OPTIMIZATION OF COST EFFECTIVENESS FOR SLOPE STABILITY

AFIQ BIN MOHAMAD NOR

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ABSTRACT

The development of infrastructure in Malaysia have been expand and more development within slope area were build widely that cause many slope failures. The dilemma that engineers nowadays face are to determine the suitability of the analysis methods and construction cost that is one of the main problems that cause lack of quality in construction of any infrastructure especially in slopes area. The knowledge of analysis and design of slope stability and the suitability of the slope protection used has been crucial to prevent any disaster happen. There were different methods used for slope stability analysis such as Ordinary, Bishop, Janbu, Spencer, Sharma etc including various types of slope protection used in Malaysia occording to the suitability and costing. The objectives of this study are to compare the various methods of slope stability analysis used and hence determine the optimum cost for the selected slope protection. This study was made based on two selected slopes at Lot 4189, Bandar Tanjong Bungah, Jalan Selari Pantai Utara, Pulau Pinang using Ordinary, Bishop, Janbu dan Morgenstern-Price methods. The analysis were performed by using software GeoStudio 2007. The result of the analysis showed that Morgenstern-Price method was the realistic and reasonable method that can be used in analysing both of the selected slopes while Reinforced concrete retaining wall gives the optimum cost for both selected slopes.

ABSTRAK

Pembangunan infrastruktur di Malaysia telah berkembang dan banyak pembangunan di kawasan cerun telah dibina dengan berleluasa sehingga timbul kejadian tanah runtuh. Dilema yang dihadapi para jurutera dalam menentukan kaedah analisis serta kos yang perlu ditanggung merupakan masalah utama yang menjadi punca kurangnya kualiti dalam pembinaan sesebuah infrastruktur khususnya yang melibatkan kawasan cerun. Pengetahuan tentang kaedah analisis dan kesesuaian sesuatu kaedah keselamatan cerun sangat penting untuk mengelakkan bencana dari berlaku. Terdapat perbagai kaedah menganalisi di gunakan dalam mengkaji kestabilan cerun seperti Ordinary, Bishop, Janbu, Spencer, Sharma dll disamping pelbagai kaedah keselamatan cerun yang digunakan di Malaysia mengikut kesesuaian dan kos. Tujuan am kajian ini adalah untuk menbandingkan kaedah-kaedah yang ada untuk menganalisis kesetabilan cerun dan menentukan kos optimum bagi kaedah keselamatan yang dipilih untuk cerun tersebut.. Kajian ini telah dibuat berdasarkan dua buah cerun di Lot 4189, Bandar Tanjong Bungah, Jalan Selari Pantai Utara, Pulau Pinang yang dianalisis mengunakan kaedah Ordinary, Bishop, Janbu dan Morgenstern-Price. Analisis telah dilakukan dengan mengunakan perisian GeoStudio 2007. Keputusan daripada analisis menunjukkan kaedah Morgenstern-Price adalah yang paling sesuai digunakan bagi menganalisis cerun tersebut serta pemilihan kaedah konkrit besi tetulang besi penahan sebagai kaedah yang memberikan kos paling optimum.

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LIST OF SYMBOLS

$(\sigma - u_a)$, $(\sigma_n - u_a)$ - Net normal stress

$(u_a - u_w)$ - Matric suction

FS - Factor of Safety

τ - Shear strength of the soil

τ_f - Shear stress that resist the soil mass from sliding

τ_m - Shear stress developed in soil / stress mobilized

c - Cohesion of the soil

c' - Effective cohesion

σ, σ_n - Total normal stress on failure plane at failure

σ_n' - Effective normal stress on failure plane at failure

φ' - Effective angle of internal friction

u, u_w - Pore-water pressure

u_a - Pore-air pressure

φb - Unsaturated friction angle

W - Total weight of the slice

N - Total normal force on the base of the slice

S - Shear mobilized on the base of the slice

b - Width of each slice

z - Depth of expected slip failure from ground surface

h - Ground water height above the slip surface

β - Slope inclination / slope angle

x - Equipotential line at the centre of the slice

P - Interslice forces

U - Water force

l - Width of inclined surface for each slice

CHAPTER 1

INTRODUCTION

1.1   INTRODUCTION

In 2008, there are eight landslides occurred in Malaysia starting from January until December. That was the highest record of landslides ever occurred in Malaysia. The total of eight landslides occurred especially around Klang Vally and Pahang area. There were six people dead in those incidents of landslides. Besides that, the collapse of Block 1 of Highland Towers in 1993, slope failure at Taman Hillview in November 2002 and the tragic 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 occasion. Hence, it is importance that the current practice of slope stability analysis to be revised in order to minimize the tragedies. (The Star, 6th Dec 2008)

Landslide is one of the many natural processes that shape the surface of the Earth. It is only when landslides threaten mankind that they represent a hazard. Recently there have been many occurrences of landslides in Malaysia. Most of these have occurred on cut slopes or on embankments alongside roads and highways in

mountainous areas. Some of these landslides occurred near high-rise apartments and in residential areas. A few major and catastrophic landslides have occurred within the last decade.

The dilemma occurred for construction companies nowadays are the safety of the types of slope stabilization methods they used that are directly proportional with the cost. This issue needs to be solved in order to ensure the public safety that will involves government together with the geotechnical engineer and contractors. The design of the slope stability should be improved with the latest technology plus the used of correct analysis by the geotechnical engineer. This is important to make sure that those landslides incidents would never happened again. (Bernama, 2008)

1.2   PROBLEM STATEMENT

The problems of slope failure could result fatal which play with human life and safety. The designing of slope stability is totally dependable to the value of factor of safety and types of slope stabilization methods used. The main issue here is the condition of the slope design that is directly related with the cost. In order to find the optimum cost, the best method of analysis need to be identified besides the used of correct slope protection methods.

1.3 OBJECTIVES OF THE STUDY

The objectives of the study are:

I. To identify the best method of slope design analysis at the selected slope location.

II. To find the optimum cost for constructing slope protection method for the selected slope location.

1.4 SCOPE OF STUDY

Scopes of study includes the following:

I. Analysis, design, and determination factor of safety using Ordinary, Bishop, Janbu and Morgenstern and Price methods.

II. Analysis and determination the cost for each types of slope stabilization methods used

III. Determination of the optimum cost of slope stabilization method used for the design slope.

IV. The study area of this project is at Lot 4189, Bandar Tanjong Bungah, Jalan Selari Pantai Utara, Pulau Pinang.

V. Using interpretation from local resources such as JKR and consultants.

1.5 SIGNIFICANT OF STUDY

The study will be a good reference to any geotechnical engineer in order to design slope stability with optimum cost of built. The data obtained from the design and the comparisons between each type of slope stability are crucial in designing safe slope stability. The dilemma between types of slope stability with cost is one of the crucial problems that can be solved through this study.

CHAPTER 2

LITERATURE REVIEW

2.1   Introduction

Landslide is one of the many natural processes that shape the surface of the Earth. In Malaysia, it happened in many high hill places that cause to death. Most of these have occurred on cut slopes or on embankments alongside roads and highways in mountainous areas. Landslides occur when the down slope component of soil or rock weights exceeds the maximum resistance to sliding along a particular surface. (Handy Spangler, 2007)

The need of correct design of slope stability is required to be done by the geotechnical Engineers. The stability of a slope depends on its ability to sustain load increases or changes in environmental conditions, which may affect the geomaterials mechanically or chemically (e.g. weathering) (Eberhardt, 2002)

Geotechnical engineer frequently are called on to analyze the mechanics of landslides and propose fixes. The Geotechnical engineers are using various types of method of analysis to analyze the type of slope stability that should be used based on the condition of the soil. (Richard L. Handy,2007)

The dilemma of cost of the stabilization method plays big roles in order to ensure the safety of the slope design. This factor should be considered as the first priority

2.2 Soil Formations

Soils are classified geologically by their origin as residual, colluvial, alluvial, eolian, glacial, or secondary soils. They are sub classified on the basis of their mode of occurrence, which refers to the landform or surface expression of a deposit, or its location relative to the regional physiographic. (Roy E. Hunt, 2002)

Knowledge of these characteristics provides the basis for formulating preliminary judgments on the engineering properties of permeability, strength, and deformability for intelligent planning of exploration programs. Especially in locations where the investigator has little or no prior experience; and for extending the data obtained during exploration from a relatively few points over the entire study area.

Table 2.1: Classes and Mode of Occurrence

Class	Mode of Occurrence
Residual Soils	Developed *in situ* from the decomposition of rock, residual soils have geomorphic characteristics closely related to the parent rock.
Colluvial Soils	Colluviums refer to soils transported by gravitational forces. Their modes of occurrence relate to forms of land sliding and other slope movements such as falls, avalanches, and flows.
Alluvial Soils	Alluvium is transported by water. The mode of occurrence can take many forms generally divided into four groups and further subdivided. In this chapter the term is used broadly to include marine deposits. Fluvial or river deposits include stream bed, alluvial fan, and floodplain deposits (point bar, clay plugs, natural levees, back swamp), deposits laid down under rejuvenated stream conditions (buried valleys, terraces), and those deposited in the estuarine zone (deltas, estuary soils). Lacustrine deposits include those laid down in lakes and playas. Coastal deposits include spits, barrier beaches, tidal marshes, and beach ridges. Marine deposits include offshore soils and coastal-plain deposits.
Eolian Soils	Eolian deposits are transported by wind and occur as dunes, sand sheets, loess, and volcanic dust.
Glacial Soils	Soils deposited by glaciers or glacial waters can take many forms, subdivided into two groups: • Moraines are deposited directly from the glacier as ground

	moraine (basal till, ablation till, drumlins) or as end, terminal, and interlobate moraines. • Stratified drift is deposited by the melt waters as fluvial formations (kames, kame terraces, eskers, outwash, and kettles) or lacustrine (freshwater or saltwater deposition).
Secondary Deposits	Original deposits modified *in situ* by climatic factors to produce duricrusts, permafrost, and pedological soils are referred to as secondary deposits. The duricrusts include laterite, ironstone (ferrocrete), caliche, and silcrete.

Source: From Geotechnical Engineering Investigation Handbook, *Soils Formations: Geologic Classes and Characteristic* (2002)

2.3 Geotechnical Properties

The properties of geologic materials are measured to provide the basis for identification and classification of soil. Geotechnical properties can be divided into four types of properties:-

1. Basic Properties

Basic properties include the fundamental characteristics of the materials and provide a basis for identification and correlations. Some are used in engineering calculations.

2. *Index Properties*

Index properties define certain physical characteristics used basically for classifications, and also for correlations with engineering properties.

3. *Hydraulic Properties*

Hydraulic properties, expressed in terms of permeability, are engineering properties. They concern the flow of fluids through geologic media.

4. *Mechanical Properties*

Rupture strength and deformation characteristics are mechanical properties. They are also engineering properties, and are grouped as static or dynamic.

2.4 Shear Strength of Soil

Soil strength is largely a matter of resistance to shearing, whether the soil is bulging out from under one side of a foundation or sliding off down a hill. (Richard L. Handy,2007) The shear strength of a soil mass is the internal resistance per unit area that the soil mass can offer to resist failure and sliding along any plane inside it. (Braja M. Das, 2005). It also can be defined as the maximum value of shear stress that the soil can withstand.

Mohr (1900) presented a theory for rupture in materials that contended materials fail because of a critical combination of normal stress and shearing stress and not from either maximum normal or shear stress alone.

The failure envelope is a curved line which is for the most soil mechanics problems, it is sufficient to approximate the shear stress on the failure plane as a linear function of the normal stress. It can be written as

$$\tau_f = c + \sigma \tan \varphi \qquad \qquad (2.1)$$

Where, τ_f = shear strength

c = cohesion

φ = angle of internal friction

σ = normal stress on the failure plane

In saturated soil, the normal stress at a point is the sum of the effective stress (σ') and pore water pressure (u). The effective stress σ' is carried by the soil solids. The Mohr-Coulomb failure criterion, expressed in term of effective stress as equation 2.1

$$\tau_f = c' + \sigma' \tan \varphi' \qquad\qquad\qquad (2.2)$$

Where, τ_f = shear strength

           c' = cohesion

           φ' = friction angle

           σ' = effective stress on failure plane at failure

The relationship between shear strength and effective stress can be represented by the Mohr-Circle Diagram as shown in Figure 2.1
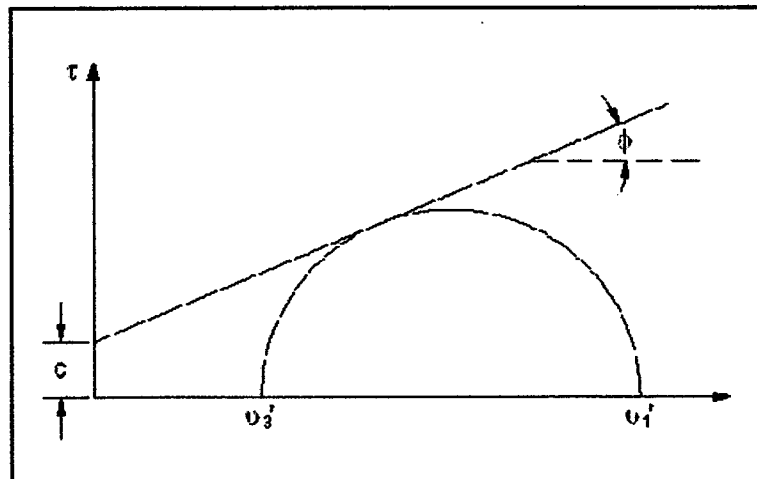

Figure 2.1: Mohr-Circle Diagram

2.5   Factor of Safety

Factor of safety is defined as the ratio between a design value and a failure value. The more variables the soil, the less able one is to accurately define its average or most critical properties, and the higher the factor of safety.(Richard L. Handy, 2007) Analysis of stability of slopes in terms of factor of safety is important to define the stability of a slope. (Agrahara Krishnamoorthy, 2007). The factor of safety also known as safety factor is used to provide a design margin over the theoretical design capacity to allow for uncertainty in the design process.

Increasing a factor of safety can add substantially to cost. The strength and the number of bonds that form at the interface between two particles are influenced very much by the physical and chemical nature of the surface of the particles. In other word, the shear resistance can be developed from effective stress on the failure plane at failure, cohesion and internal friction of soil.

To make sure that slopes are safe, the shear resistance, τ_f should be higher than the shear stress developed along the potential failure surface soil, τ_d as shown in Eq. 2.3.

$$\tau_f \geq \tau_d \qquad\qquad (2.3)$$

Therefore, from this principle factor of safety, FS can be derived as shown in Eq.2.3.9.

$$F_S = \frac{\tau_f}{\tau_d} \qquad (2.4)$$

Where, F_S = factor of safety with respect to strength

τ_f = average shear strength of the soil

τ_d = average shear stress developed along the potential failure surface

Factor of safety also can be expressed in terms of resistance/mobilize forces or resistance/sliding moment depends on the method applied in stability analysis. It is assumed that the shear strength is mobilized simultaneously along the entire (predetermined) failure plane. Then the factor of safety for the predetermined failure wedge can be defined based on either the forces or moments as follows:

$$F_S = \frac{(Force/Moment)*Stabilizing}{(Force/Moment)*Destabilizing} \qquad (2.5)$$

It must be noted that the stabilizing force or the stabilizing moment is the maximum force or the maximum moment that can be generated by the failing soil along the failure plane. Hence, these quantities can be determined by assuming that shear strength is mobilized along the entire failure surface.

In common practice, the task of the engineer charged to provide an appropriate factor of safety in their analysis of slope stability. This is important to make sure that the designed slopes are safe and to avoid critical condition where the stress mobilized in soil is less than or equal to the shear resistance and to prevent any unexpected factors during analysis and construction. The minimum factor of safety as suggested by FHWA and AASTHO are given in the Table 2.2 and Table 2.3 while Table 2.4 shows the guideline for Safety Factor.

Table 2.2: Suggested Minimum Factors of Safety from FHWA

Condition	Recommended Minimum Factors of Safety (FS)
Highway embankment	
Side slopes	1.25
Slopes affecting significant structures	
(e.g., bridge abutments, major retaining walls)	1.30

Source: From Federal Highway Administration, 1998, *Load and Resistance Factor Design (LRFD) for Highway Bridge Substructures*, Washington, DC.