FIBRE OPTIC SENSING MONITORING SYSTEM FOR PILE ON SLOPE

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DEDICATION

ALHAMDULILLAH...

Praise to Allah for His unlimited guidance and blessing

This thesis is dedicated to my beloved parents Khairul Anuar bin Kassim (father) and Nor Azrina binti Deris (mother), to my precious siblings, to my supervisor, lectures and all of my friends.

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ABSTRACT

Monitoring system is very important in geotechnical works. In slope reinforced with pile, monitoring system is needed to monitor the displacement of the pile due to the slope instability. Therefore, this study will focus on a newly develop monitoring system using an optical fibre sensing technology to measure the strain of the pile install on the slope. The strain on the pile will be measure due to the slope instability and load increment on the slope crest. The advantage of using Optical fibre sensing technology is that it can give the strain measurement along the optical fibre length instead of from discrete points. This paper describes the experimental work conducted with the use of a distributed sensing technology called Brillouin Optical Time Domain Analysis (BOTDA). A small scale physical soil slope model was stimulated to measure the strain and calculate the displacement of the pile. The physical model result is then compared with numerical modeling using SLOPE/W and SIGMA/W. As a result, fibre optic is a good approach for geotechnical instrumentation and monitoring since they are sensitive toward the movement of geotechnical structure and soil. The optical fibre can measure the strain along the pile up to micro strain (με).

ABSTRAK

Sistem pemantauan sangat penting dalam kerja-kerja geoteknik. Bagi cerun yang dikukuhkan dengan cerucuk, Sistem pemantauan diperlukanuntuk memantau anjakan cerucuk disebsbkan oleh ketidak stabilan cerun. Oleh itu, kajian ini akan tumpu kepada kaedah baru bagi sistem pemantauan yang menggunakan teknologi gentian optik untuk mengukur keterikan cerucuk di cerun. Keterikan cerucuk akan diukur berdasarkan oleh ketidak stabilan cerun dan penambahan beban pada puncak cerun. Kebaikan menggunakan teknologi gentian optik adalan ia dapat mamberi bacaan sepanjang kabel gentian optik dan bukan hanya ukuran diskrit. Kajian ini nenerangkan kerja-kerja ekseperimen yang dijalankan dengan bantuan taknologi yang bernama Brillouin Optical Tmi Domain Analysis (BOTDA). Kerja fisikal cerun skala kecil diransangkan untuk mengukur keterikan and mengira anjakan cerucuk. Hasil kerja model physical cerun di bandingkan dengan model numerical menggunakan SLOPE/W dan SIGMA/W. Hasilnya, serat optik merupakan pendekatan yg baik bagi pemantauan geoteknik kerana seret optik sensitif terhadap struktur geteknik dan tanah. Serat optik boleh mengukur keterikan sepanjang cerucuk hingga keterikan micro (με).

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LIST OF ABBREVIATIONS

BOTDA	-	Brillouin Optical Time-Domain Analysis.
FDM	-	Finite Difference Method.
FEM	-	Finite Element Method.
BEM	-	Boundary Element Method.
DEM	-	Distinct Element Method.
DDA	-	Discontinuous Deformation Analysis.
BPM	-	Bonded Particle Model.
FBG	-	Fiber Bragg Grating.
UTM	-	Universiti Teknologi Malaysia
DSTS	-	Distributed Strain and Temperature Sensor.

LIST OF SYMBOLS

m	-	Metre
μm	-	Microns
c_1 *and* c_2	-	Shear Strength
k_1 *and* k_2	-	She
T	-	Shear Force
d	-	diameter
l	-	Length
n_I *and* n_R	-	Indices of refraction
I	-	Angle of incident
R	-	Angle of refraction
Ø	-	Friction Angle
c	-	Cohesion
γ_{bulk}	-	Unit Weight Bulk
$\mu\varepsilon$	-	Micro- strain
υ	-	Poisson' Ratio

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

Slope failure is one of the geotechnical failures that are widespread in many regions in the world. With the development of the economy and infrastructure constructing, more and more artificial slopes are encountered in practical engineering, such as embankment, road excavation, dike, surface mining and so on (Wang, Li, Shi, & Wei, 2009)A slope failure is a phenomenon that a slope collapses abruptly due to weakened self-retain ability of the earth under the influence of a rainfall or an earthquake. This failure directly threatens people lives and causes significant economic losses due to its sudden collapse. Therefore, countermeasures and early warning monitoring system plays a crucial role.

Different kinds of countermeasure have been developed in order to control the slope failure occurrence and to ensure the slope stability. One of the methods used to improve the slope stability is the installation of piles. The use of piles as a retaining element has been applied successfully in the past and proved to be an effective solution, since piles can be easily installed without disturbing the equilibrium of the slope (Hassiotis, Chamean, & Gunaratne, 1997). However, a proper stability analysis need to be carried out and monitoring system is still needed after the piles been installed at the slope to monitor the behavior of the structure due to the movement of slope.

In previous studies, instrumentation such as inclinometer was used to monitor the bending moment induced in the pile by slope movements (Smethurst et al, 2007). However, the data obtained need to be done at a few discrete points which consume more time and energy.

At present, monitoring techniques are changing from conventional methods which consist of point mode monitoring to a distributed monitoring system. In recent years, a distributed strain sensing used for monitoring structural health of building, bridges, dams, tunnels and others vital civil engineering infrastructures has been developed using light scattering based on Brillouin optical time- domain Analysis (BOTDA) technique. This technique is a nondestructive, compatible with distributed monitoring and on distance monitoring, anti-electromagnetic interference, corrosion resistance and durable. It is suitable for monitoring and early warning for structural and geotechnical engineering. It is also small, lightweight and can be easily installed into or on the surface of the monitored objects (Wang et al., 2009).

1.2 Problem Statement

The selection of monitoring instrumentation on slope is very critical. The instrumentation selected should be able to provide a reliable data. Most of the conventional strain sensing instrumentation can only produce data from a few discrete points. This only cause to consume more time and energy. This might also cause engineers to miss critical locations of soil movements. This problem can be solved by using the distributed fibre optic strain sensor which is incorporated using Brillouin Optical Time Domain Analysis (BOTDA) technique. The BOTDA will measure strain and temperature along the length of the optical fibre cable.

However, the accuracy and effectiveness of the optical fibre sensing tehnology is still a concern point since the application of the optical fibre sensing technology is not fully developed and established. Mohamad (2008) stated that the effectiveness of the fibre optic depends on the contact between the fibre optic and the geotechnical element or soil mass where the fibre optic can measure the correct amount of strain. Mohamad (2012) also stated that the accuracy of the strain measurement among others depends on the instrument laser setup.

Therefore, the effectiveness and accuracy of the optical fibre sensing technology is evaluated by considering the contact between the fibre optic and the geotechnical element and the laser setup of the optical fibre sensing technology. By producing a physical model and assisted with a numerical model the effectiveness of the optical fibre sensing technology can be validated.

1.3 Aim and Objective

The aim of this study is to determine the deflection of the pile due to the instability of the slope as well as to validate the effectiveness of the optical fibre sensing technology and to fulfill the objective of this study. The objectives are set as follows:

(a) To model a physical soil slope and estimate the slope failure.

(b) To model pile on slope.

(c) To monitor the pile behavior due to slope instability, and loading increment using BOTDA technique.

(d) To validate the application of distributed optical fibre strain sensors using software application.

1.4 Scope of Study

The scope of this study will be based on the objectives that were stated. This study will start by producing a soil slope model with determined geometry. Then a pile prototype is selected to be installed on the soil slope model. The pile prototype install will be stimulated as an inclinometer which allowing the presence of lateral force on the pile to determine the strain on the pile faster. No axial force will be acted on the pile. Therefore, a PVC pipe was chosen as a prototype pile to be used on the soil slope model since it’s more flexible. The pile will be monitored by using distributed optical fibre strain sensor using BOTDA technique. The monitoring of the pile will be based on the slope instability and loading increment on the slope. The

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