SIMULATION OF RIVER EMBANKMENT STABILITY: A CASE STUDY ON FAILURE AND REMEDIAL METHOD AT MUAR RIVER, PANCHOR, JOHOR

SITI NORAZELA BINTI HASAN

UNIVERSITI TEKNOLOGI MALAYSIA

ABSTRACT

The soil movement on failed slope had caused substantial failure of soldier pile wall at Muar River embankment, Panchor town, Johor. The existing retaining wall has totally collapsed during low tide period is due to insufficient embedded length of existing wall system and failure due to excessive deformation of the wall and slope sliding under backfilling surcharge and human and traffic activities. To facilitate investigating causes of the failure, a computer simulation of slope stability using SLOPE/W is performed to simulate slope condition before and after construction of the study area and to check the total displacement after the construction by using PLAXIS V8.2. The river embankment collapsed during low tide period thus, the calculated back analysis of factor of safety (FOS) is based on the different at every changes of water level.The result of simulation analysis established the fact that global soil mass had a lateral movement direction toward to installed soldier pile wall generates a combination of mobilized shear force and lateral pressure larger than the capacity or strength of the soldier pile wall. Furthermore, the simulation analysis deduces that the slope instability become greater as moisture or pore-water pressure in the slope increase or decrease in soil’s shear strength. FOS determined is 0.966 during low tide period where the existing retaining wall has totally collapsed. Therefore there are 3 options of methods to be introduced to overcome the failure which are all the options introduced show the FOS ranging from 1.378 to 1.435. The anticipated settlement is in the order of 409mm over 25 years after construction.

ABSTRAK

Pergerakan bumi atas cerun telah menyebabkan kegagalan tembok cerucuk di Sungai Muar, Pekan Panchor, Johor. Tembok cerucuk awalnya telah mengalami kegagalan sewaktu air surut dan ianya berlaku disebabkan kedalaman tembok cerucuk yang tidak mencukupi serta mengalami pergerakkan yang disebabkan oleh beban dan aktiviti lalulintas di atasnya. Perisian SLOPE/W digunakan bagi menyiasat kegagalan sebelum dan selepas pembinaan dan manakala perisian PLAXIS V8.2 juga digunakan untuk menyemak pergerakan total selepas aktiviti pembinaan di kawasan tersebut. Oleh kerana tambakan mengalami kegagalan sewaktu air surut, analisis bagi nilai faktor keselamatan disemak berdasarkan pada setiap perubahan paras air. Keputusan analisis simulasi menunjukkan bahawa keseluruhan tanah mengalami pergerakan sisi menuju ke arah tembok cerucuk dan menghasilkan daya ricih dan tekanan sisi yang diaruh oleh pergerakan ini adalah lebih besar daripada kekuatan tembok cerucuk. Keputusan analisis ini juga mendapati bahawa kestabilan cerun akan terjejas dengan kenaikan tekanan air atau dengan penurunan kekuatan ricih tanah. Oleh yang demikian, nilai faktor keselamatan yang diperolehi sewaktu air surut adalah 0.966. bagi mengatasi masaalah keruntuhan tembok cerucuk ini, 3 jenis kaedah kerja pembaikan dikenalpasti dan dianalisa setiap satunya. Berdasarkan analisa yang dibuat, ketiga-tiga kaedah ini memberi nilai faktor keselamatan di antara 1.378 - 1.435. Manakala tanah mengalami pemendapan sebanyak 409mm bagi tempoh 25 tahun selepas pembinaan.

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c	:	Cohesion of Soils
C_c	:	Compression Index
C_v	:	Coefficient of Consolidation
D	:	Total deformed clay thickness
E	:	Modulus of elasticity
G_s	:	Specific gravity
H_{nc}	:	Threshold height
I	:	Moment of inertia
Ip	:	Plasticity Index
m_v	:	Ceofficient of Volume Change
s	:	Settlement
S_u	:	Undrained Shear Strength
w_L	:	Liquid limit
w_P	:	Plastic Limit
y_m	:	Maximum Horizontal Displacement
σ_o	:	Initial total stress
σ_{vo}'	:	Initial effective stress
γ_d	:	Dry unit weight
γ_s	:	Saturated unit weight

CHAPTER I

INTRODUCTION

1.1 General

Evaluating the stability of the slope in soil is an important, interesting, and challenging aspect of civil engineering. Concern with the slope stability has driven some of the most important advance in our understanding of the complex behavior of soil.

Experience with the behavior of slope and often with their failure, has led to development of improved understanding of the changes in soil properties that can occur over time, recognition of the requirements and the limitations of laboratory and in situ testing for evaluating soil strength, developments new and more effective types of instrumentation to observe the behavior of slope, improved understanding of the principles of soil mechanics that connect soil behavior to slope stability, and improved analytical procedures augmented by extensive examination of the mechanics of slope stability analyses, detailed comparisons with field behavior and use of computers to perform thorough analyses.

This study will focus on riverbank slope failure and remedial method have been done and to analyze the failure before and after the construction. Although many mitigation works had been planned and designed prior to the construction of the project, there still exist many uncertainties associated with the material, spanning from it is complex origin.

The emergence of development in construction industry has minimized the preferred site of geotechnical quality for construction although these sites are known to reduce technical problems and thus the cost associated with their construction. By that, socio-economic and political considerations have forced the use of sites of lower quality and in particular, the sites covered by compressible soils. In developed country such as Malaysia, the chances to have good quality construction sites become rarer and it is necessary to choose sites that include compressible soils, especially for industrial structures and transportation projects. Therefore, the tasks to do constructions on these compressible soils have become a challenge for geotechnical engineers all over the world.

Soils with characteristics of low strength and compressible exist all over the world. One of the most significant problems arises because of its characteristics that are difficulties in supporting loads on such foundation. The problem arises with low strength is that it leads to difficulties in guaranteeing the stability of the structure on this type of soil. On the other hand, this type of soil also associated with high compressibility which leads to large settlements and deformations of the structure.

Clays, referring to the United Soil Classification System, are fine-grained soils with more than 50% by weight passing No.200 US Standard sieve (0.075 mm). Soft clay is defined as clay with shear strength below 25 kPa (Brand & Brenner, 1989). Soft soils have weak compressibility and known to engineers as very complex, problematic, and treacherous materials. That is why many structures constructed on soft clay experiencing failure.

Because of this, it is important to continue research effort on this problem in order to resolve the problems posed by construction on soft clay.

1.2 Problem Statement

There are many circumstances in slope, where the civil engineer must investigate the stability of slope by performing stability analysis. The construction on soft cohesive soil is increasing lately because there are too many suitable sites for construction or infrastructures or any other developments. The problems related to this type of soil are stability and settlement. Due to that the understanding of knowledge of engineering characteristic on soft clay are critical and should understand by people related to this field. The selection of construction method on this formation is restricted by cost, duration of completion and benefit.

The development in South East Asia had been so rapid that studying the soft clay is very important. However the study have been done mostly concentrated on major cities such as Kuala Lumpur, Singapore, Bangkok, Jakarta and others. Because of that the marine clay area in Muar, Johor are chosen in this study in order to develop the simulation analysis of slope stability for riverbank of Sungai Muar, Johor.

It is difficult to get samples from soft clay for laboratory testing, such as shear strength. Some of the tests take a long time to complete and also need a careful analysis. So correlations with basic properties play an important role to overcome this problem. Besides that, the correlation of shear strength with depth could also help the engineer to make prediction of the shear strength soil at certain depth below ground level.

Existing method of slope stability analysis using slice (Bishop 1955, Janbu 1957) are based on the limit equilibrium theorem. An implicit assumption in equilibrium analyses of slope stability is the stress-strain behavior of the soil is ductile, i.e., the soil does not have a brittle stress-strain curve (where the shearing resistance drops off after reaching a peak). This limitation result from the fact that the method provide neither information regarding the magnitudes of the strain within the slope, nor any indication about how they may vary along slip surface (Duncan, 1996). Besides it, the analysis only considered force and moment acting on the slice with total disregard to the deformation developed in the slice. Thus, it is not possible to obtain reliable result from the analyses of solely based on the method of slice (Terado et al., 1999).

Thus, in order to obtain a unique solution it is necessary to introduce extra conditions. Better analysis should therefore take into account the displacement and deformation of the slices, and also the stresses in the soil mass in determining the stability of slope.

In the other hand, the stability analyses are performed not only to provide a factor of safety once the soil properties are know, but also to establish field shear strength from the study of failures. It is rational to carry out the study determining what actually happened after an unexpected instability has occurred. It is therefore necessary to do some analyses in reverse, which is usually termed as ‘back analyses’. The investigation is not mean to blame who or whom should be responsive to the failure but it collects valuable information that could be used in designing the remedial works as well as guidelines for further projects. The awareness of importance of back analysis has resulted in development of various methods. However the problem always arise in determining the suitable method of analysis and the way back analysis can be carried out.

Failures of slopes will cause economic loss to the community. In addition to the economic loss, sometimes there is loss of life too. There are many factors to cause failure of a riverbank slope and very often these factors are interrelated. In the design of a slope, stability analysis shall be carried out prior to the construction. When the analysis results indicate undesired low factors of safety, strengthening measures should be introduced. When a slope failed and remedial works are required, it is essential to carry out failure investigation to find out the possible causes. Suitable remedial design can only be carried out after knowing the causes of failure.

Once the main causes of slope failure have been identified, the remedial design can be carried out to correct the problems. Failure investigations were carried out. The possible causes of slope failure were identified. Remedial measures adopted were based on the investigation results, the site conditions, comparison of the construction costs and technical knowledge of the remedial measure. . The investigation is not mean to blame who or whom should be responsive to the failure but it collects valuable information that could be used in designing the remedial works as well as guidelines for further projects.

1.3 Objective and Scope of the Study

The objective of the study is:

1. To determine the stability of the slope before and after the construction of Muar River at Panchor town, Johor.

2. To determine the total displacement after completion of construction on soft soil

Stability analysis of slope is carried out based on the computer modeling using SLOPE/W, limit equilibrium software and PLAXIS V8.2, a finite element package.

1.4 Limitation of the Study

The scope of the study includes several aspects as follows:

(i) Literature review on previous embankment failure cases including the problems, mode of failure, shear strength parameter obtain from the field test and laboratory test and factor of safety.

(ii) To simulate, verify and modify the various construction stages in term of constructability, stability and cost-effectiveness, using relevant limit equilibrium method software such as SLOPE/W.

(iii) The analysis also been conducted by using relevant finite element method such as PLAXIS. Stresses of the soil mass along the critical slip surface as well as the displacement and deformation are determined using the theory of finite element.

Jabatan Pengairan dan Saliran (JPS) had commissioned Kumpulan IKRAM Sdn Bhd to undertake soil investigation for detail study, while the JPS undertake the design of the failure of the embankment of Sungai Muar, located at Pekan Panchor, Johor based on the soil investigation. Field works for the investigation were carried out by IKRAM Engineering Services Sdn. Bhd, IKRAM Selatan from 23 April 2008 to 26 April 2008, understanding supervision by Kumpulan IKRAM Sdn Bhd and JPS. However the laboratory test was completed on 28 August 2008. Geotechnical investigation to perform the Standard Penetration Test (SPT), carry out the provision of disturbed, undisturbed sample and monitoring of ground water, in-situ Vane Shear Test to determine the undrained shear strength of cohesive soil and to carry out Laboratory Test on disturbed and undisturbed sample. The test locations are shown in the site plan as shown in **Appendix 1**. Thus the result of field testing as attached in **Appendix 2**.

The **Table 1.1** summarizes the soil investigation works that were carried out at site. The works were carried out in accordance with JKR specification.

Investigation works	**Quantity**
23 April 2008 - 26 April 2008	
Boreholes	4 nos
Vane Shear Test (sampling in borehole)	4 nos
26 April 2008 - 28 August 2008	
Laboratory testing	Refer **Appendix 3**

Table 1.1: Summarizes the soil investigation works that were carried out at site

Field explorations that are carried out using the Boring plant type 'YWE' which is capable of boring and drilling to the depth required which was 30m deep. These boring rings are also suitable for advancing the borehole, sampling, in-situ testing such as vane shear test and rock drilling in accordance with the relevant specification of each of these operations.

The methods for advancing the borehole were rotary boring, continuous sampling rotary drilling or a combination of these methods. When undisturbed sample were taken, a reasonably clean hole was provided and the portion of soil to be sampled was not unduly disturbed. Disturbed sample were obtained by means of split spoon samplers, which equipped with flap retainer or other attachments necessary for cohesion less soil. The maximum amount of soil sample obtained was such that the quantity is sufficient to carry out various classification tests. The vane shear test results as attached in **Appendix 4.**

Soil sample were collected in the form of undisturbed. About 40mm of the soil were removed from the top and bottom of the thin-wall sampling tube. Then the ends of the tubes were filled with non-shrinking microcrystalline wax before sending to the laboratory. Laboratory test that was carried out are as listed below:

(i) Moisture Content
(ii) Atterberg Limit
(iii) Particle size Distribution
(iv) Unconsolidated Undrained Triaxial Test
(v) Consolidated test - 1D
(vi) Visual and Manual examination

1.5 Research Area

This study presents the failure of embankment of Sungai Muar located at Pekan Panchor Muar, Johor.

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