critical factor of safety. The factor of safety calculation can be based on a wide range of methods, dependants on the likely mode of slope failure and the user's option (Felix, 2003).

One of the earliest analyses which are still used in many applications involving earth pressure was proposed by Coulomb in 1773. According to Felix (2003), Coulomb idea on produce solution approach for earth pressure against retaining walls used plane sliding surfaces, which was extended to analysis of slope in 1820 by Francais.

Beyond 1840, experience with cuttings and embankments for railways and canals in England and France show that many failure surfaces in clay were not plane, but significantly curved. Later, there are reports regarding the curved failure surfaces from the failure of pier structures in Sweden around the year of 1916.

In analyzing these failures, cylindrical surfaces were used and the sliding soil mass was divided into a number of vertical slices. The procedure is sometimes referred to as the "Swedish method of slices". By mid 1950's further attention was given to the methods of analysis using circular and non-circular sliding surfaces. In recent years, numerical methods have also been used in the slope stability analysis with the rapid development of computer hardware and software (Felix, 2003).

2.3 Movement in natural and artificial (man-made) slopes

In all slopes there exists an inherent tendency to degrade to a more stable form (ultimately towards horizontal) and in this context instability is constructed as the tendency to move, and failure as an actual mass movement (Roy, 2001). The main forces that lead to the instability are both gravity and seepage, while there is resistance towards the failure consequential mainly from a combination of slope geometry or shape and the shear strength of the soil or rock mass itself.

Mass movement can we defined as the result of a shear failure along an internal surface or when there are general decreases in effective stress between particles. Some types of the movement (failure) have been observed; three (3) classes to be considered:

2.3.1 Falls

These are characterized by movement away from existing discontinuities, such as joints, fissures, steeply-inclined bedding planes, fault planes, etc. and within which the slope failure assisted or precipitated by the effects of water or ice pressure (Roy, 2001). Figure 2.1 shows the example of falls.

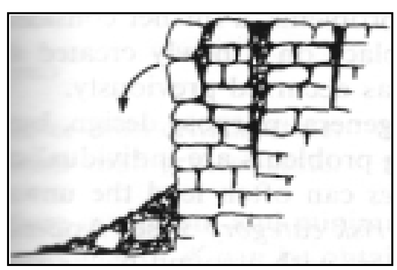

Figure 2.1: Falls (Roy, 2001)

2.3.2 Slides

In this form of movement, the mass remain basically intact while sliding along a definite failure surface. This form consists of two structural sub-divisions:

(a) Translational slides happen when there is linear movement of rocks blocks along soil layer or surface lying near to the (sloping) surface (Roy, 2001). These movements are normally fairly shallow and parallel to the surface as shown in Figure 2.2.

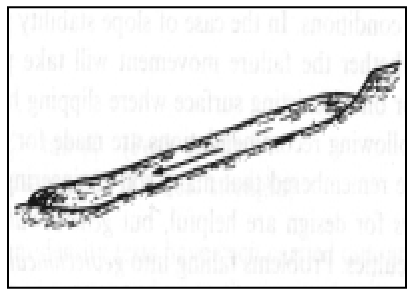

Figure 2.2: Translational Slide (Roy, 2001)

(b) Rotational slips occur in homogeneous soft rocks or cohesive soils. The movement takes place along the curved shear surface in such a way that the slipping mass slumps down near the top of the slope and bulges up near the toe (Roy, 2001). Detail of this mode of movement can be seen in Figure 2.3.

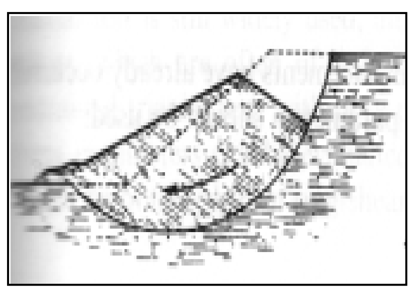

Figure 2.3: Rotational Slide (Roy, 2001)

2.3.3 Flows

The soil at surface moves partially or wholly as a fluid. The flowing mass often exists in weak saturated soils when the pore pressure has increased plus decreasing the shear strength of soil (Roy, 2001). The example of this flow mode is shown in Figure 2.4.

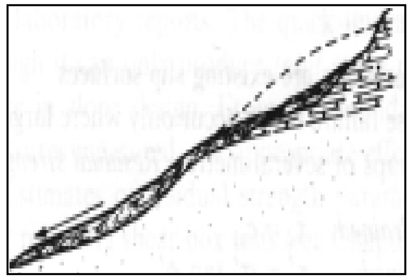

Figure 2.4: Flow (Roy, 2001)

2.4 Classification of slope failure

Landslides, slips, slumps, mudflows, rock falls, are some of terms that are normally used to describe the movement of slopes under the influence of gravity. In view of the wide scope or range of different ways in which these movements can occur, a system of description and classification is required, so that all individual can describe in standard or uniform parameters. Besides that, it is also important so the technical literature is consistent.

There are too many classifications system that are available. Varnes (1978) classification system, which takes in account types of movement and types of material, is illustrated in Table 2.1. Table 2.2 enables the user to know the major parts/ factors of the movement, including the movement form, failure surface form (arc, planar, etc.), mass coherency, constitution and failure cause. As addition, Figure 2.2 has classified the form of slope failure in terms of the velocity of the movement.

Felix (2003) found that major source of difficulty with these schemes is the limited terminology which can be used to describe different types of mass. This may gives a different assumptions or analysis on the various results from different practitioners but there are also have are very close similarity. The classification system can avoid the problem of the slope failure by reduce the large gap of unsimilarity between each system. Below are the notable schemes of classification system which have different perspective or evaluation for certain slope failure or movement of soil mass;

Table 2.1: Varnes Classification System (Felix, 2003)

Type of movement			Type of material		
			Bedrock	Engineering soil	
				Predominantly coarse	Predominantly fine
Falls			Rock fall	Debris fall	Earth fall
Topples			Rock topple	Debris topple	Earth topple
Slides	Rotational	Few units	Rock slump	Debris slump	Earth slump
	Translation		Rock block slide	Debris block slide	Earth block slide
		Many units	Rock slide	Debris slide	Earth slide
Lateral spreads			Rock spread	Debris spread	Earth spread
Flows			Rock flow (deep creep)	Debris flow (soil creep)	Earth flow (soil creep)
Complex			Combination of two or more principle types of movement		

Table 2.2: A classification of slope failure (Felix, 2003)

Type	Form	Definition
Falls	Free fall	Sudden dislodgement of single or multiple blocks of soil or rock which fall in free descent.
	Topples	Overturning of a rock block about a pivot point located below its center of gravity.
Slides	Rotational or slump	Relatively slow movement of an essential coherent block (or blocks) of soil, rock, or soil-rock mixture along some well-defined ach-shaped failure surface.
	Planar or translational	Slow to rapid movement of an essential coherent block (or blocks) of soil or rock along some well-defined planar failure surface.
	Subclasses • Block glide • Wedges • Lateral spreading • Debris slide	 • A single block moving along a planar surface. • Block or blocks moving along intersecting planar surface. • A number of intact block moving as separate units with differing displacement. • Soil-rock mixture moving along a planar rock surface.
Avalanches	Rock or debris	Rapid to very rapid movement of an incoherent mass of rock or soil-rock debris wherein the original structure of the formation is no longer discernible, occurring along an ill-defined surface.

Type	Form	Definition
Flows	Debris, sand, silt, mud, soil	Soil or rock-soil debris moving as a viscous fluid or slurry, usually terminating at distances far beyond the failure zone: resulting from excessive pore pressure. (subclassed according to material type).
Creep		Slow, imperceptible down slope movement of soil or soil-rock mixtures.
Solifuction		Shallow portions of the regolith moving down slope at moderate to slow rates in Artic to sub-Artic climates during period of thaw over a surface usually consisting of frozen ground.
Complex		Involves combinations of the above, usually occurring as a change from one form to another during failure with one form predominant.

Table 2.1 shows the classification system produces by Varnes which is mentioned the type of material for each kind of movement. The definition of the type and its form (slope failure) are shown at Table 2.2 above. While Figure 2.5 illustrated about the velocity of movement of the slope failure.

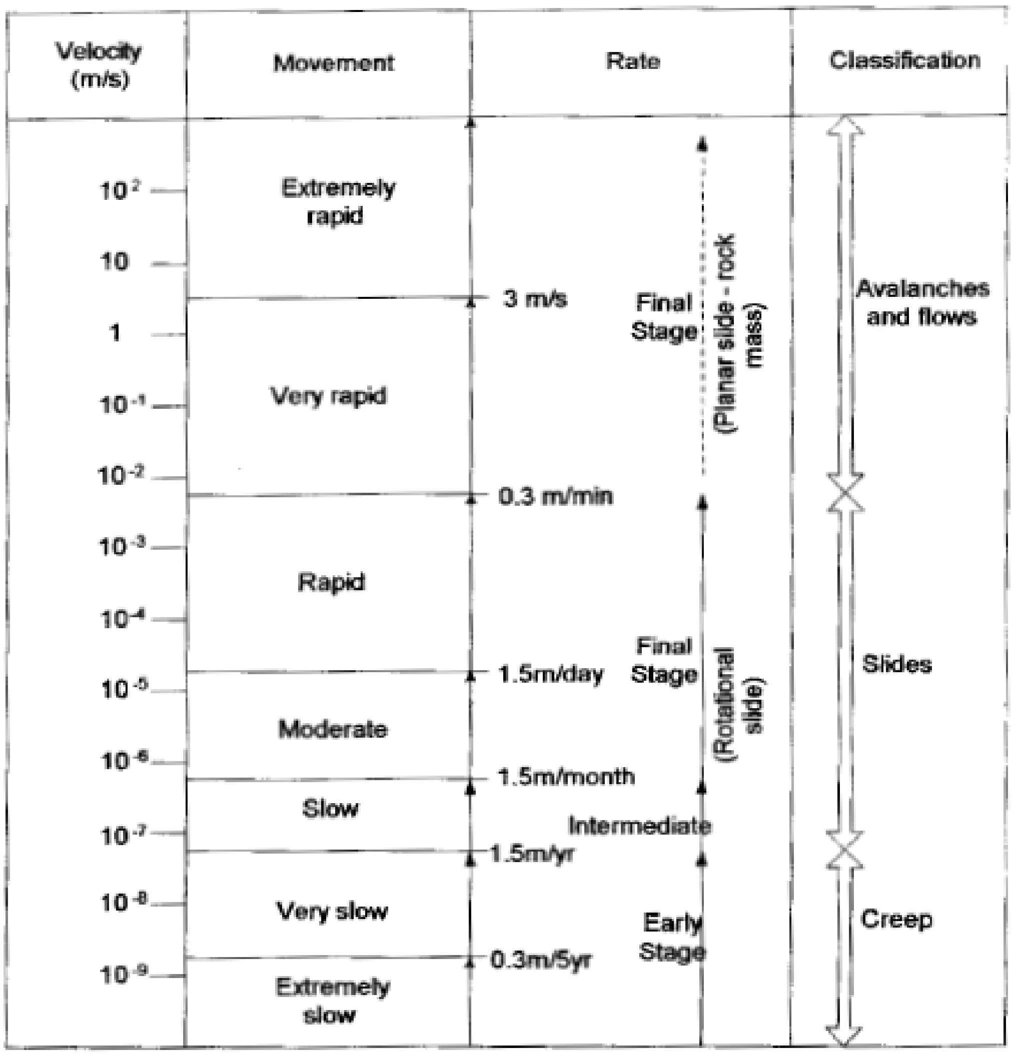

Figure 2.5: Velocity of movement of slope failure (Felix, 2003)

The type of movement; from extremely slow into extremely rapid; and its rate plus its classification can be seen in Figure 2.5.

2.5 Causes of slopes failure

Slope failures are caused, in general, by natural forces, human misjudgment and activities, and burrowing animals. Below are several causes which act as the most contributors in the slope matter:

2.5.1 Erosion

Water and wind continuously erode natural and man-made slopes. Erosion may change the geometry of the slope. Erosion may not take its result in quickest way. This erosion process has ultimately resulting in slope failure or, more appropriately, a landslide.

From Figure 2.6, it shown the slope has been steepen by the action of erosion. This situation may occur when there are surface runoffs due to excess water on a slope that cannot be absorbed into the soil or trapped on the surface. The amount of runoff can be increased if infiltration is reduced due to soil compaction, crusting or freezing. River and streams continuously scour their banks undermining their natural or man-made slope. Figure 2.7 below visualize the action of river and stream to the banks.

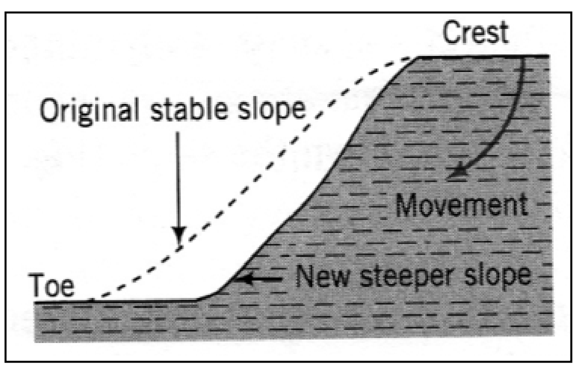

Figure 2.6: Steepening of slope by erosion (Budhu, 2000)

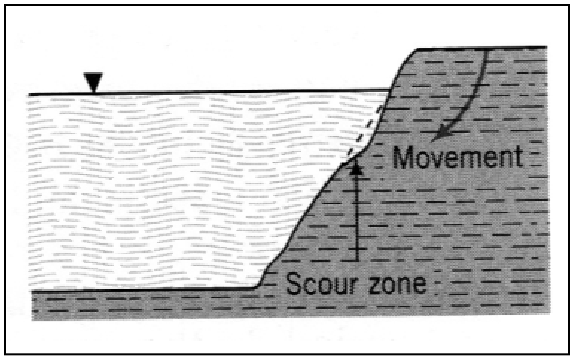

Figure 2.7: Effect of rivers and streams (Budhu, 2000)

2.5.2 Rainfall

Slope is inactive during dry times and become active during or following extended periods of infiltration or penetration from rain. Long periods of rainfall saturate, soften, and erode soils by referring to Figure 2.8. Waters enter into existing cracks and may weaken underlying soil layers, leading to failure, for example mud slides (Budhu, 2000). The excess of water will activate the seepage thus decrease the shear strength of soil. Water holds a major role in soil strength. Excess in water that enters the soil voids will reduces friction, while too little presence of water can increase cohesion. With our country receives a huge mass of rainfall volume, no wonder certain area will become vulnerable into failure.

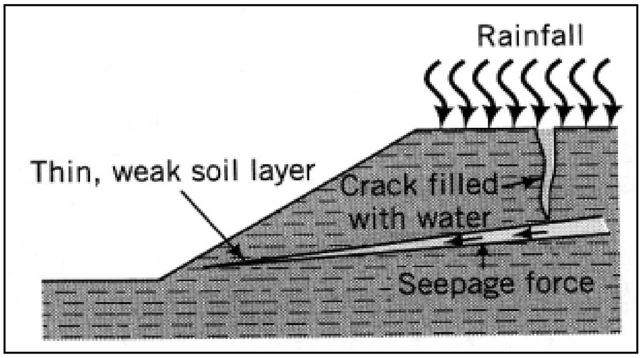

Figure 2.8: Effect of rainfall (Budhu, 2000)

2.5.3 Earthquakes

Earthquakes induces dynamic forces (example in Figure 2.9), especially dynamic shear forces that reduce the shear strength and stiffness of the soil. Pore water pressure in saturated coarse-grained soils could rise to a value equal to the mean stress and cause these soils to behave like gluey or viscous fluids which this phenomenon called dynamic liquefaction.

Structures founded on these soils would collapse; structures buried within them would rise. The quickness which only takes several seconds in which the dynamic forces are induced prevents even coarse-grained soils from draining the excess pore water pressures (Budhu, 2000). Thus, failure in a seismic event occurs under undrained condition.

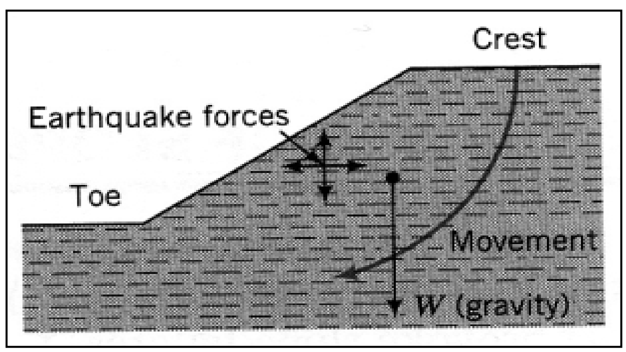

Figure 2.9: The earthquakes forces give effect on the stability of slope (Budhu, 2000)

2.5.4 External Loading

Loads places on the crest of a slope (the top of the slope) add to gravitational load and may cause slope failure. From Figure 2.10, the external loading will increase the height of slope and produce the failure. A load placed at the toe, called a berm, will increase the stability of the slope. Berms are often used to remediate slope problems.

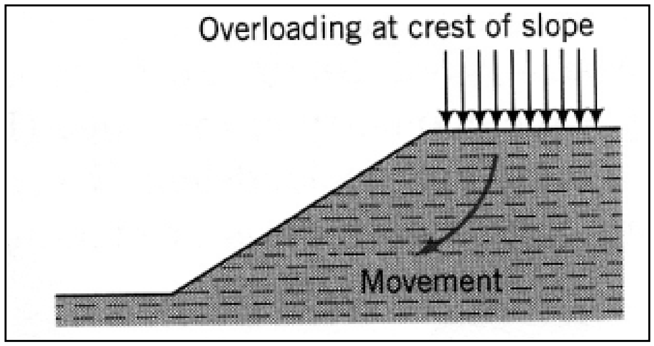

Figure 2.10: External loading places at the top (Budhu, 2000)

2.5.5 Geological Features

Many failures commonly result from unidentified geological features. A thin seam of silt (a few millimeters thick) under a thick deposit of clay can easily be overlooked in drilling operations or one may be careless in assessing borehole logs only to find later that the presence of the silt caused a catastrophic failure (Budhu, 2000). Sloping, stratified soils are prone to translational slide along a weak layer (Figure 2.11). Thus, the beneath understanding towards geological features in assessing slope stability must be increased first.

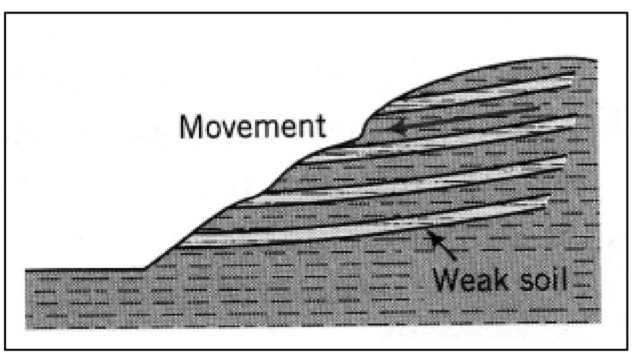

Figure 2.11: Effect of geological feature; soil stratification (Budhu, 2000)

2.5.6 Construction Activities

As stated by Budhu (2000), failure of slope can occur whenever there are constructions activities are held near the toe of an existing slope because lateral resistance is removed. The effect for this process is shown at Figure 2.12. Civil engineers can expediently divide slope failures due to construction process into two cases. The first case is excavated or cut slope and the second case is fill slope.

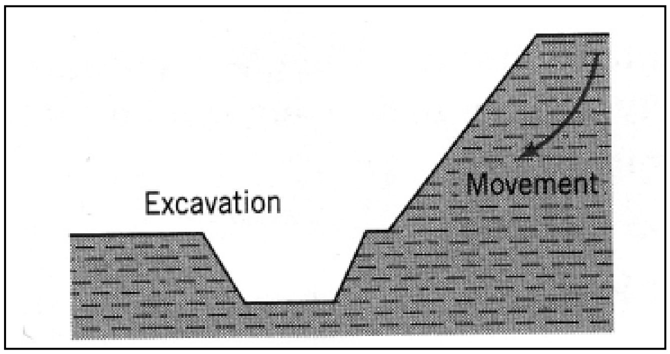

Figure 2.12: Effect of excavation at toe of slope (Budhu, 2000)

2.5.6.1 Excavated Slopes

When excavation occurs, the total stresses are reduced and negative pore water pressures are generated in the soil. With time the negative pore water pressure dissipate, causing a decrease in effective stresses and consequently lowering the shear strength of the soil (Budhu, 2000). If slope failures were to occur, they would take place after the construction is completed.

2.5.6.2 Fill Slopes

Fill slopes are common in embankment construction. Fill (soil) is placed at the site and compacted refer to some specifications, usually greater than 95% Proctor maximum dry unit weight (Budhu, 2000). The soil invariably unsaturated and negative pore water pressures develop.

The soil on which the fill is placed, which calls the foundation soil, may or may not be saturated. If the foundation soil is saturated, then positives pore water pressures will be generated from the weight of the fill and the compaction process.

The effective stresses decrease and therefore the shear strength decreases. With time the positive pore water pressure dissolve the effective stresses and shear strength of the soil both increase (Budhu, 2000). Thus, slope failures in fill slopes are likely to occur during or immediately after construction.

2.5.7 Rapid Drawdown

Reservoirs can be subjected to rapid drawdown. In this situation the lateral force provided by the water removed and the excess pore water pressure does not have enough time to dissipate (Figure 2.13). The net effect is that the slope can fail under undrained conditions. If the water level in the reservoir remains at low levels and failure did not occur under undrained conditions, seepage of groundwater would occur and the additional seepage forces can produce failure (Budhu, 2000). The visualization of the rapid drawdown can be seen in Figure 2.14.

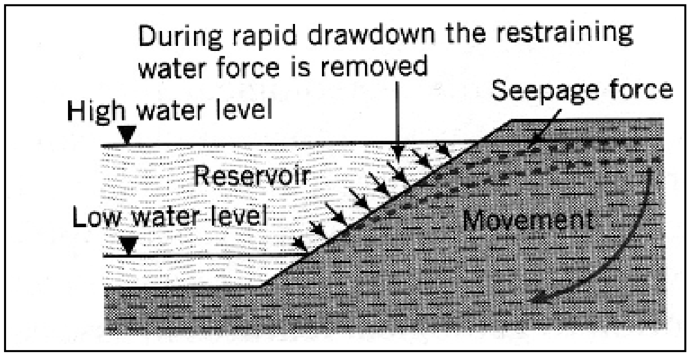

Figure 2.13: Effect of rapid drawdown (Budhu, 2000)

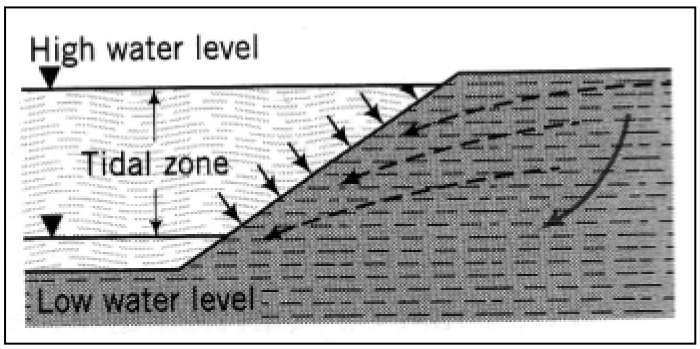

Figure 2.14: Effect of groundwater seepage (Budhu, 2000)

2.6 Factors Contributing To Slope Failure

It is important to understand the agents of instability in slopes. The reason of the deeply understanding towards the factors is because for the purpose of the designing and constructing a new slopes. Significantly, able to anticipate the changes in the properties of the soil within the slope that may occur over time and the various loading and seepage conditions to which the slope will subjected over the course of its life.

Slope failures are often caused by process that increase shear stresses or decrease shear strengths of the soil mass. Processes that most commonly cause a decrease in the shear strength of slope materials are listed in Table 2.3. Processes that most commonly cause an increase in the shear stresses acting of the slopes are listed in Table 2.4.

Table 2.3: Factors decreasing shear strength in slopes (Lee *et al.*, 2002)

Factors	Causes
Factors inherent in the nature of the materials	• Composition • Structure • Secondary or inherited structures • Stratification
Changes caused by weathering and physiochemical activity	• Wetting and drying processes • Hydration • Removal of cementing agents
Effect of pore pressure	• No specific causes
Changes in structure	• Stress release • Structural degradation

Table 2.4: Factors increasing shear stresses in slopes (Lee *et al.*, 2002)

Factors	Causes	Examples
Removal of support	Erosion	• Stream and river • Glaciers • Action of waves or marine currents • Successive wetting and drying
	Natural slope movement	• Falls • Slides • Settlements
	Human activity	• Cuts and excavation • Removal of retaining walls or sheet piles • Drawdown of bodies of water
Overloading	Natural causes	• Weight of precipitation • Accumulation of materials because of past landslide
	Human activity	• Construction of fill • Buildings and other overloads at the crest • Water leakage in culverts, water pipes and sewers
Transitory effect	Natural causes	• Earthquake

Factors	Causes	Examples
Removal of underlying materials (act as support)	Natural causes	• Rivers or seas • Weathering • Underground erosion due to seepage
	Human activity	• Excavation or mining • Loss of strength of the underlying materials
Increase in lateral pressure	Natural causes	• Water in cracks and fissures • Freezing of the water in the cracks • Expansion of clays

2.7 Basic Concepts Applied To Slope Stability

The discovery of the principles of effective stress by Terzaghi in 1920s marks the beginning of modern soil mechanics (Lee *et al*, 2002). This concept is very relevant to problems associated with slope stability. Consider three principal stresses, σ_1, σ_2, and σ_3, at any point in a saturated soil mass and let *u* be the pore water pressure at that point. Changes in the total principles caused by a change in the pore water pressure *u* (also called the neutral stress) have practically no influence on the volume change or on the stress conditions of failure. Compression, distortion, and a change of shearing resistance result exclusively from changes in the effective stresses, σ_1', σ_2', and σ_3', which are defined as

$$\sigma_1' = \sigma_1 - u \tag{2.1}$$

$$\sigma_2' = \sigma_2 - u \tag{2.2}$$

$$\sigma_3' = \sigma_3 - u \tag{2.3}$$

Therefore, changes in *u* lead to changes in effective stresses.

Slope masses have a propensity to slide due to shearing stresses in the soil by gravitational and other forces (like water flow, tectonic stresses, seismic activity and etc.). This propensity is resisted by the shear strength of slope masses expressed by Mohr-Coulomb theory (Figure 2.15) as

$$S = c + \sigma_n \tan \phi \tag{2.4}$$

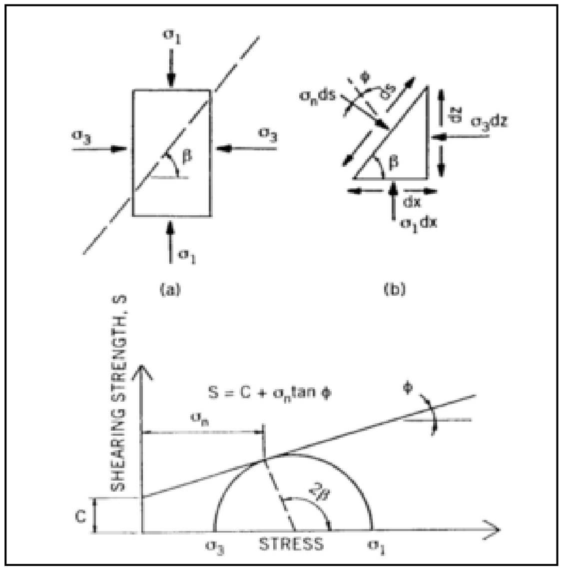

Figure 2.15: Mohr-Coulomb envelope: (a) Soil element (b) Stress vectors (c) Shear strength (Lee *et al.*, 2002)

where S = total shear strength of the soil

c = total cohesion soil

σ_n = total normal stress

Φ = total angle of internal friction

In terms of effective stresses,

$$S' = c' + (\sigma_n - u) \tan \phi' \qquad (2.5)$$

where S' = drained shear strength of the soil

c' = effective cohesion

σ_n = normal stress

u = pore water pressure

ϕ' = angle of internal friction in terms of effective stress

Practically all slope stability analyses are based on the concept of limit equilibrium (Figure 2.16). In the equation

$$\tau = S / FOS \tag{2.6}$$

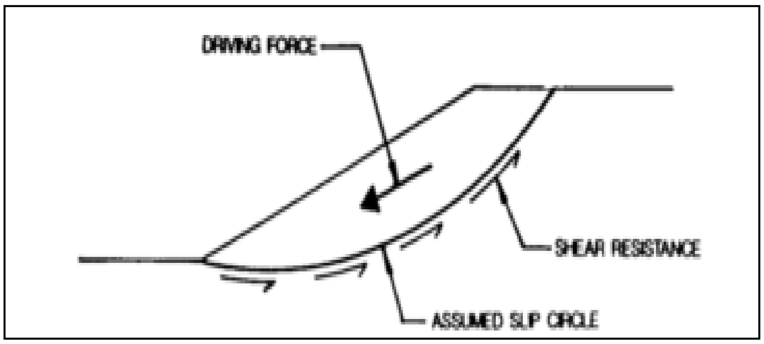

Figure 2.16: Geometry used in slip circle analysis (Lee *et al.*, 2002)

Where τ = shearing stress along the assumed failure surface

S = shear strength of the soil

FOS = factor of safety

A state of limit equilibrium is assumed to exist when the shearing resistance along an assumed failure surface (slip circle) equals the shear strength of the soil, or in other words, when FOS equals unity. The determination of c – Φ shear strength value is made by field investigations and laboratory testing.

2.8 Method of Slices

Felix (2003) stated that simple sliding models fall into category of limit equilibrium method. In the method of slices, soil mass above the slip surface is divided into wedges or slices. Table for various assumptions is shown below.

There are not fixed to say that this method is an exact one because there are more unknowns than equilibrium equations. This requires that an assumption have to be made concerning the interslice forces (Felix, 2003).

Table 2.5: List of commonly used method of slices: assumptions concerning interslice forces for different method of slices (Felix, 2003)

Type of Method of Slices	Assumption concerning interslice forces	Reference
Ordinary Method of Slices	Resultant of the interslice forces is parallel to the average inclination of the slice.	Fellenius (1936)
Bishop simplified method	Resultant of the interslice forces is horizontal (no interslice shear forces)	Bishop (1955)
Janbu simplified method	Resultant of the interslice forces is horizontal (a correction factor is used to account for interslice shear forces)	Janbu (1968)
Janbu generalized method	Location of the interslice normal force is defined by an assumed line	Janbu (1957)

	of thrust	
Type of Method of Slices	**Assumption concerning interslice forces**	**Reference**
Spencer method	Resultant of the interslice forces is of constant slope throughout the sliding mass	Spencer (1967, 1968)
Morgenstern-Price method	Direction of the resultant of interslice forces is determined by using a selected function	Morgenstern and Price (1965)

Table 2.6: Characteristics of equilibrium methods of slope stability analysis (Felix, 2003).

Method	Characteristics
Slope Stability Charts (Janbu 1968; Duncan	• Accurate enough for many purpose • Faster than detailed computer analyses
Ordinary Method of Slices	• Only for circular slip surfaces • Satisfies moment equilibrium • Does not satisfy horizontal or vertical force equilibrium
Bishop’s Modified Method	• Only for circular slip surfaces • Satisfies moment equilibrium • Satisfies vertical force

	equilibrium • Does not satisfy horizontal force equilibrium
Method	**Characteristics**
Force Equilibrium Methods	• Any shape of slip surfaces • Satisfies all conditions of equilibrium • Permits side force locations to be varied • More frequent numerical problems than some other methods
Janbu's Generalized Procedure of Slices	• Any shape of slip surfaces • Satisfies all conditions of equilibrium • Permits side force locations to be varied • More frequent numerical problems than some other methods
Morgenstern and Price's Method	• Any shape of slip surfaces • Satisfies all conditions of equilibrium • Permits side force orientations to be varied
Spencer's Method	• Any shape of slip surfaces • Satisfies all conditions of equilibrium • Side force are assumed to be

	parallel

2.9 Slope/ W

Slope/W is leading stability software product for computing the factor of safety of earth and rock slopes. Slope/W enable the user to analyze both simple and complex problems for a variety of slip surface shapes, pore-water pressure conditions, soil properties, analysis methods and loading conditions.

Using limit equilibrium, slope/W can model heterogeneous soil types, complex stratigraphic and slip surface geometry and variable pore-water pressure conditions using a large selection of soil models.

Slope stability analyses can be performed using deterministic or probabilistic input parameters. Stresses computed by a finite element stress analysis are may be used in addition to the limit equilibrium computations for the most of complete slope stability analysis available.

Through this comprehensive assortment of features, slope/W can be used to analyze almost any slope stability problem that will encounter in the geotechnical, civil and mining engineering projects.

The unique CAD-like technology in slope/W is able to create the geometry by drawing it on the screen. A DXF format picture can even imported to assist, and then choose an analysis method, specify soil properties and pore-water pressures, define reinforcement loads and create the trial slip surfaces (Amar, 2007).

The slope/W Full License is a unlimited version with complete full-featured software. It includes all command names contained in the full-featured edition. Many slope/W commands supported in the Full License and creating of slope simulating analysis become easier. Essentially, this version can use to:

i. Analyze problems with two different soils plus a bedrock layer.

ii. Describe soil using a total unit weight (γ), cohesion (c) and/ or a friction angle (ϕ).

iii. Specify pore-water pressure conditions with one piezometric line.

iv. Examine circular and non-circular slip surfaces.

v. Compute factors of safety using six different methods of slices.

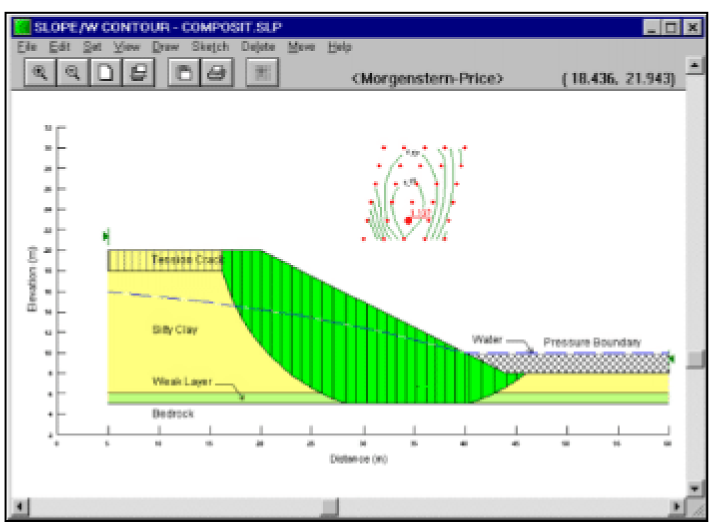

Figure 2.17: The model produce from analyzing using slope/ W software

2.10 Factor of Safety

In essence, the satisfactory FOS is dependent on combination of economic risk and risk to life deemed acceptable. Although no specific guidelines on acceptable figures for the FOS for slope designs are universally adopted in local practices, the simplified classification of risk to landslide for hill site development and recommendation by Institution of Engineers, Malaysia (IEM) were referred.

Referring to IEM recommendation the failed slope is classified as high risk of landslide is as follow:

i. Total height of slope > 15m
ii. Global angle of slope > 27°

The Geotechnical Control Office of Hong Kong, 1984 which experiences similar tropical soil condition as in Malaysia, has provided same basic guidelines as in Table 2.8 and 2.9 below. The recommended value of safety factor depends on the types of slopes which are new slopes, existing slopes and natural slopes. According to Amizatulhani *et al.* (2007), although a factor of safety of 1.5 is generally the minimum value for new construction, a lower factor of safety may be acceptable due to the deep-rooting plants will increase the long term surficial stability of the slope.

Table 2.7: Recommended factor of safety for existing slopes (Amizatulhani *et al.*, 2007)

Risk to life	Negligible	Low	High

Factor of safety	> 1.0	1.1	1.2

Table 2.8: Recommended factor of safety for new slopes (Amar, 2007)

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

Below is the comparison between two (2) analyses gathered from the past and previous researcher:

Table 2.9: Comparison of two (2) slope analyses by different researcher

Researcher	**Location**	**Type of analysis**	**FOS**
Amizatulhani *et al*. (2007)	Kuala Lipis, Pahang	Software slope/W	Upper slope; 1.609, 1.641 and 1.886 (different remedial measure and existence of groundwater)
			Lower slope; 1.470, 1.667, 1.441 and 2.146 (different remedial measure and existence of

			groundwater)
Hamdan *et al*. (2007)	KL-Karak Highway, Pahang	Remote sensing data	< 1.0

From the comparison of these two types of analysis, the slope/ W analysis can produced more accurate value. It also produce ground improvement element that needed when to remodel the selected slope. Remote sensing data can cover more wide area by using a satellite. Combined with the required parameters, this type of analysis can involved into the geotechnical practice, especially in highway slope stability specializes.

Analysis of slope failure at Maran Highway using Slope/W

(Annas Robani b Aminudin : AA06080)

Table of Content

No.	Table of content
2.1	Introduction
2.2	History of slope analysis development
2.3	Movement in natural and artificial (man-made) slopes
2.4	Classification of slope failure
2.5	Causes of slopes failure
2.6	Factors Contributing To Slope Failure
2.7	Basic Concepts Applied To Slope Stability
2.8	Method of Slices
2.9	Slope/ W software
2.10	Factor of Safety

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter shows the flow of the methodology for the Final Year Project. There are three phases of methodology applied in this research. For the first part, the research reviewing after the discussion of title and determines of objectives. This part required the collection of information and knowledge from the reliable resource (related to the scope of project) and the last person that had performed the similar research. In addition, this reviewing process enable researcher to deeply understand about the scope of this case study before continuing to the next phase.

For the next phase, it is more about the gathering the materials for the Chapter 1 until Chapter 3. The materials then can be categorized into two types; which is primary and secondary revision. The primary revision can be collect from the books and journal while secondary revision is from the internet.

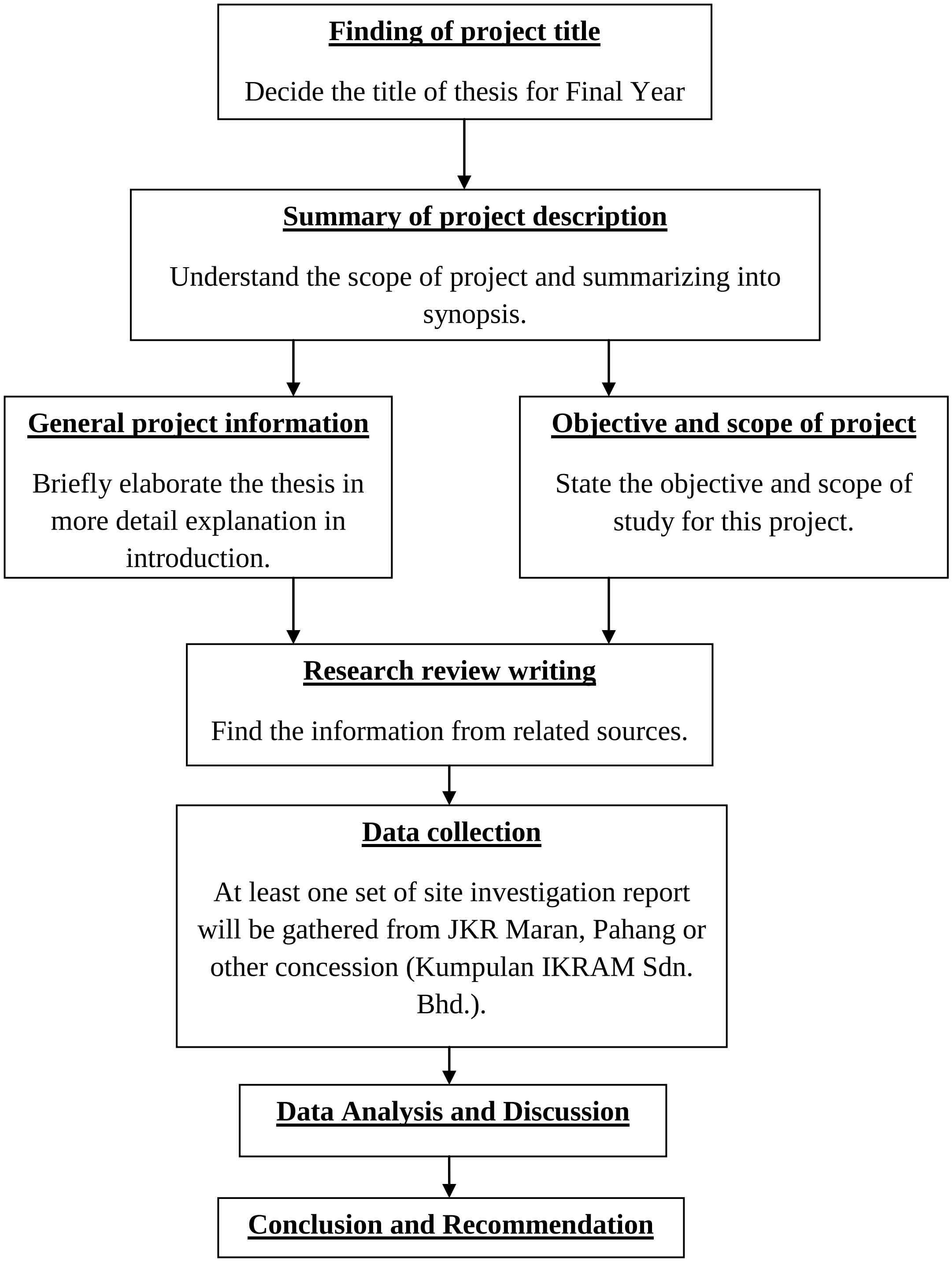

Figure 3.1: Flow of Methodology in Final Year Project

3.2 Finding of Project Title

The main thing before getting through this Final Year Project is choosing the title related to the civil engineering field. Geotechnical Engineering have been part of the civil course and it can help to endure the matter regarding to soil and slope in our country. In order to get the suitable title based in current knowledge and study, discussion with the supervisor is being held.

3.3 Summary of Project Description

Description of Final Year Project was been summarized into synopsis which briefing generally the scope of study, the problem statement, the objectives and also the important of the scope of case study. This role of this stage is in giving general information about the overall of the thesis.

3.4 General Project Information

Introduction of this thesis is described by related the title of the thesis to the current issues in the country. The location of this thesis also was described generally to give a view about the site location. Normally for the introduction, it is almost elaborations towards the development of the country and also the general important that relate to the title of this thesis. Introduction also important to describes detail about the title to give information about the scope of work for this Final Year Project.

3.5 Objective and Scope of Project

The objective has been stated in order to ensure the target of this thesis is achieved successfully. The scope of project act as a boundary which means the project is still remains in one scope and not out of it. All of these objectives are effect on the outcome of the result. Because of that objectives of the thesis are very important to ensure our scope of work was being conducted in order to achieve the objectives.

3.6 Research Review Writing

Literature review is refer to existing facts, data or others existing or previous research that related to thesis that been carry out. This review writing stages needs a deeply understanding towards the research with an assists from the reliable sources and materials. This stage will give an idea of what the research is talk about. The important of the research review writing is to gather the supportive data that related to our research. The related data were being collected from many sources which been categorized in two (2) types; primary and secondary sources. Materials such as books, journals, and past thesis report can be classified into primary sources. While internet, magazines and others can be known as secondary sources.

However, for this thesis, there are many parts in the literature review that give detail information for certain things such origin of soil, soil structure, consistency of soil and others. All of the data gathered is from different sources, different perception and opinion that been summarizing after review all of these sources.

3.7 Data Collection

Before running the analysis stages, the data collection must be obtained. For the slope analysis, the soil investigation reports at the case study area have to be gathered. The report or data will be collected from the JKR Maran & Kumpulan IKRAM Sdn Bhd (IKRAM). The report gathered have the parameters required for the analysis. At least one soil investigation report must be gathered for the selected area around the Maran Highway.

3.8 Data Analysis and Discussion

From the soil investigation reports, analysis of the data can be carried out. The data gathered are encompassing information such as total unit weight (γ), cohesion (c) and/or a friction angle (ϕ). To generate the slope analysis, the slope/W software is needed to remodel the existence slope. From the analysis, the new model of slope stability will be produced and suggestion remedial measure has to been made. The factor in chosen the remedial measure is according to its strength, quality and cost.

3.9 Conclusion and Recommendation

Conclusion is one of the important things for each of the thesis writing. This because conclusion is the final statement that briefly explains about the result and the achievement of the objectives. It also can be described as summarizing complex information to one simple paragraph or simple sentences. Conclusion statement for each the analysis and result data is also one of the important requirements.

CHAPTER 4

ANALYSIS & DISCUSSIONS

4.1 Introduction

Simulation modeling of slope stability is carried out to determine the stability of the slope at selected or specific location of Maran Highway. The simulation is created from software developed by Geostudio called ‘slope/W’. There are several parameters required to analyze this study for the selected slope which are total unit weight (γ), cohesion (c) and/ or a friction angle (ϕ).

All this parameters is gathered from the soil investigation (SI) report. The investigation is carried out at the KM 99 and 101, Lane 2, Kuantan – Kuala Lumpur road, Maran, Pahang Darul Makmur.

For this study, the Morgenstern and Price’s Method is choose to analyze and create a simulation for the slope profile. The results of stability analysis using slope/ W software are presented for this chapter in contour view. The properties for the ground layer beneath the slope are stated as table below:

Table 4.1: The soil properties for the selected slope

	Total unit weight (γ), kN/ m^2	**Cohesion (c), degree (°)**	**Friction angle (ϕ), kN/ m^2**
Ground layer	12	2	17

The analyses for the slope stability are divided into 4 cases, as stated below:

i. Case 1: Natural condition (without slope protection)
ii. Case 2: Slope stabilized using benching method
iii. Case 3: Slope stabilized using ground anchor
iv. Case 4: Slope stabilized using soil nailing

Although installing the slope protection (remedial measure) can improve the stability of the slope, continues maintenance works may ensure the slope remains stable. At the end of this chapter, there is some guidance for maintenance works to prevent the repaired slope from suffering another failure.

4.1.1 Case 1: Natural condition (without slope protection)

Original slope showed the exact shape of the chosen slope without remediation works (slope protection) towards the slope. The model is set to the mohr-coulomb. After analysis through the SI report, the number of layer for the soil can be assumed as one, which its properties have been noticed earlier. The Morgenstern and Price's method selected to run the slope stability analysis. This method can be used for any shape of slips surfaces and satisfied all conditions of equilibrium.

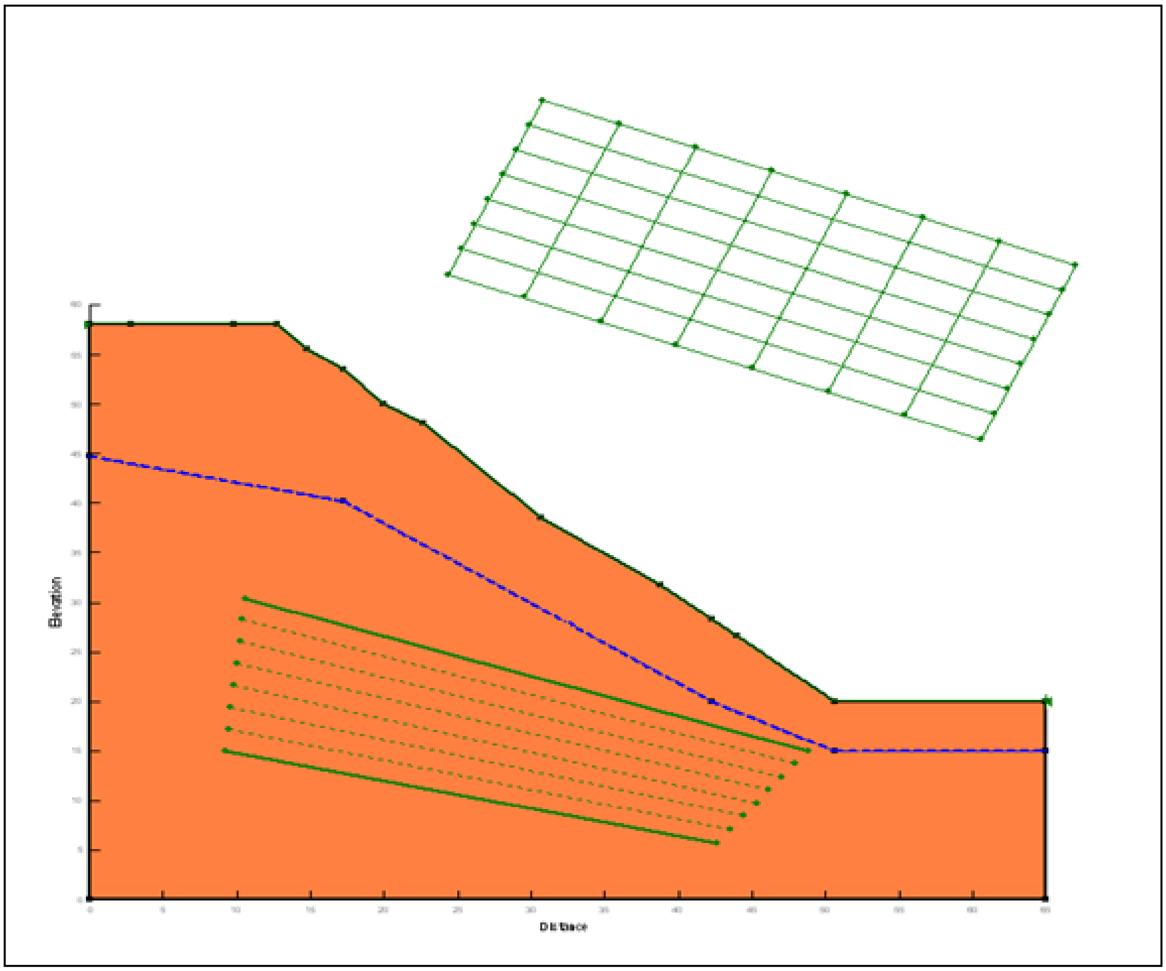

Figure 4.1: Default condition of slope generated using required software without the circular slip surface.

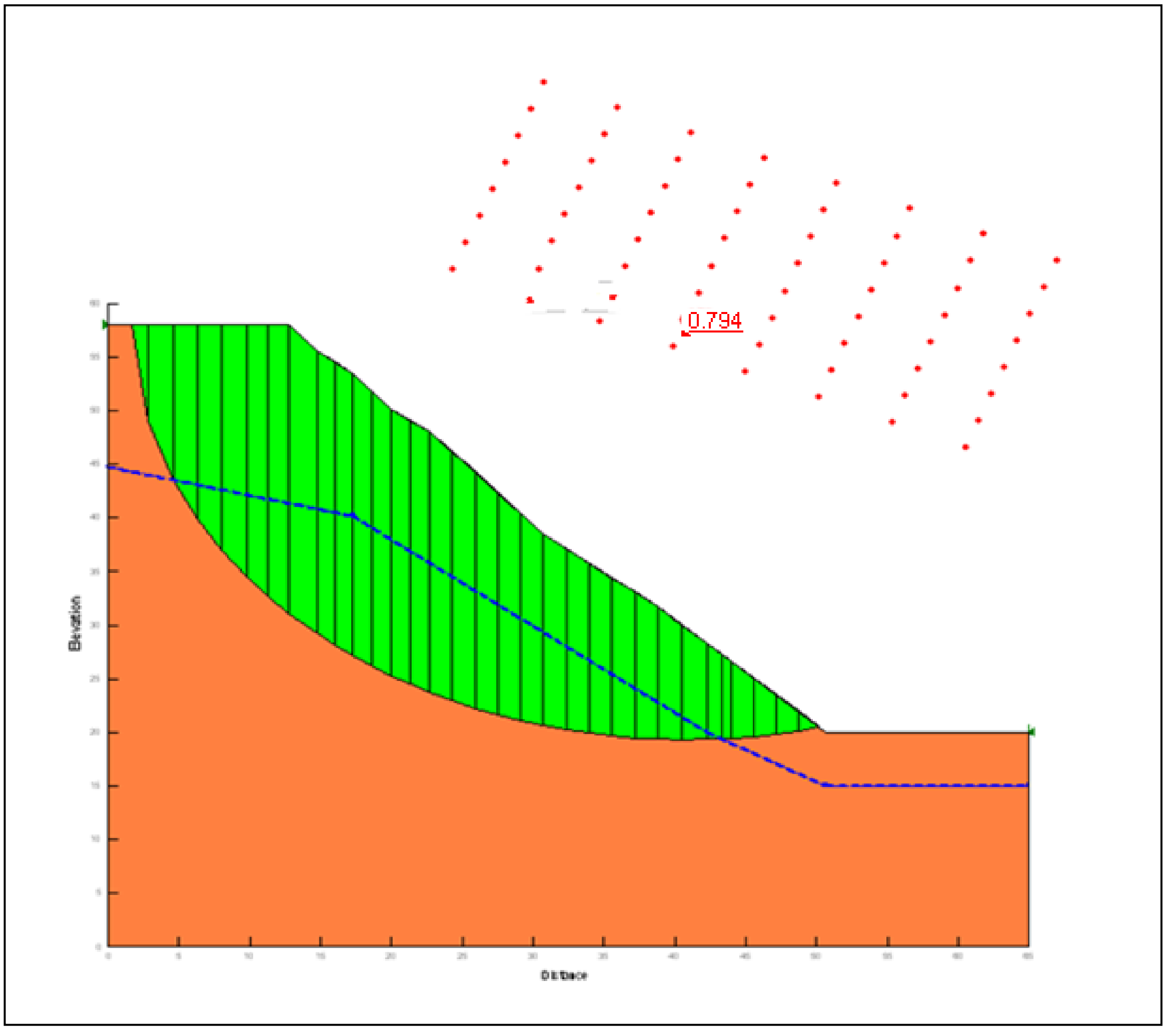

Figure 4.2: Picture shows the circular slip surfaces for the selected slope.

As the result for this case analysis referred to Figure 4.2, the factor of safety (by using Morgenstern and Price's) is 0.794, which it is not safe. The minimum of factor of safety required for stable slope by according to The Geotechnical Control Office of Hong Kong, 1984 must past the value of 1.00 and the slope can be considered safe enough for the future.

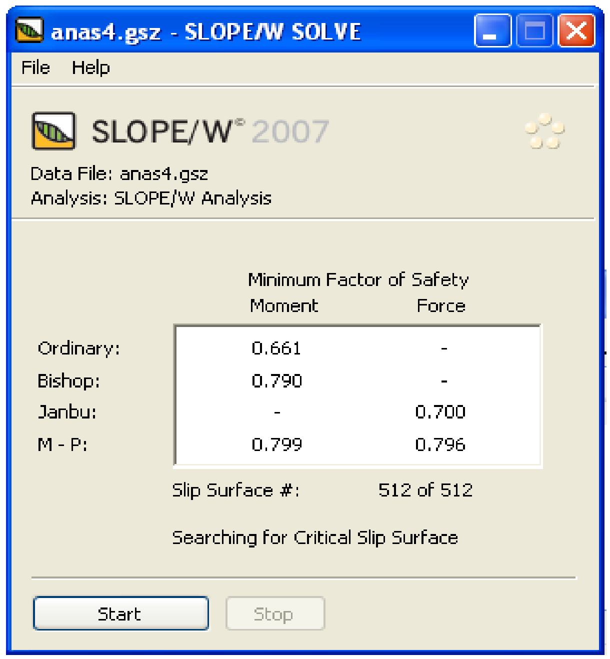

Figure 4.3: The value of FOS for Case 1.

Simulation analysis of slope stability at natural condition shows that the stability of the slope might be influenced by the pore water pressure. The result of the FOS for this case (as illustrated in Figure 4.3) proved that the slope condition is governed by the existence of water.

Slope angle might contribute towards the slope instability. According to recommendation of safe slope stated by Institution of Engineers, Malaysia (IEM), the angle of slope must not exceed 27°. For this slope, the angle of slope is quite high and steep, so the slope is prone to slide and fail. In Malaysia roughly received the huge amount of rainfall due to the effect of repeatal process of wetting and drying. This phenomenon increased the amount of excess water penetrates through the soil hence decrease the soil strength and decrease the slope stability.

4.1.2 Case 2: Slope stabilized using benching method

Benching or terracing act as one of the slope stabilization method. For this steep slope, applying this method by converted into a series of steps, with horizontally or nearly horizontal ledges, and vertical or almost vertical walls between the ledges. This method requires the cut and fill process, which it involves the usage of machineries including backhoe and truck.

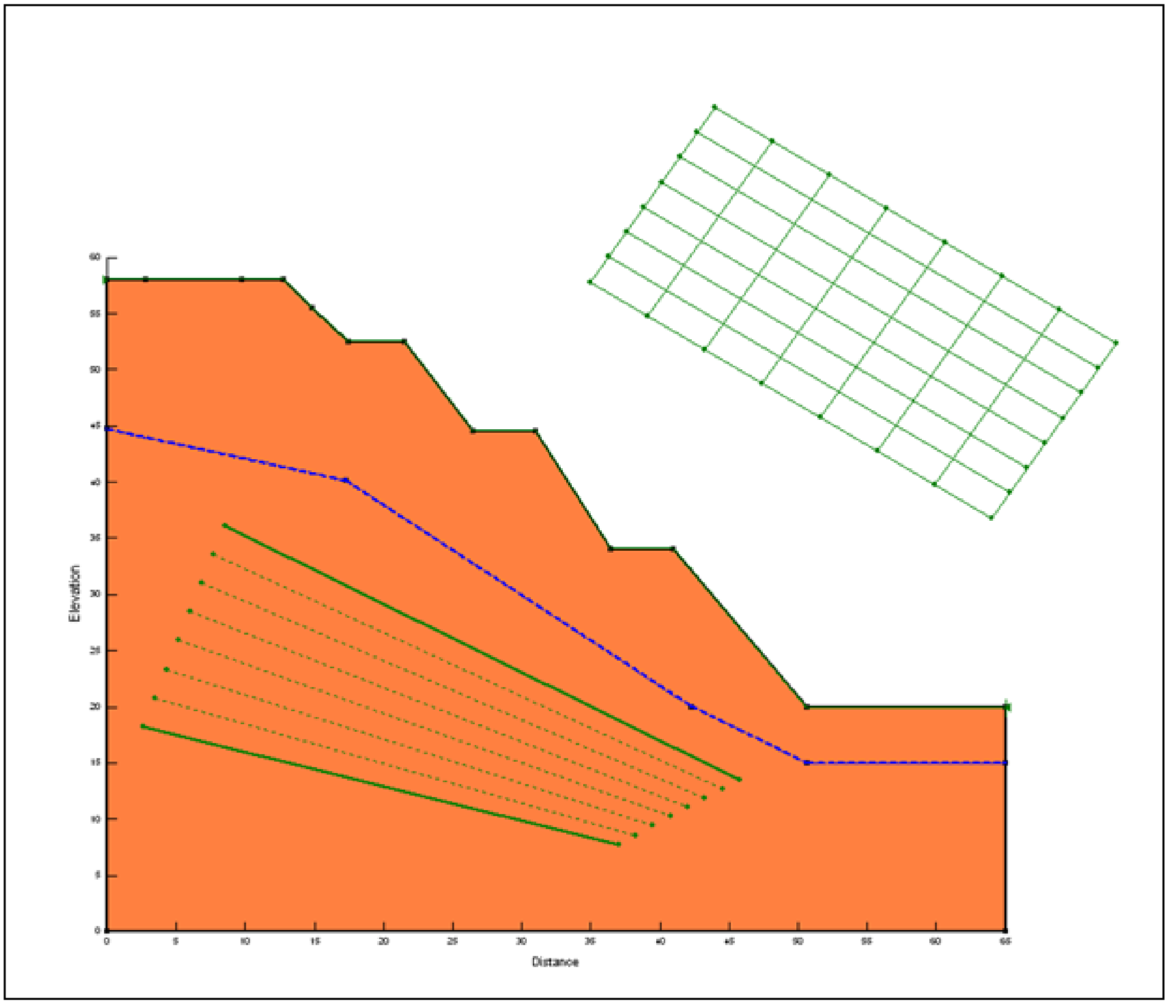

Figure 4.4: Benching method being applied to the slope.

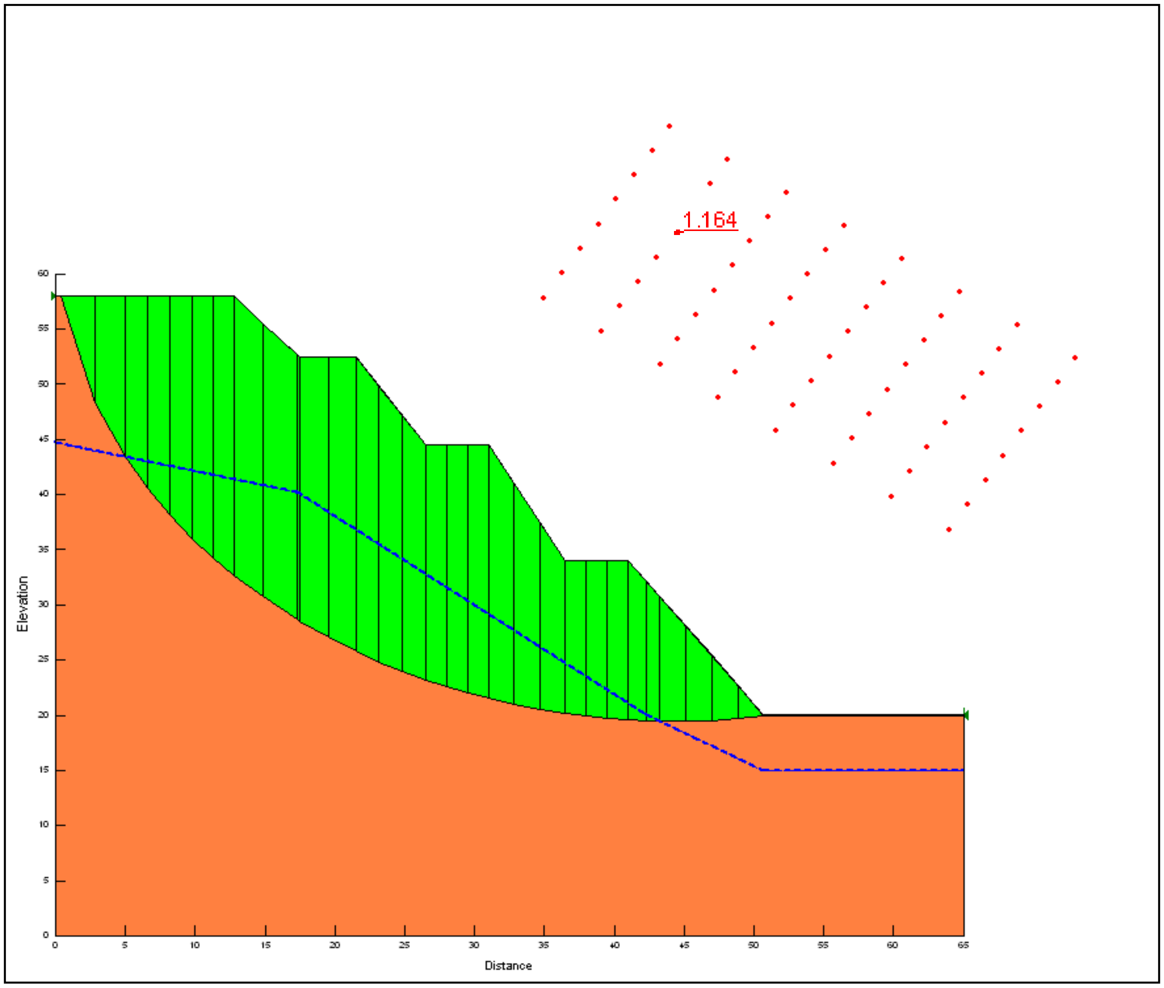

Figure 4.5: The figure proved there are improved in the value of FOS.

The value of FOS for Case 2 has increased from 0.794 into 1.164 that illustrated in Figure 4.5 and Figure 4.6. This result proved that when the slope protection is applied into the slope, it can improve the stability of the slope.

The application of benching and terracing can reduce the length and the degree of slope. After this slope protection being applied, the slope become slanting which means the slope angle has been decreased.

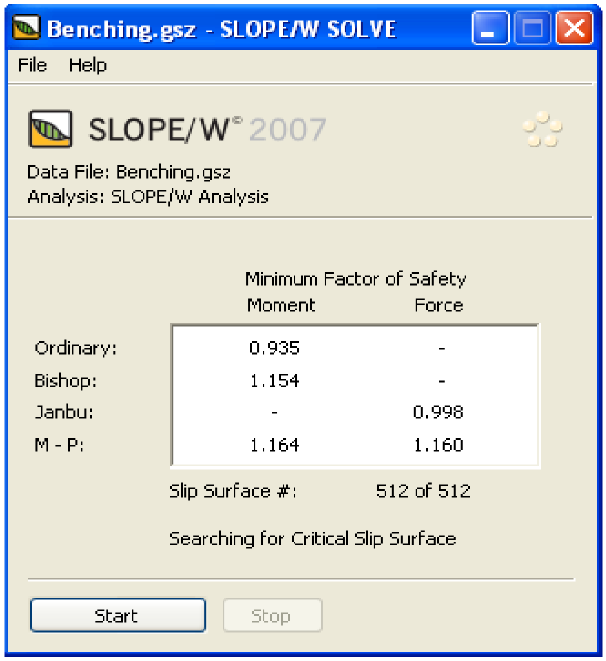

Figure 4.6: The FOS value for Case 2.

The fundamental of this method is to change the originality condition of the slope from the steep into the mild slope. By reducing the angle and the height of the slope, the velocity of surface runoff became slow.

While the surface runoff has been slowed, the excessive erosion of surface can be avoided, plus it can improve the strength of the ground layer surface. In order to produce a very stable slope, the walls (created from the benching method) can be held by vegetation, and in others some structural walls are necessary, as brick, stone or timber.

4.1.3 Case 3: Slope stabilized using ground anchor

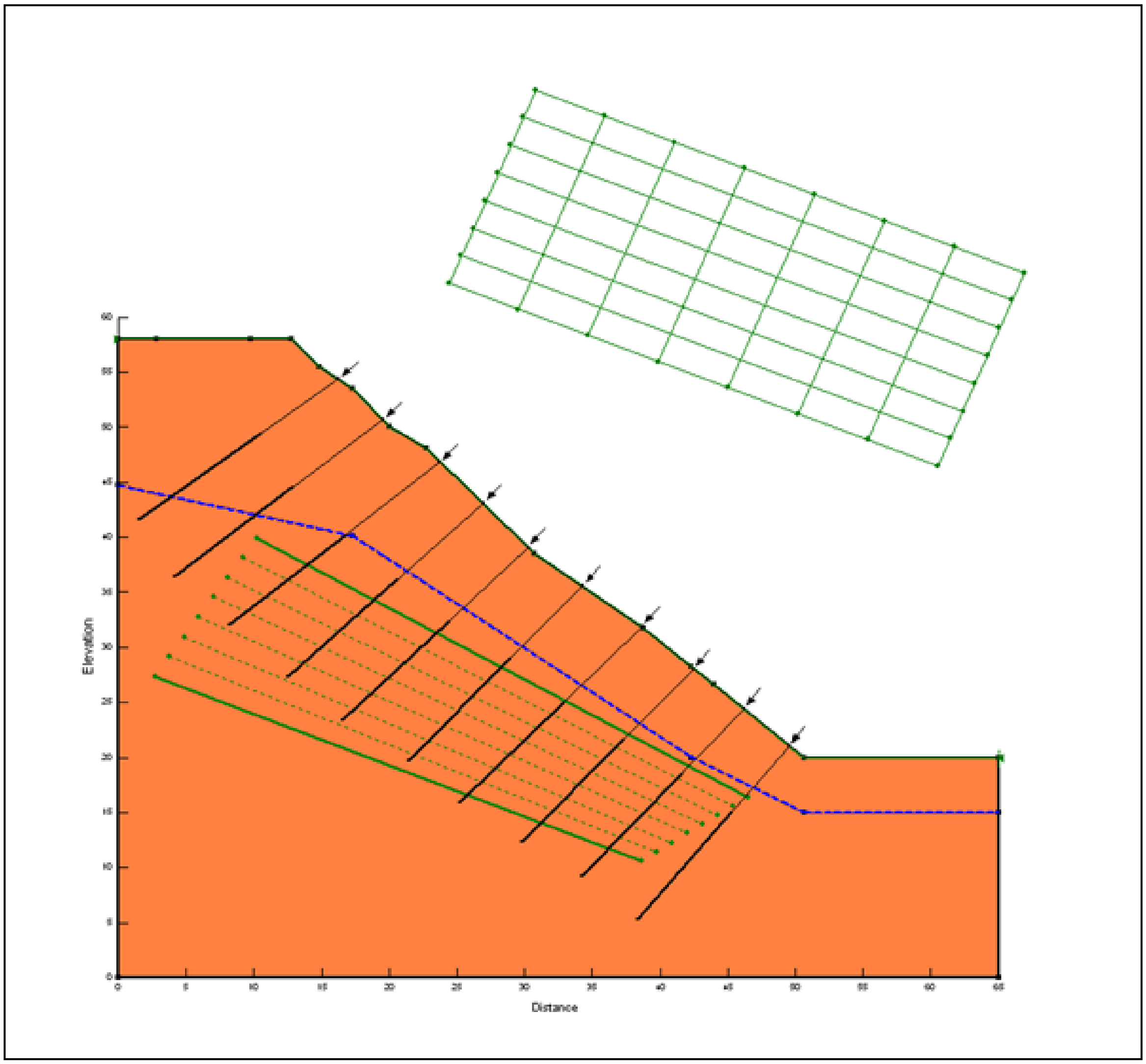

Figure 4.7: Implementation of anchor to improve the stability of the slope.

For this study, the number of anchor used to stabilize the unstable slope is 10, but adding a little more not just can improved the stability but also the cost will rise up. The gap between the anchors is around 2-5 meters. The average length for each ground anchor is around 25 meters.

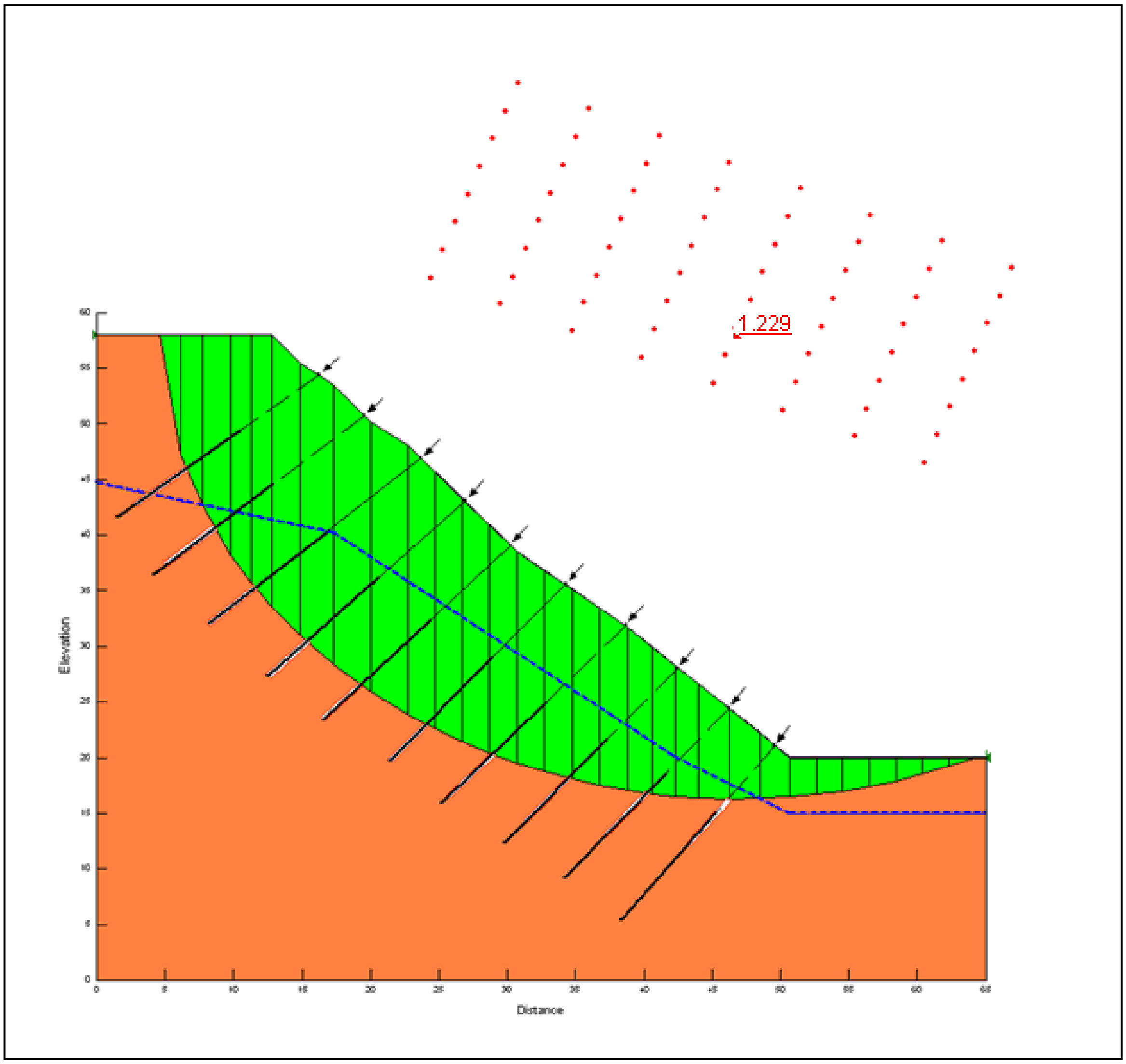

Figure 4.8: The value of FOS increased when applying the anchor.

From the analysis shows in Figure 4.8 and Figure 4.9, the value of FOS is 1.229. The result of analysis justified that this method is better than benching or terracing method in term of factor of safety. Although there is increment in the value of FOS, the other factor such as cost and price criteria if this method suits the budget plans.

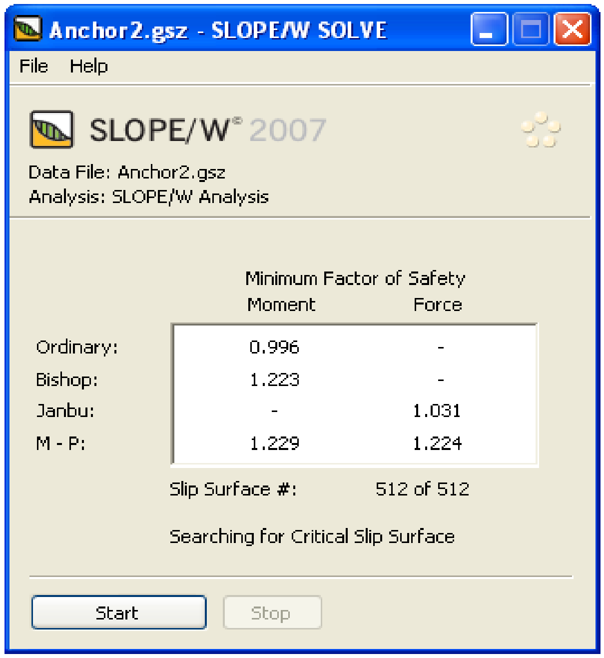

Figure 4.9: The value of FOS for Case 3.

The fundamental of using ground anchor in strengthen the slope condition is to prevent the circular slip surface from slide easily, hence lock down the soil. The skin friction occurred between the anchor and soil has decreased the probability for the slope to fail.

The end section of ground anchor that penetrates into soil beneath act as a lock between the upper layer of soil with lower layer. This kind of characteristic has given an extra grip for the slope towards the landslide.

4.1.4 Case 4: Slope stabilized using soil nailing

Basically, soil nailing consists of reinforcing the slope with reinforcement bars in drilled holes with cement grout until a block of soil mass is adequately formed to resist lateral earth pressure, sliding, overturning and bearing pressure and possess overall stability. The basic concept of soil nailing is to reinforce and strengthen the existing ground by installing closely-spaced steel bars, called 'nails', into a slope as construction proceeds from 'top-down'.

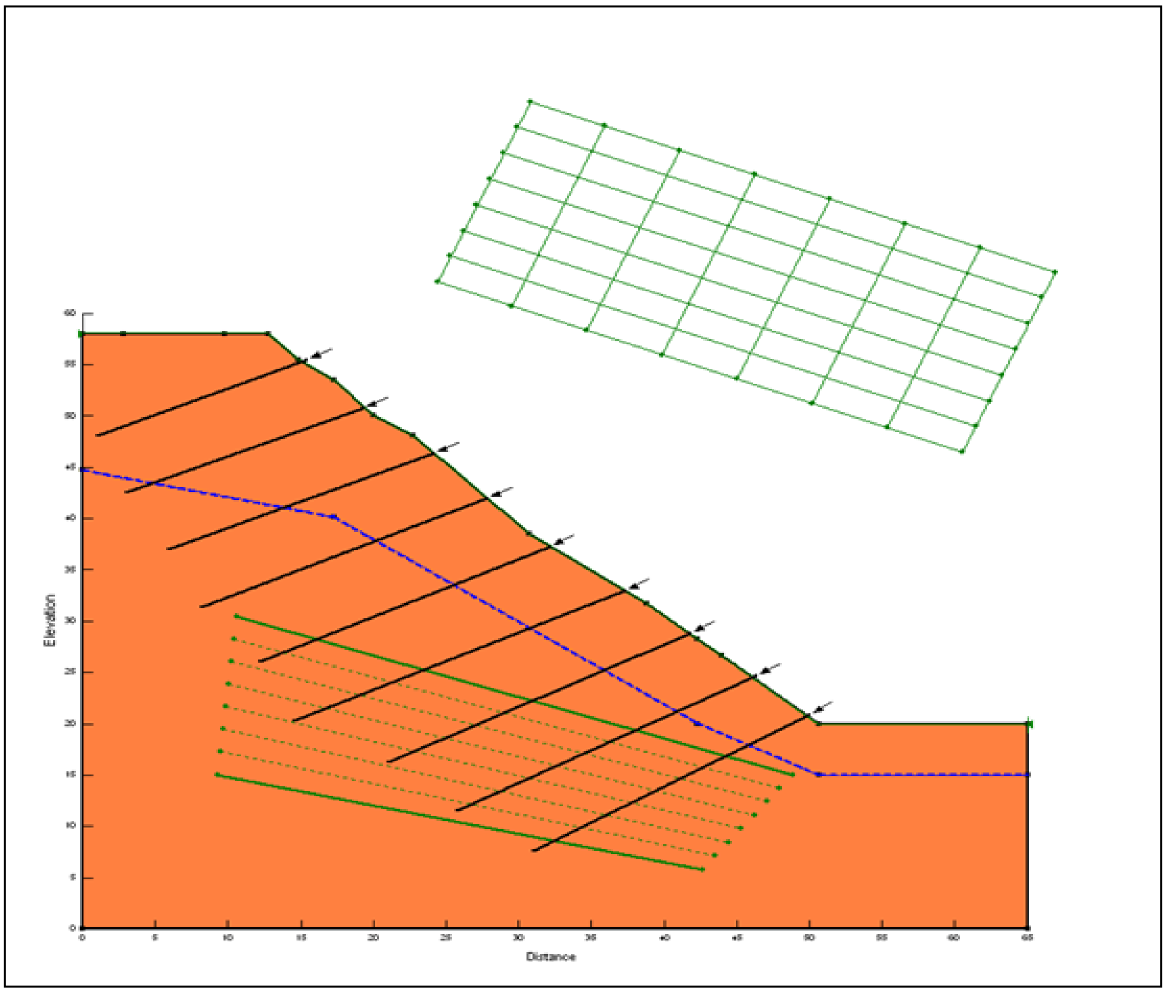

Figure 4.10: The soil nailing use as remedial measure (without circular slip surface).

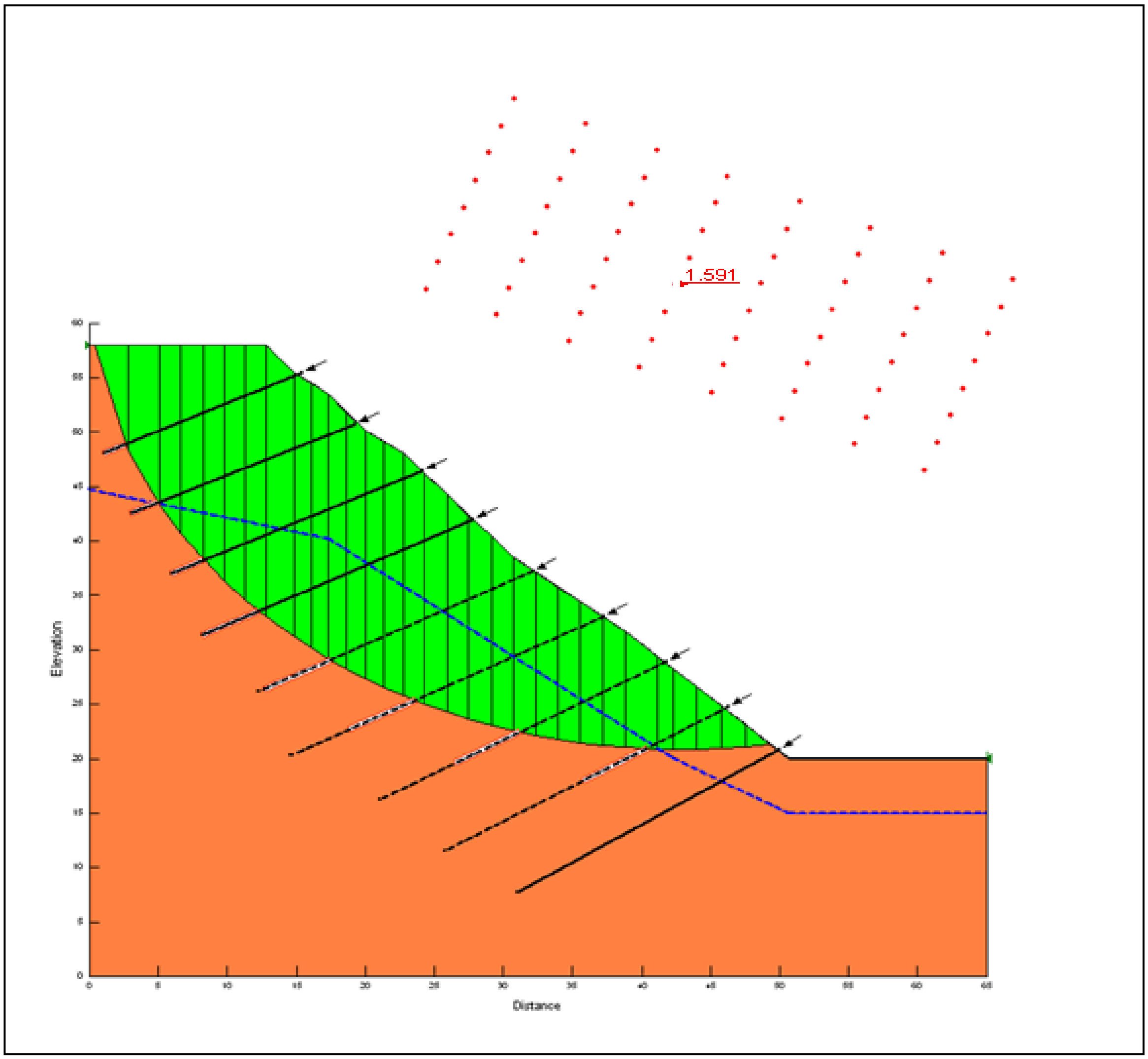

Figure 4.11: The diagram shows the circular slip surface for case 3; while the values of FOS increased.

As shown in Figure 4.11 and Figure 4.12, by using the Morgenstern & Price method, the value of FOS is 1.591. This method is the most enhanced slope protection when compared to the other previous method. The application of soil nailing must be followed by guniting, which is a process of spraying dry mix cement/sand mortar at high velocity on soil or rock surface of slopes.

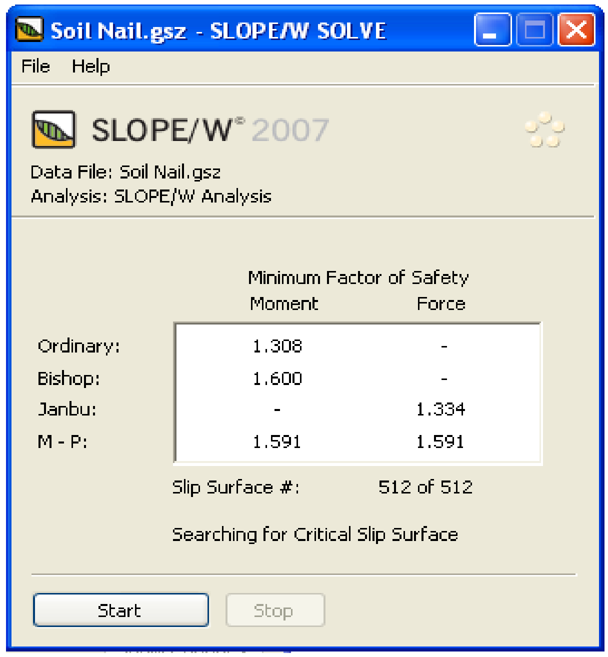

Figure 4.12: The highest FOS value achieved by soil nail method

Soil nail is commonly used in Malaysian slopes both as stabilization measure for distressed slopes and for very steep cut slopes. Soil nailing often finished by applying the thin mortar surface called gunite (continuous flow of mortal or concrete mixes projected at high speed perpendicularly onto the exposed ground surface). This add-ons can endure any excess water (obviously came from a rainfall) from penetrates into the soil beneath that can affect in soil strength.

Typically, soil nails are spaced at closed spacing to achieve immense soil-nail interaction within the soil mass for its reinforcement effect. For this study, 2m is used as the soil nail spacing to increase the durability towards the circular slip surface. Nail head give extra strength that is governed by the flexure or punching shear of the facings, and the nail head connections.

4.2 Results

Table 4.2: The factor of safety occupied for each types of method

Analysis Method	Case 1	Case 2	Case 3	Case 4
Ordinary	0.692	0.976	0.996	1.372
Bishop	0.789	1.154	1.223	1.600
Janbu	0.713	1.014	1.031	1.362
Morgenstern & Price	0.796	1.164	1.229	1.591
Percentage of increment (%)	0	46.23	54.44	99.87
Cost (Price)	-	RM41.44/ m^3	RM96/ ft^2	RM119/ ft^2
Overall estimated cost	-	RM250 000	RM450 000	RM700 000

From the table, in the perspective of Morgenstern & Price method and the method of slope protection, the highest FOS value is achieved by the Case 4 (soil nailing method) which is 1.591.

In contrast, the FOS value for Case 2 (benching & terracing method) is the lowest one with 1.164. While for the unprotective slope (Case 1), the value of FOS is 0.796 and this value do not pass the requirement for the stable slope.

The result for other method (ordinary, bishop and janbu) also shows the value of FOS is increased after the installation of slope protection have been made. As the value of FOS seems increased from Case 1 until Case 4, it gives the hints that the strength of the slope have improved. The improvement is measured in terms of percentage of increment, which are starts from the increment of 46.23%, 54.44% and lastly 99.87%.

For the comparison on the cost, the most expensive method is soil nailing method with the overall cost around RM700 000. The lowest value in term of price is achieved by the benching method for the estimated cost at the range of RM250 000 while for the moderate cost is owned by ground anchor method.

4.3 Analysis

The natural condition of the slope (Case 1) shows its strength and stability is weak and more prone towards the failure. The effect of external or excess water (mainly from the rainfall) that occurred in the soil ground is best influential factor in weaken the soil strength. This observation is generally accepted where as landslides on hill-site in Malaysia are always triggered by water. These included the Highland Towers, the Genting Sempah debris-flow and more recently, the Bukit Antarabangsa slope failures.

The external force such as the existence of excess water is one of the most contributors to landslides. The strength of the soil decreases rather rapidly under the action of the external force cause from the repeated seasonal of drying and wetting.

The soil properties also act as one of the main role in reducing the soil strength. For this study, the soil major group for the slope is clay. This kind of soil has an ability to gather or absorb more water compare to the other type of soil. Thus, as a result, the water penetration plus the already groundwater will increase the pore water pressure in the ground and activate seepage flow in the soil that weaken the stability of slope.

Thus, special treatment (remedial measure) is required to ensure the stabilization of the under-strength slope. In Case 2, benching or terracing method shows the improvement in the stability of the slope. The value of FOS has increased from 0.796 to 1.164 with the percentage of escalating around 46.23%. The cost estimated for the benching method is RM41.44 per meter cube while for the overall cost estimating, the cost is RM250 000.

When compared to Case 3, the stability of the slope seems safer than the Case 2. Anchor proved to be a decisive remediation step with the 1.229 in the value of FOS. The increasing percentage of this method is 54.44%. The overall cost for using the anchor as slope protection is higher than using a benching method (RM450 000).

Soil nailing is the most suitable method in produce a good strength support for the slope. The value of FOS is 1.591, the highest value compared to the other method. There is about 99.89% of percentage rising (in the value of FOS) and the huge margin shows the superiority of this method in developing or improving the unstable slope. While this method has advantages in repair the slope, it seems the cost is quite pricey. This method is expensive (RM700 000) and extra work such as guniting and drilling process can probably increased the price afterwards.

The results noticed that the natural condition must be repaired by using several slope protection methods. For this study, the benching, anchoring and soil nailing have been choose and all of the method have make the slope increase in its strength. Overall, the soil nailing method is best choice although the cost is a little bit expensive. The ability of this chosen method in produce immense interaction in skin friction (between nail and soil) that can hold and grip the slope from slide is the factor in selection of this method.

4.4 Discussion

The criterias in choosing the best or suitable remediating method is based on the safety and economical also the improvement in the value of FOS. Plus, the quality requirement must not be ignored because it will ensure the continuity towards slope stability for the long period.

The stabilization of certain slope for the long term phase is really important to consider while taking the remediation method. Maintenance is an adequate way as a follow up after the remediating method being installed. Improper maintenance work will act as a catalyst in leading into slope failure. For example, shallow failures due to surface erosions will deteriorate and if it is being left abandoned can generate consequent slope failure.

According to Amar (2007), there are several aspects, consider can give effect to slope performance through time, like deterioration of slope condition, progressive in slope deformation and possible changes in surrounding conditions as enhanced infiltration through a dilapidated hard surface cover, leakage from water carrying services should be carefully considered before one can confidently count on past performance in the use of the back analysis approach.

In particular, the use of the back analysis approach to derive mass shear strength parameters for designing upgrading works should be done with extreme caution where the replacement of a hard surface cover with a vegetated cover (Amar, 2007).

Thus, routine or daily inspections are required in order to ascertain the need for basic maintenance works. As addition, it should been carried out at least once a year to inspect any sign of slope failure.

All the needed maintenance works should also be finished before wet season to avoid from more difficult situation. The owner have the authority to hire worker for inspection task including looking out for the drainage channels and clear any blockages after heavy rainstorm or a storm to ensure the water flow is perfect.

Engineer inspection for maintenance is also needed to guarantee the slope is safe in geotechnical aspect or view. The depth inspection towards the slope must be handled properly by a qualified geotechnical engineer at least once every 5 years to detect any indication of slope stabilization. The geotechnical engineering will give advice on maintenance of the slope and any required improvement works.

There are several typical tasks to satisfy routine maintenance for each slope that should be carried out as recommended by Geotechnical Engineering Office, Hong Kong, as been attached at Appendix, are as follow:

i. Clear debris, undesirable vegetation and other obstructions.
ii. Clear any obstacle in weepholes and pipe ends
iii. Regrade eroded areas with compacted soil followed by re-planning
iv. Repaired cracked or spalled concrete surface and support.

Each slope can be classified as in safe condition only when it have been supervised and maintained in the correct way suggested by the Geotechnical Engineer.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIOS

5.1 Conclusions

From the results that successfully obtained from this study, the conclusions that can be stated are as follows:

i. The value of FOS for the Case 1 (natural condition) is 0.794 and this value cannot be classified as a stable slope. Hence, slope protection is needed to improve the stability of the slope.

ii. The instability towards the slope is most likely from the effect of excess water penetrates into the soil and decrease the strength of the soil itself. The water penetrates activate the seepage which lays down beneath the ground layer and make the slope more prone to slip easily.

iii. For Case 2, the slope stabilization using benching, produce an improvement in term of FOS. The value of FOS for this case is 1.164 with the percentage of increment about 46.23%. This method changes the steep slope into the mild slope by reducing the slope angle and height; means that it can reduces the velocity of surface runoff (produce erosion at slope surface).

iv. Case 3 shows the implementation of anchor into the slope in order to increase its stability. The result of this case is better than Case 2, which the FOS have been rise up into 1.229. The percentage of increment is 54.44%. The end section of anchor acts as a lock which holds down the soft layer with a firm layer; hence prevent the circular slip surface from slide easily.

v. The result from Case 4 concluded that soil nailing have produced the reliable value of FOS, 1.591. The result mentioned the soil nail usage increased the percentage of increment into 99.89%. This method produces immense soil-nail interaction within the soil mass for its reinforcement effect.

vi. If the criterion in choosing the suitable remediating method is based on the safety and economical, the soil nailing method is choose for this case study. The reason of proposed the soil nailing method are it is common use nowadays in Malaysia, plus ease in construction and relatively maintenance free. The fundamental in using this method is it will produce massive interactions between the soil mass and the reinforcement of the structure, hence grip the soil from slide.

5.2 Recommendations

i. Slope protection has to be installed at the KM 99 and 101, Maran, Pahang to guarantee the slope safe for people surrounding.

ii. Inspection and maintenance works must be carried out regularly (for the critical slope) to ensure its stabilization will last for the long period.

iii. Proper analysis and investigation towards the high risk potential of slope must be conducted to produce a suitable remediating process.

iv. For future study, gather the complete Soil Investigation report for the certain slope can produce more accurate result for the analysis.

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APPENDICES

DATA USED

APPENDIX A

Sample of summary of Laboratory Testing for KM 99 & 101, Kuantan-Kuala Lumpur Road, Maran, Pahang at Borehole 3

KUMPULAN IKRAM SDN. BHD
(IKRAM TIMUR CAWANGAN KUANTAN)

SUMMARY OF LABORATORY TEST

Project: PEMBAIKIAN CERUN DI KM 99 & KM 101 JALAN KUANTAN - KUALA LUMPUR MARAN, PAHANG. Date 12.6.2002

BH	Sample	DEPTH	M.C	BULK	DRY		UNCONF	UU TRIAXIAL		CONSOLIDATION		CIU		ATTERBERG LIMITS				MECHANICAL AND				CHEMICAL TESTS			
							COMP	COMPRESSION		TEST		TEST		TEST				HYDROMETER ANALYSIS							
No	No	m	%	DENSITY	DENSITY	S.G		C	ø	Pc	Cc	C'	O	L.L	P.L	P.I	L.S	CLAY	SILT	SAND	RAVE	O.G	So3	Cl	pH
				Mg/m3	Mg/m3		kN/m2	kN/m2	Angle	kN/m2		kN/m2	Degree	%	%	%	%	%	%	%	%	%	%	%	%
BH 3	D 1	1.5-1.95	20											57	26	31		6 2		14	24				
	MZ 1	3.0-4.00	22					17	2	51	0.135			69	30	39		19	47	23	11				
	D 3	7.5-7.95	17											56	25	31		2 9		29	42				
	D 4	9.0-9.45	14											41	23	18		2 8		34	38				
	D 5	10.5-10.95	22											69	29	40		4 1		19	40				
	D 6	12.0-12.45	21											52	24	28		2 1		23	56				
	D 7	13.5-13.95	26											63	29	34		5 4		8	38				
	D 8	15.0-15.45	23											53	27	26		6 2		18	20				
BH 4	D 1	1.5-1.95	17											46	25	21		3 5		16	49				
	D 2	4.5-4.95	24											45	25	20		6 7		24	9				
	D 4	9.0-9.45	32											73	34	39		9 6		4	0				
	D 6	12.0-12.45	33											62	30	32		9 0		8	2				
	D 7	13.5-13.95	32											57	27	30		8 4		10	6				
	D 8	15.0-15.36	12											36	20	16		6 2		19	19				

Note : NES = NOT ENOUGH SAMPLE NA = NOT APPLLICABLE

APPENDICES B

Summary of result from Unconsolidated Undrained Compression Test for Borehole 3