GROUND IMPROVEMENT BY USING GEOSYNTHETICS IN SLOPE/W

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SCHOOL OF CIVIL ENGINEERING
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GROUND IMPROVEMENT BY USING GEOSYNTHETICS IN SLOPE/W

by

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ENDORSEMENT

Appendix A5

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2020/2021

FINAL YEAR PROJECT EAA492/6
FINAL DRAFT ENDORSEMENT FORM

Title : GROUND IMPROVEMENT BY USING GEOSYNTHETICS IN SLOPE/W

I, NURIN SYAZWINA BINTI SUKRI hereby declare that I have checked and revised the whole draft of dissertation as required by my supervisor.

Student's Signature:

Supervisor's Signature:

Date: 9/7/2021

Name of Supervisor: Professor Dr. Fauziah Ahmad

Date: 9/7/2021

SHOULD BE STAMPED BY THE GENERAL OFFICE OF THE SCHOOL OF CIVIL ENGINEERING, UNIVERSITI SAINS MALAYSIA

Appendix A8

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2020/2021

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: GROUND IMPROVEMENT BY USING GEOSYNTHETICS IN SLOPE/W

Name of Student: Nurin Syazwina binti Sukri

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

Signature:

Date: 6/8/2021

Endorsed by:	Approved by:
(Signature of Supervisor)	(Signature of Examiner)
Name of Supervisor: Professor Dr. Fauziah Ahmad	Name of Examiner: DR. MUHD HARRIS RAMLI Pensyarah Kanan Pusat Pengajian Kejuruteraan Awam Universiti Sains Malaysia Email: cemhr@usm.my
Date: 6/8/2021	Date: 6/8/2021

(Important Note: This form can only be forwarded to examiners for his/her approval after endorsement has been obtained from supervisor)

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ABSTRAK

Oleh kerana keadaan geografi dan cuaca di Malaysia, kestabilan cerun telah menjadi salah satu masalah yang besar dalam sektor pembinaan. Reka bentuk analisis cerun yang tidak betul boleh mengakibatkan keruntuhan cerun, yang merupakan salah satu bencana yang paling biasa yang boleh mengakibatkan kehilangan harta benda dan nyawa yang besar. Untuk mengatasi masalah ini, analisis kegagalan cerun mesti dilakukan untuk menentukan kestabilan cerun dengan melakukan kaedah keseimbangan had. Selain itu, pemasangan geosintetik telah dibuat untuk meningkatkan penstabilan tanah dan pengukuhan tanah. Kaedah ini akan menunjukkan faktor keselamatan bagi setiap tanggul cerun dan dinding penahan tertentu. Penyelidikan ini menyelidiki kestabilan cerun dan menawarkan strategi peningkatan tanah yang menjimatkan kos dan selamat digunakan di lereng iaitu dengan menggunakan Fibrogrid-geogrid sebagai elemen penguat. Analisis kestabilan cerun akan dilakukan dengan menggunakan analisis berangka dalam perisian pemodelan berasaskan fizikal, GeoStudio-SLOPE / W. Sama seperti kajian sebelumnya, kaedah keseimbangan had digunakan untuk menganalisis faktor keselamatan tetapi dalam keadaan yang berbeza seperti kestabilan cerun lebuh raya di bawah keadaan hujan dan kestabilan cerun tampalan pengisian jalan. Selain itu, kriteria model Mohr-Coulomb juga digunakan untuk mewakili lapisan tanah. Dalam kajian ini, dua hipotesis lain yang dapat dibuat iaitu penggunaan geosintetik akan memberikan impak yang tinggi terhadap indeks keselamatan untuk semua ciri cerun dan kenaikan beban tambahan yang diedarkan di atas struktur akan menangani kegagalan sekiranya kapasiti beban melebihi keupayaan struktur bertetulang dengan menganalisis faktor keselamatannya. Penyelidikan kegagalan cerun ini telah menyumbang kepada penyelidikan kejuruteraan tempatan yang menangani kejatuhan cerun yang berlaku dalam tiga kajian kes yang berbeza. Penemuan kajian ini dapat dijadikan panduan bagi jurutera untuk meningkatkan kestabilan cerun dinding penahan dan tanggul di ketiga lokasi ini, serta cerun lain di masa depan.

ABSTRACT

Due to the geography and weather conditions in Malaysia, slope stability has become one of the most pressing issues in the construction sector. Improper slope analysis design can result in slope collapse, which is one of the most common disasters that can result in significant property and lives loss. To deal with these problems, a slope failure analysis must be performed to establish the slope stability by performing limit equilibrium method. Besides, geosynthetics installation has been made to improve the ground stabilization and soil reinforcement. This method will display factor of safety for any particular slope embankment and retaining wall. This research investigates slope stability and offers a ground enhancement strategy that is both cost-effective and safe to use on the slope which is by using Fibrogrid-geogrid as reinforcing elements. The slope stability analysis will be done by using numerical analysis in physical based modelling software, GeoStudio-SLOPE/W. Similar case to previous research, limit equilibrium method is being used to analyze factor of safety but under different circumstances such as slope stability of the highway under rainfall condition and slope stability of a road fill embankment. Besides, Mohr-Coulomb model criteria is also being used to represent the soil layer. In this study, two other hypothesis can be made which are the usage of geosynthetics will give the high impact on safety index for all slope characteristic and increment of surcharge loading that distributed on top of the structure will address to failure if the load capacity is exceeding the ability of reinforced structure by analyzing its factor of safety. This slope failure research has contributed to local engineering research addressing the slope collapse that occurred in three different case studies. The findings of this study can be used as a guide for engineers to improve the slope stability of retaining walls and embankments at these three locations, as well as any other slope in the future.

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LIST OF SYMBOLS

λ	*Bulk Unit weight*
C	*Cohesion*
f_3	*Creep factor*
f_2	*Durability factor*
$f(x)$	*Function*
f_1	*Installation damage factor*
S_{IA}	*Interface adhesion*
δ	*Interface shear angle*
φ	*Internal friction angle*
X	*Interslice Force*
E	*Normal Force*
T_u	*Ultimate tensile*
T_{des}	*Design value*

LIST OF ABBREVIATIONS

FOS	Factor of Safety
FPR	Factored Pull-out Resistance
FTC	Factored Tensile Capacity
PR	Pull-out Resistance
RF	Reduction factor
RF_R	Reduction Factor Pull-out Resistance
RF_T	Reduction Factor Tensile Capacity
RRF	Resistance reduction factor
TC	Tensile capacity

CHAPTER 1

INTRODUCTION

1.1 Background

Slope stabilization refers to any approach used to stabilize a slope that is unstable or insufficiently stable. Slope stabilization techniques are used to raise a slope's Factor of Safety to a level that is regarded acceptable. Almost every field of engineering is concerned with safety. Traditionally, safety was incorporated by applying safety factors or margins to the projected ultimate capacity, but this approach is being phased out in favour of probabilistic risk management as a method for defining safety measures, the Probability Risk Assessment (PRA) was used as mentioned by (Doorn, 2011).

Piles, rock bolts, pre-stressed anchors, geosynthetic reinforcement, soil nailing, and retaining walls are some of the tools utilized in support stabilization and to improve safety index. Usage of geosynthetic reinforcement is a practical tool for improving the stability of geotechnical structures. Geosynthetic is used to reinforce a slope, the material is placed in strips of a certain width. Structures are influenced by problems with regard to soil and reinforcement material properties is usually recommended to use it to improve soil behaviour.

Highway slopes comprised solely of heavy materials are frequently erected above soft ground, which can result in slope failure and collapse especially at East –West Highway in Hulu Perak that need to carry out more investigation works as mentioned by Gasim, 2015.

1.2 Problem Statement

Nowadays, due to Malaysia's terrain and environmental conditions, slope stability has become a major issue in the construction industry. Improper slope analysis design can result in slope instability, which can result in significant property and life loss. Slope failure may be caused or regulated by a variety of factors, including changes in slope geometry, drainage, retaining walls, and internal slopes. Due to the unstable land, development activities could face significant difficulties. Similarly, slope failure may disrupt critical services such as traffic flow, drinking water supply, power generation, and other infrastructure.

In 1999, when the Gerik-Jeli Highway was completed, a significant slope displacement occurred at 36.2 kilometers. In 2020 slope has been reconstructed but a rapid sedimentation along the discontinuity surfaces occurred for the second time with a several slope disruptions that ruptured the drains. Two times of slope failure occurred subsequently in this particular location. Highway slopes comprised solely of heavy materials are frequently erected above soft ground, which can result in slope instability and collapse especially at East –West Highway in Hulu Perak that need to carry out more investigation works as mentioned by Gasim, 2015.

As of 17 December 2020, the geological instability causing landslide in Tota Ghati, India on National Highway 58 in Tehri district. As mentioned, they employed the Critical FOS analyses to assess slope stability via numerical methods to predict the risk due to slope failure. Their analyses showed that for the slopes FOS lay between 1 (unstable) to 1.3 (marginally stable). In worst-case scenario, improper slope analysis design can result in slope instability.

Besides, most people think of roads and bridges when they hear the word infrastructure. However, numerous sewage structures, the that can now be categorized as culverts, support those roads which are functioning over capacity. Surface drainage and rainwater is carried from one side of the roadway to another by these culverts according to Tenbusch, 2013. Erosion at the edge of road causes by rainfall activities may also result in steep slope.

1.3 Objective

The objectives of this research are:

1. To determine the stability of slope by evaluating design parameter based on related theory.
2. To evaluate stabilization using different strength of geosynthetics.
3. To compare the increment of surcharge loading.

1.4 Scope of Work

The scope of this study: “Ground Improvement by using Geosynthetics” is expected to address such instability problems. This project involves analysis using GeoStudio-SLOPE/W, a simulation software to examine the safety factor in slope area such as embankment and retaining wall that are subjected to loading from highway road, housing outlet drain culvert.

Nowadays in geotechnical industry, the most appropriate and accurate stability analysis approaches have a wide variety of applications, and they are becoming increasingly in demand. The chosen approach should be capable of identifying current safety conditions to recommend manageable solutions such as the installation of geosynthetics as reinforcing element. Limit Equilibrium method which needs to be analysed in SLOPE/W software consist of five methods, Spencer’s method, Janbu’s method, Ordinary method, Morgenstern–Price method and Bishop method is used to compute the factor of safety (FOS) after geosynthetics element being installed. The comparison is mainly based on slope geometry and surcharge loading.

However, the scope of work for this project is limited safety analysis of the geogrid reinforced embankments and reinforced wall. Hence, it will not consider the effects of precipitation, seismic events and the variations in heights for the embankments and wall.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Slope stability analyses in geotechnical engineering have evolved as a result of advances in soil and rock mechanics. Concerns about certain aspects of slope failure must be alleviated by a slope analysis in order to prevent it from occurring frequently. Slope stability basic theory is crucial in the study of slopes in terms of types of soil, stabilizing methods, and soil movement. Slope construction is completely linked to soil, so it's important to consider the history of soil and slope analysis approaches used in the construction of new slopes or the development of existing slopes (Mizal-Azzmi, 2011).

The rate of failure is usually quite slow, taking hours to days to manifest. In the first section of this chapter, a review of slope instability investigation will be discussed, that are existed and represent to instability. Slope stability concepts include a detailed understanding of geology, soil properties and hydrology. The primary objective of soil reinforcement is to increase stability, capacity, and minimize settlements and lateral movement. The properties mechanism of soil-geosynthetics need to be highlighted in this chapter that geosynthetic acts as a tensioned member to the composite material include the restraining of tensile deformations by mobilizing tensile load in the geosynthetic and preventing the soil from sliding over the geosynthetic or pulling out the soil by facilitating bond resistance, interlocking, adhesion or confinement, and therefore maintaining the ground mass's stability (Awdhesh, 2011).

The 1610 collapse data from the previous 15 years were recorded in touch with the rest of the current state of slope collapse. As illustrated in figure 2.1 by Y. Zhang & Ding, 2019, around 79 percent of the collapse incidents have a slope of 30°–50°, with 40° being the steepest.

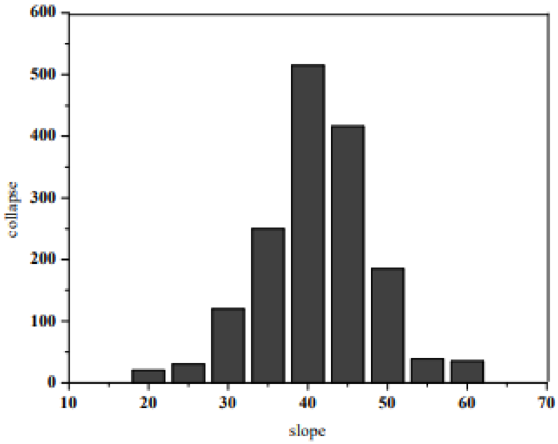


Figure 2.1: The relationship between collapse and slope

2.2 Classification of Slope Failure

Slope failures available in a wide range of sizes and shapes, as well as consistency, ground area affected, and occurrence and movement speed Internal deformations caused by movement will profoundly remould the mass, favouring the development of cracks and fissures, depending on landslide mechanisms. Furthermore, sliding causes a deformations shear zone to form just at the interface with the underlying stable formation. As a result of the motions and related deformation phenomena, the soil properties and thus the hydrological and mechanical slope response are constantly changing (Comegna et al., 2020).

Mudflows, slips, rockfall, landslides, and slumps are some of the terminology widely used to classify slope movement caused by gravity. System of classification and definition is needed for this movement occurrence, so the movement can be explained using standard or universal parameters.

There are six types of slope movement which are: lateral spreads, topples, flows, falls, drops, and complex. To signify the slope movement, various types of materials have different names. Slope material is divided into three categories, according to Kehew, 2006, which are soil composed of primarily fine clasts, soil composed of debris and bedrock.

Depending on the researcher, the definition of slope failure can differ. Varnes classification scheme, for example, considers forms of motion and composition of material, with various movement of slope having classification as shown in table 2.2, Felix, 2003 has provided a categorized scheme with a description that categorizes slope failure types in terms of movement velocity.

Table 2.1: Hunt Classification of slope failure (Felix, 2003)

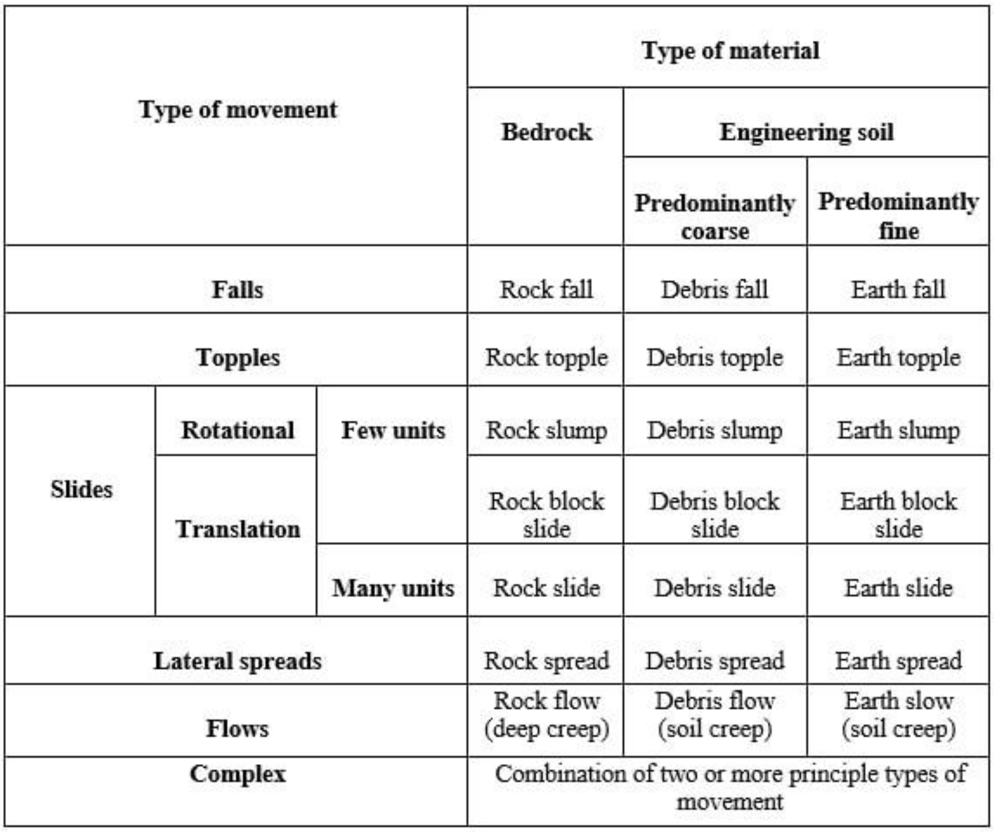
TYPE	FORM	DEFINITION
Falls	`Free fall	Sudden dislodgement of single or multiple blocks of soil or rock which fall in free descent.
	Topples	Overturning of a rock block about a pivot point locatedbelow its center of gravity.
Slides	Rotational or slump	Relatively slow movement of an essential coherent 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 planarfailure surface.
	Subclasses • Block glide • Wedges • Lateral spreading • Debris slide	• A single block moving along a planar surface. • Block or blocks moving along intersecting planarsurface. • A number of intact blocks moving as separateunits 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.
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 achange from one form to another during failure with one form predominant.

2.3 Types of Slope Failure

The movement of rock fragments and soil down slope caused by the gravitational pressures is known as mass wasting or slope collapse. The most typical causes of probable slope failures are immense pressure or a decline in the soil's shear strength. Increasing the load or vibration factor near the slope would typically result in an increase in pressure. The analysis of causes and modes of ground movement has shown a number of different types of failures.

According to Varnes, 1978, falls, topples, slides, spreads, and flows are the five main types of movement (described as in table 2.3). Complex slope movements are a sixth type that combines two or more of the other five types.

Table 2.2: Varnes Classification System



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 slow (soil creep)
Complex			Combination of two or more principle types of movement		

i. Falls

Falls occur when natural materials such as rock formation break away from steep slopes or hills in unpredictable ways. Separation occurs on discontinuity such as joints and bedding planes, cracks, bouncing, free-fall movement, and sliding. The presence of interstitial water, mechanical weathering, and gravity all have a major effect on falls.

ii. Topples

A forward movement of a unit or a group of units around a key point, gravitational forces and pressure generated by nearby units or fluids in fractures distinguish falling events.

Figure 2.2: Topple incident at USA, Utah, Canyonlands

iii. Slides

Although the term "landslide" covers a wide variety of mass movements, Rotational slides and translational slides are the two primary types of slides.

- Rotational Slides: The rupture surface is concavely upward and the slide movement is roughly rotational around an axis parallel to the ground surface.
- Translational Slides: The landslide mass travels along an approximately planar surface with some rotation or backward shifting in this form of slide

iv. Lateral Spreads

Lateral spreads are the most common of movement, which is often followed by tensile or shear fractures. The failure is due to liquefaction, which is the transformation of cohesionless, loose, and saturated sediments a transition from a solid to a liquid condition.

v. Flows

Five basic types of flows, each with its own set of characteristics as below: -

- Debris flow: Rapid mass movement in which a slurry of loose dirt, organic matter, rock, air, and water mobilizes and flows downslope as a slurry. Fines make up about half of the debris flows. Due to extreme surface-water movement, which mobilizes and erodes loose soil or rock on steep slopes caused by heavy precipitation or rapid snowmelt.
- Earth flow: The material on the slope liquefies and runoff occur, leaving a bowl or slump at the top. The flow is usually found in clay-bearing rocks or fine-grained materials under saturated conditions and on moderate slopes. Dry granular material flows, on the other hand, are probable.
- Mud flow: Form of earth flow made up of moist material to flow quickly and contains silt, at least 50% sand and clay-sized particles. Mudflows and debris flows are often referred to "rain slides" in some cases.

vi. Complex

A complex landslide is one that incorporates two or more of the above forms. These processes are often complex and function at a deep level, making it difficult to investigate and characterize contributing factors (Eberhardt, 2003).

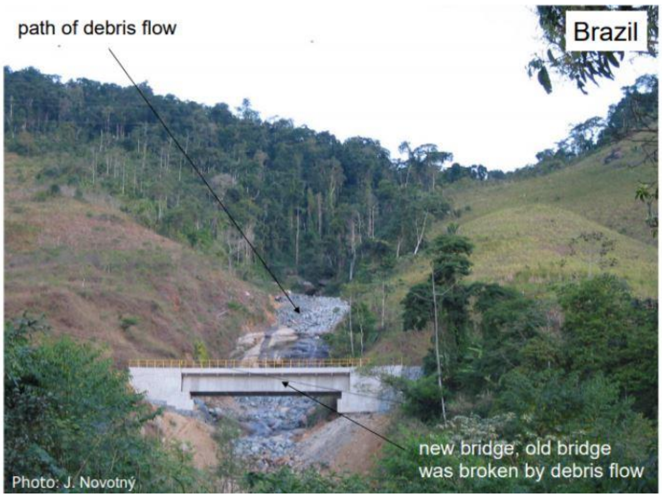


Figure 2.3: Path of Debris Flow and Earth Flow

2.4 Factor that Causes Slope Instability

Slope stability is a problem that must be addressed prior to any operation that takes place primarily in hilly terrain. Natural and human-made causes are two other factors that may contribute to slope instability. According to Jagriti Mandal et al., 2017, to prevent such losses, remedial slope stabilization steps are required, which can only be calculated by determining what caused the slope failures in the first place. To determine the shear strength, pore pressure, or other conditions present at the time of failure, an effective methodology is needed.

NATURAL FACTOR

i. Rainfall

Prolonged rain and storm can cause landslides and erosions, which can lead to slope failures. Temperatures are expected to rise over time, and rainfall may become more extreme and less regular (Strauch et al., 2015). The fluctuation of boundary conditions across the ground surface are determined by changes in rainfall patterns in particular. Changes in groundwater hydrology can reduce shear strength and soil effective stress, which could lead to rainfall-induced slope failures. Changes in groundwater hydrology can cause slope failure by lowering ground shear forces and effective pressure (Ghani et al., 2020).

ii. Triggering Events

When a slope becomes unstable, a mass movement event also may occur. When the slope is unstable all of the time, as it is in the case of creep, the process is constant. Other times, however, triggering events may occur, resulting in a sudden onset of instability. It can only take a small incident to cause a failure and catastrophe (Nelson, 2013). For example, a sudden shock, such as an earthquake, may cause a slope to become unstable. Minor shocks, for example trees blowing in the wind, large vehicles crashing down the road or human-caused explosions, may also cause mass movement.

iii. Roles of water

Water reduces cohesiveness in sediments while increasing pore pressure and density in granular material. Besides, volume of water that penetrates through into slope plays an important role. Even little amounts of water might cause some slopes to become unsafe, meaning that others are more susceptible to the amount of water that falls over time. After severe rain, numerous landslides may occur simultaneously resulting in a characteristic impoverished landscape (Noroozi & Hajiannia, 2015).

HUMAN FACTOR

i. Quarry/ Mine

As quarry/mine faces are exposed, the rock relaxes, which can cause loose material to fall or roll off the face. Where there is poor soil, bedding, joints, structures, blast damage, vehicle vibrations, crest failure, adverse weather (rainfall, wind), or inadequate design, the risk of rockfalls and slope instability increases.

Consider all activities involving ground instability, such as digging/excavating, leveling, water cart, drilling, loading shots, unplanned equipment operation, surveying, sampling, and installing/moving pumps. The failures can occur in a mine or quarry such as wedge failure, planar failure and toppling failure, Strang, 2010 .

ii. Forestry

Many studies have recorded the subsequent sediment supply and acceleration of erosion to streams caused logging. Soil strength earlier given by tree roots is decreased and the initiation of landslides is increased where soils are steep and shallow do not have the potential to vegetate. It is clear that different tree species react to logging in different ways. This refers to tree species with roots that do not die when the tree is cut down but still help to stabilize the slope. Clear cuts and thinning of the forest canopy expose residual trees to wind stress, which increases the risk of blow down, exposing barren soil and encouraging saturation failures (Kellerer-pirklbauer, 2002)

Figure 2.4: Deforestation-induced landslide near Jayapura, Indonesia

iii. Construction activities

The natural topography of a region is typically altered as a result of construction activities. These changes in geomorphology may have an effect on other systems, especially the hydrological system. More weight on the top of a slope or undercutting of a slope causes artificial changes in the geometry of a natural slope (Kellerer-pirklbauer, 2002).

Hillside housing development: Because of the existence of paved streets and roofs, the building and occupation of houses at the top of a sloping area which can results in changes of groundwater conditions due to the use of sewage.

Transportation Infrastructure: In order to achieve a flat surface when building transportation infrastructure in a mountainous environment, it is usually important to increase the angle of the slopes on at least one edge of the new road. To achieve this plain surface, either more load and therefore stress is added to the top of a slope as a result of embankment material, or the slope angle is artificially steepened. The slope's strength is diminished as a result.

2.5 Method of Analysis

In slope stability analysis, limit equilibrium methods (LEM) are the most commonly used analytical methodology. To analyse the shear strength along the failure surface, they use the Mohr-Coulomb criterion. The concept throughout limit equilibrium methods is to reduce the material's shear strength by a factor of safety in order to achieve equilibrium against shear stresses (Jagriti Mandal et al., 2017).

A technique that currently use in this method is method of slices for software analysis in SLOPE/W. The slope is divided into vertical slices, and the factor of safety is determined by taking the slices in equilibrium. The shear forces (T) and inter-slice normal (E) act upon the slices into which the slope is divided are assumed differently in each LEM.

The possibility of rock or soil slippage due to gravity is investigated using limit equilibrium methods. The comparison of resistance forces, moments, and stresses during mass motion to destructive forces, moments, and stresses that cause instability motion is the basic of this method. In this way, the failure that leads to instability is taken into account in the calculation based on known failure modes (Khalkhali, 2019).

2.5.1 Factor of Safety

The stability of a soil mass against possible failures is represented by the factor of protection (Das 2010). The stability of slopes is affected by a variety of factors. Existing stress, soil friction angle, soil cohesion, and water surface level are among the parameters. Various approaches have been created to provide various safety aspects, with the method of slices being offered to evaluate the strength of cohesive soils (Salmasi et al., 2019). So far, two forms of safety factors have been established (Lin et al., 2015) :-

1. The safety strength reserve factor attained by reducing the strength of the soil mass and rock.
2. The driving force reserve factor overloading is a landslide thrust design value determined by amplifying the driving force along the slope while maintaining the resisting force unchanged.

2.5.2 Geosynthetics

Geosynthetics are well-establish used for separation, protection, drainage, filtration and sealing. Furthermore, through integrating polymeric materials, geosynthetic reinforcement neutralize steep cliffs, making it one of the most low-priced methods for not only accommodating budgetary constraints but also lessening room constraints (Kim et al., 2019).

The geogrid indicates greater peak pullout resistance compare to the other geosynthetics. The pullout strength of a geosynthetic is defined as the ultimate force required to produce outward sliding of the geogrids through the reinforcing soil mass. The pullout resistance of the geogrid is made up of bearing resistance and frictional resistance that assembled against the transverse members (Ferreira et al., 2020).

In comparison to traditional concrete structures, geogrid reinforcement structures provide major economic and environmental benefits. Field tests and large-scale experiments have also shown that geosynthetic-reinforced constructions have a higher bearing capacity than measured and lower deformations than assumed (Ziegler, 2017).

2.5.3 Software Used

Geotextiles and geogrids are examples of geosynthetic reinforcement that can be used in GeoStudio-SLOPE/W. The measured pullout resistance alternative requires the input of the following (GEO-SLOPE International Ltd., 2008): -

- **Interface adhesion** (S_{IA}): apparent cohesion (adhesion) if effective drained soil strengths are taken into account. In other way, the parameter may be used to resolve the undrained strength at contact between the geosynthetic and soil.
- **Interface shear angle** (δ): angle of interface shearing resistance if effective drained soil (δ) strengths are being expected.

The following inputs are needed regardless of the approach chosen:

- **Resistance reduction factor** (RRF): “scale effect correction factor” to indicate nonlinear stress reduction over the embedded length of highly extensible reinforcement
- **Tensile capacity** (TC): Reinforcement’s tensile strength
- **Reduction factor** (RF): reasons for the reduction in the ultimately tensile capacity of the reinforcement due to physical processes such as durability, creep and installation damage

2.5.3 Comparison of Previous Study

Author	Description/ perimeter	FOS
Y. Zhang & Ding, 2019	- Slope stability analysis of highway - Change in porewater pressure parameter caused by rain water infiltration. - Consider permeability of rock soil $5 \times 10^{-4} \mathrm{m/s}$ - Consider moister content of 0.3 and saturated water content of 0.37 - Type of slope: Rock slope - Mohr-Coulomb model criteria to represent soil layer - Compute FOS using limit equilibrium method using GeoStudio-SLOPE/W	**Ordinary method** 0.898 **Bishop method** 1.012 **Janbu method** 1.001 **Morgenstern Price method** 0.960
Liu & Hounsa, 2018	- Slope stability analysis on road embankment - Geotechnical embankment with simple 2:1 slope, 12 m height, internal friction angle, φ = 20° and cohesion, C = 29 kPa - Type of slope: Soil slope - Mohr-Coulomb model criteria to represent soil layer - Compute FOS using limit equilibrium method using GeoStudio-SLOPE/W	**Ordinary method** 1.928 **Bishop method** 2.080 **Janbu method** 2.041 **Spencer method** 2.073

<table>
<tr><th>Author</th><th>Description/ perimeter</th><th>FOS</th></tr>
<tr>
<td>A. Ashour et al., 2006</td>
<td>- Slope stability analysis of highway side slope and retaining wall
- Case study: Road Adjacent Water Ways in Upper Egypt
- Carry out experimental work in determining water content, bulk, dry densities, shear strength parameters, and initial modulus of elasticity of soil.
- Type of slope: Soil slope
- Mohr-Coulomb model criteria to represent soil layer
- Compute FOS using limit equilibrium method using GeoStudio-SLOPE/W
- Factor of safety is made based on with loading and without loading condition and retaining wall with 40 cm and 25 cm thickness.</td>
<td>
<table>
<tr><th>Method</th><th>With loading</th><th>Without loading</th></tr>
<tr><td>Ordinary</td><td>0.907</td><td>0.843</td></tr>
<tr><td>Bishop</td><td>1.005</td><td>0.936</td></tr>
<tr><td>Janbu</td><td>0.907</td><td>0.846</td></tr>
<tr><td>Morgenstern Price</td><td>0.953</td><td>0.890</td></tr>
</table>
<table>
<tr><th>Method</th><th>Retaining wall of 40 cm thickness</th><th>Retaining wall of 25 cm thickness</th></tr>
<tr><td>Ordinary</td><td>1.160</td><td>1.807</td></tr>
<tr><td>Bishop</td><td>1.700</td><td>1.788</td></tr>
<tr><td>Janbu</td><td>1.279</td><td>1.525</td></tr>
<tr><td>Morgenstern Price</td><td>1.687</td><td>1.829</td></tr>
</table>
</td>
</tr>
</table>

<table>
<tr><th>Author</th><th>Description/ perimeter</th><th>FOS</th></tr>
<tr>
<td>Moldovan et al., 2017</td>
<td>- Slope stability analysis of road fill embankment
- Consist of seven cases
Case 1: two 2:3 slope embankment, framing a 2 m wide berm, sliding at lower slope.
Case 2: 2:3 and 1:3 slope embankment, framing a 2 m wide berm, sliding occur at 2:3 lower slope.
Case 3: 1:3 and 2:3 slope embankment, framing a 2 m wide berm, sliding occur at 1:3 upper slope
Case 4: 1:3 and 2:3 without berm, sliding only at upper slope.
Case 5: 1:3 and 2:3 without berm, sliding both at upper and lower slope.
Case 6: only one 1:3 slope embankment
Case 7: only one 2:3 slope embankment
- Type of slope: Soil slope
- Mohr-Coulomb model criteria to represent soil layer
- Compute FOS using limit equilibrium method using GeoStudio-SLOPE/W</td>
<td><table>
<tr><th></th><th>Fellenius</th><th>Bishop</th><th>Sarma</th></tr>
<tr><td>1</td><td>1.13</td><td>1.15</td><td>1.36</td></tr>
<tr><td>2</td><td>1.12</td><td>1.15</td><td>1.38</td></tr>
<tr><td>3</td><td>1.25</td><td>1.29</td><td>1.42</td></tr>
<tr><td>4</td><td>1.15</td><td>1.17</td><td>1.42</td></tr>
<tr><td>5</td><td>1.12</td><td>1.14</td><td>1.20</td></tr>
<tr><td>6</td><td>2.10</td><td>2.18</td><td>2.23</td></tr>
<tr><td>7</td><td>1.10</td><td>1.10</td><td>1.38</td></tr>
</table></td>
</tr>
</table>

According to Duncan, 1996, when employing circular slip surfaces in analyses, the critical factor of safety that estimated using either the ordinary method of slices or Bishop's modified method will represent the F values that are lower than those obtained using more precise approaches. This statement can be verified throughout all comparison that has been made.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses the approaches applied throughout the study which explains design parameter determination based on relation theory. The value of FOS when carry out numerical analysis for geosynthetics with different strength and size that is subjected to uniformly distributed load known as surcharge load from slope of road embankment and retaining wall structures, which will be analysed using GeoStudio-SLOPE/W, a limit equilibrium modelling software.

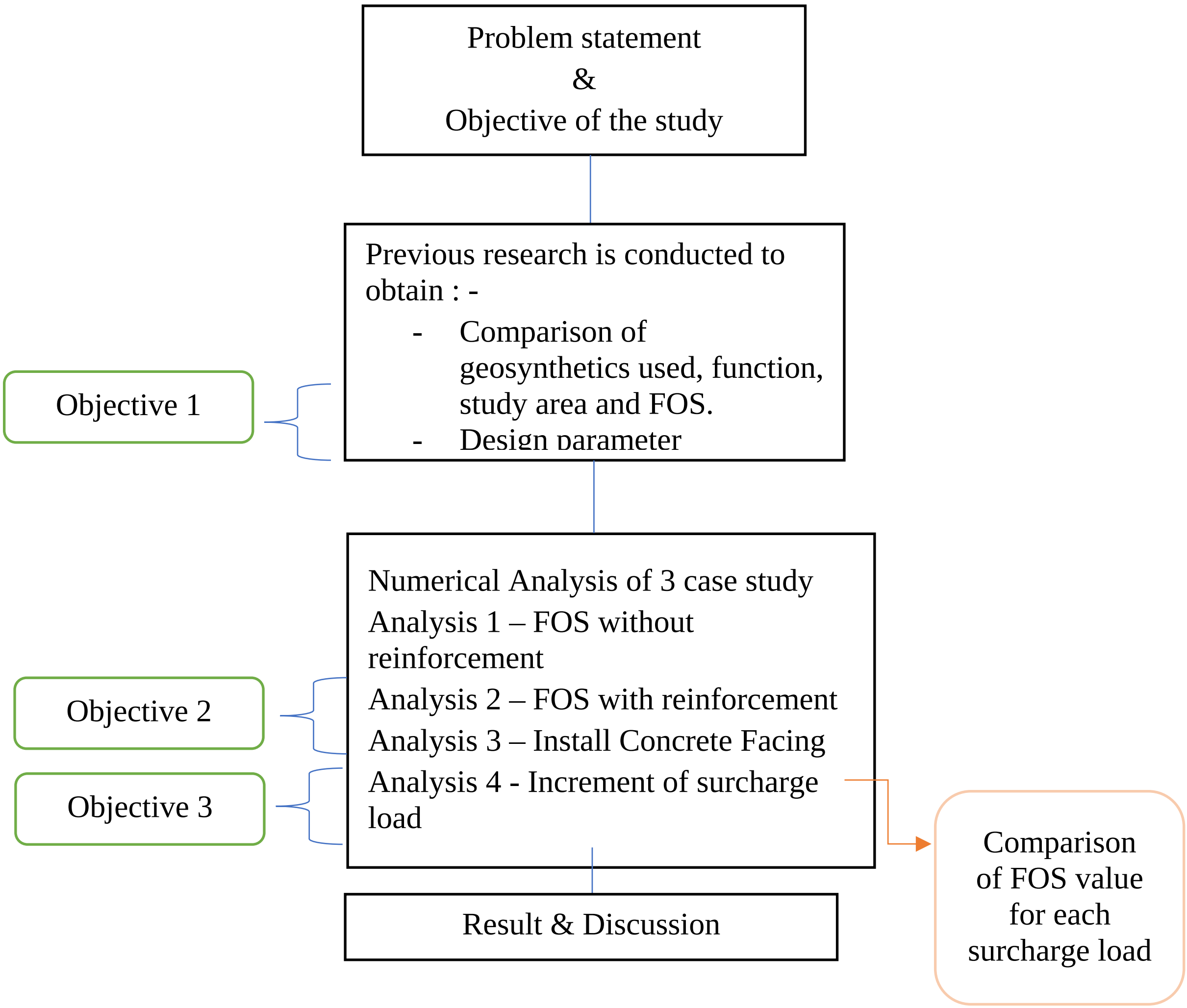


Figure 3. 1: Project Framework

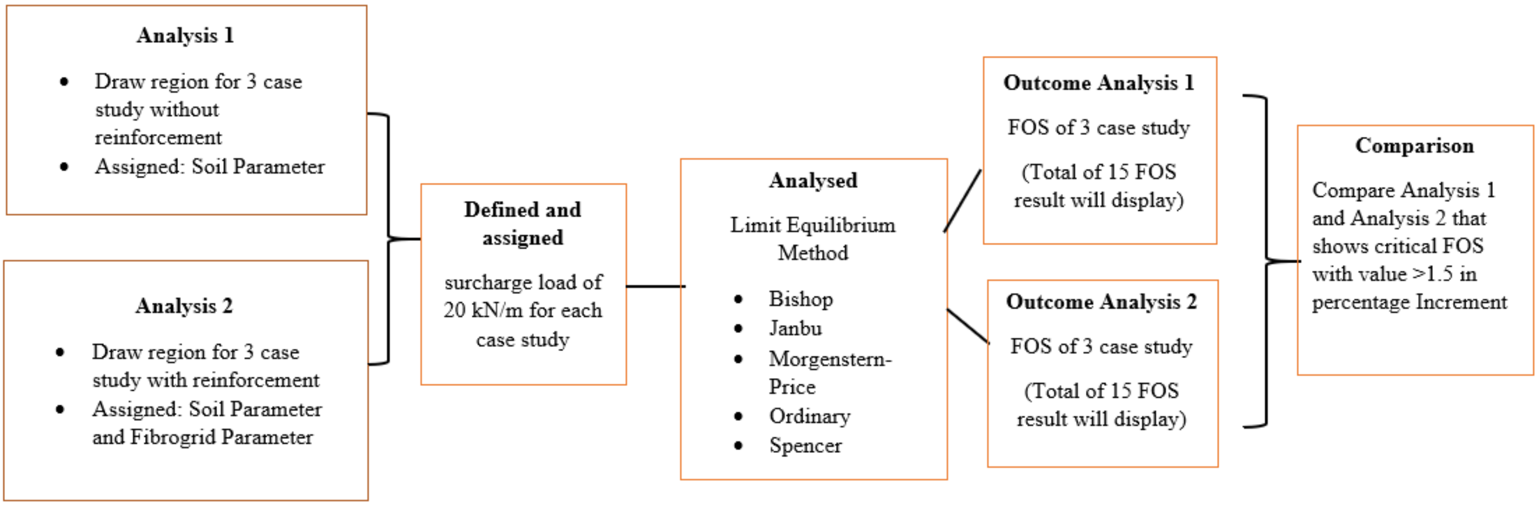


Figure 3.2: Block Diagram of Analysis Involving Reinforcement

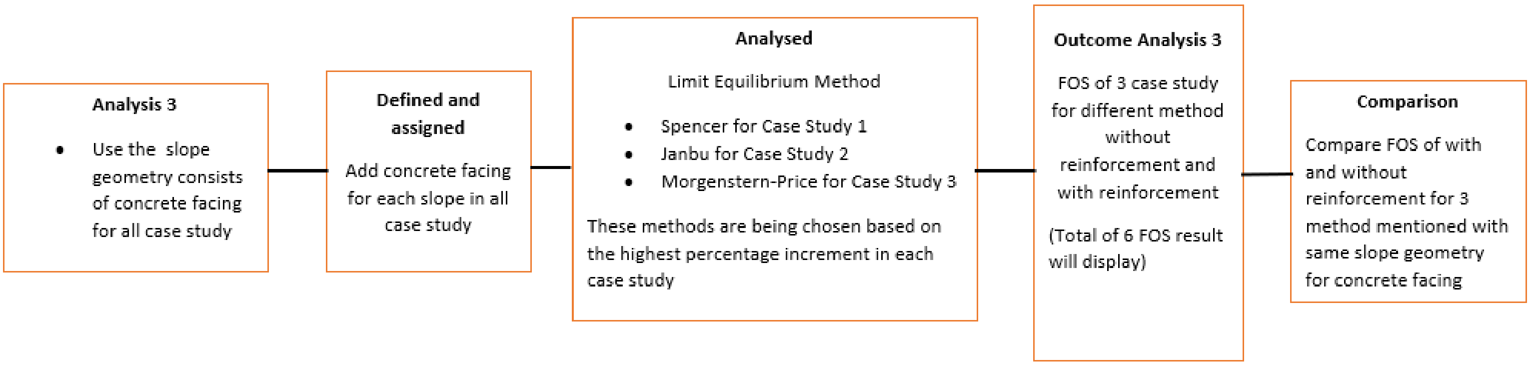


Figure 3.3: Block Diagram of Analysis using same geometry without and with reinforcement

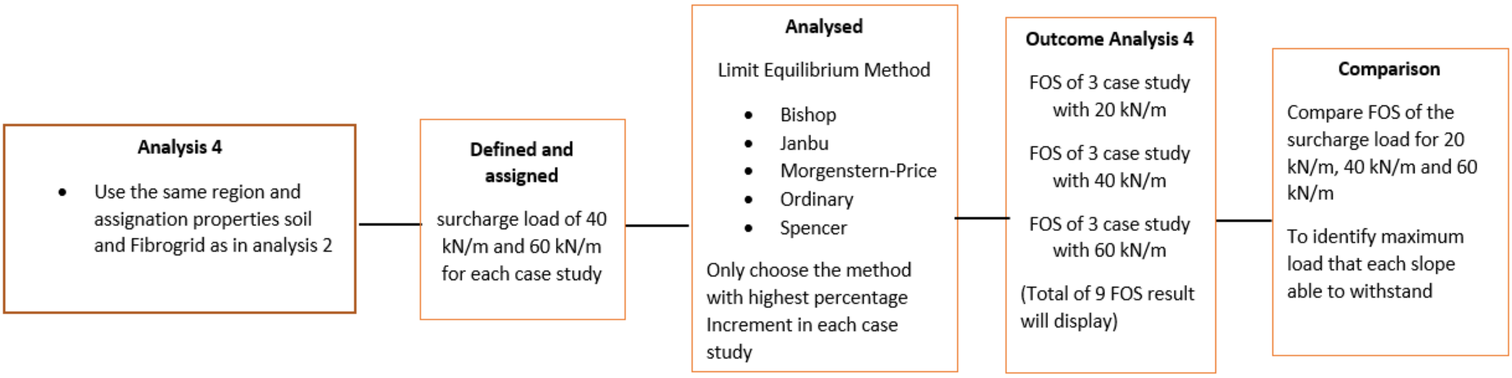


Figure 3.4: Block Diagram Analysis in Increment of Surcharge Load

3.2 Data Collection of Case Study

The design and analysis methodology and assumptions will be first presented, followed by the evaluation of analysis results and finally recommendations for the proposed slope stabilization works to be installed will be highlighted. The research location is being choose to implement slope stability analysis usually due to the presence of geotechnical engineering problems including the assessment of retaining wall overall stability, stability assessment of landslides and irregular surfaces of sliding

There are 3 research location in the case study which already being conducted

- KM96-Jalan Gerik-Jeli Highway, Perak,
- Taman Bukit Dahlia, Pasir Gudang
- Nusajaya, Johor.

Due to the lack of SI information about the site (history, hydrology, subsoil & topography survey data, underground services, etc.), some assumptions were made to accomplish the design proposal based on the knowledge and engineering judgements of the designer. All engineering assumptions have to be verified and confirmed by soil investigation and topography survey.

1.3 Design Parameter

The study area consists of different slope characteristic such as highway embankment, keystone reinforced wall at housing area and also keystone reinforced wall at road width extension above the culvert area. Soil engineering parameter is determined and assumed by using typical soil characteristic, as mentioned by Zhang et al., 2008.

Table 3.1: Typical geotechnical parameter for Hong Kong soil

Fill	Bulk unit weight, γ $(\mathrm{kN/m^3})$	Design cohesion, C $(\mathrm{kN/m^2})$	Angle of internal friction (φ)
Compacted fill			
Completely decomposed granite	19-21	0-5	38-42
Completely decomposed volcanic	18-21	0-5	35-38
Crushed rock fill	18-21	0	45->50
In situ soil			
Completely decomposed granite	16-21	5-15	35-44
Completely decomposed volcanic	16-21	5-10	32-38
Crushed rock fill	15-21	0-10	26-40

Fibrogrid-geogrid geosynthetics is used by obtaining the design parameter of reinforcement from the company industry named TenCate Geosynthetics Asia Sdn Bhd as the requirement of installation meet the specification of Tencate Miragrid ® GX geogrids model but using fibre version. Four different strength of Fibrogrid-geogrid geosynthetics has being installed in retaining wall and embankment. The product is engineered from high tenacity polyesters that have high tensile strengths, inert chemical degradation and also low creep characteristic.