AUTOMATIC WIRELESS ACCELEROMETER MONITORING SYSTEM (AWAM) FOR SLOPE

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A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Civil-Geotechnics)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JUNE 2015

Specially dedicated to my beloved parents and friends

ACKNOWLEDGEMENT

Alhamdulillah, thanks to Allah the Almighty for His guidance and help in giving me the strengths to complete this report. In particularly, I would like to express my sincere appreciation to my project report supervisor, Dr. Ahmad Safuan Bin A. Rashid, for his encouragement, knowledge, motivation, patience and time in helping me along the preparations of this report. Thanks to all staff of Geotechnical Laboratory, Faculty of Civil Engineering, UTM Skudai especially to Mr. Zulkifli, who are willing to provide technical advices, guidance and support in various occasions.

Thanks to all my friends especially Yusliza and Subha who give their support and help. They always giving their encouraging support until this project completed. I am also dedicated my thanks to all lecturers who taught me during my study at Faculty of Civil Engineering, UTM Skudai.

I wish to express my appreciation to the Jabatan Perkhidmatan Awam (JPA) for the scholarship. Without their supporter, I am not able to further my studies here in UTM Skudai. Thanks also to my employer, Public Works Department (JKR) who are willing to give time for me pursue my goal to have a Master in Geotechnical Engineering.

Last but not least, I am grateful to all my family members especially to my mother, Rohani Binti Omar, my brother and sisters for their continuous support and concern at anytime, anywhere and everything I need during completing this project. Thank you very much to all of you. A lot of thanks for all parties contributed directly and indirectly for this study. Unfortunately, there are too many of them to be listed in this limited space. I am really grateful to all of them.

ABSTRACT

There are many types of instruments that have been used for monitoring the high risk slopes as a precaution to prevent the loss of lives. Unfortunately, there is no such works of installation slope monitoring instrumentation as detectors and preventive actions before the slope failure. Automatic Wireless Accelerometer Monitoring System (AWAM) is a new device of monitoring system using accelerometer to be introduced in this research. It is more efficient than conventional techniques and less expensive. The application and operation of this system does not interrupted by physical obstacles, different climate conditions, and the construction works at site. In addition, no contact is required since the accelerometers are installed on the slope. Consequently, geomorphology limitations are not considered as limitations of the system operation. This study is to demonstrate the sensor database system by AWAM and the effectiveness of the device to monitor slope failures and act as a warning sign. It were presented in two parts; the first part consist of the physical modelling calibration test from sensor database system (AWAM device) and from load cell test, the second part will discuss on the numerical model simulated by using software (Slope/W and LimitState) and the data from vane shear test. The AWAM device can be used as a monitoring system to detect soil movements. However, accelerometers were able to give AWAM's readings if the device is moving in tilting modes.

ABSTRAK

Terdapat pelbagai jenis instrumen yang boleh digunakan untuk tujuan pemantauan cerun berisiko tinggi sebagai langkah berjaga-jaga bagi mengelakkan kehilangan nyawa. Malangnya, kebanyakkan kerja-kerja pemantauan cerun yang dilaksanakan tidak memasang sebarang peralatan pengesan dan tindakan pencegahan sebelum kegagalan cerun. Sistem pemantauan automatik tanpa wayar dengan *accelerometer* (AWAM) adalah alat baru yang diperkenalkan di dalam kajian ini dengan menerapkan konsep pecutan graviti di dalam system berkenaan. Ianya lebih berkesan dan murah berbanding teknik konvensional. Aplikasi dan operasi sistem ini tidak terganggu oleh halangan fizikal, keadaan iklim yang berbeza, dan kerja-kerja pembinaan di tapak. Di samping itu juga, alat ini tidak memerlukan sebarang pemeriksaan secara berkala setelah pemasangan dibuat di cerun tersebut. Oleh yang demikian, masalah geomorfologi tidak dianggap sebagai had kepada operasi system ini. Kajian ini dibuat bagi menunjukkan bahawa sistem pangkalan data sensor oleh AWAM berkesan sebagai peranti untuk memantau kegagalan cerun dan juga bertindak memberikan tanda amaran. Ia dibentangkan di dalam dua bahagian; bahagian pertama terdiri daripada ujian penentukuran pemodelan fizikal daripada sistem pangkalan data sensor (peranti AWAM) dan dari ujian sel beban, bahagian kedua akan membincangkan hasil simulasi model berangka dengan menggunakan perisian (Slope / W dan LimitState) dan data dari ujian *vane shear*. Peranti AWAM boleh digunakan sebagai satu sistem pemantauan untuk mengesan pergerakan tanah. Walau bagaimanapun, *accelerometer* hanya dapat memberikan bacaan kepada AWAM jika peranti bergerak dalam mod *tilting*.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION AND SYMBOLS

LoS	-	Line of Sight
GPS	-	Global Positioning System
g	-	Gravity Force
R	-	Radius
G_s	-	Spesific Gravity
w_L	-	Liquid Limit
w_P	-	Plastic Limit
I_P	-	Plastic Index
Ls	-	Linear Shrinkage
USCS	-	Unified Soil Classification System
FOS	-	Factor of Safety
c_u	-	Shear Strength
γ_s	-	Unit Weight
H	-	Height of Slope
D	-	Foundation Depth
θ	-	Slope Angle
Ø	-	Friction Angle
π	-	Phi
X_1	-	Result from Sensor Database System at X Direction for Device 1
X_2	-	Result from Sensor Database System at X Direction for Device 2
Y_1	-	Result from Sensor Database System at Y Direction for Device 1
Y_2	-	Result from Sensor Database System at Y Direction for Device 2
Z_1	-	Result from Sensor Database System at Z Direction for Device 1
Z_2	-	Result from Sensor Database System at Z Direction for Device 2

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 General

Slope engineering is one of the areas of expertise in civil engineering. Malaysia as a country that experienced rainfall throughout the year often gets reports of accidents due to slope failure. Failure of a slope especially when involving a large scale will give an impact to the human to feel insecure. Fatalities due to these failures are something that has to be prevented such as precautions by the government. Even though at times there were no deaths, failure of a slope have bad implications to the economy of a country, delays in construction project, destruction of properties and numerous other problems.

The main cause of slope failure is due to the presence of water such as groundwater or surface runoff due to the rain. Besides that, slope failure can occur before, during and after construction. The problem during designing the slope is due to the less of experienced engineers is one of the factors that can contribute to slope failure. Site investigation is very important and necessary for designing the slope. Site Investigation is the process in which all relevant information concerning the site of a proposed civil engineering or building development and its surrounding area is gathered. Ground investigation is a narrower process, involving the acquisition on the ground conditions in and around a site.

Site investigation is important for gathering of all the information on ground conditions which might be relevant for design and construction on a particular site. The most important data to be produced first by a designer is the subsoil profile with respect to subsoil properties, shear strength and groundwater condition, etc. These data are indispensable to the designer to produce a generalized subsoil profile or ground characterization for slope design. How many boreholes and what tests are necessary to be done to obtain the necessary subsoil data for a site depend very much on the experience and knowledge of the designer about the local geology and with particular reference to historical use of the site, environmental constraints and the general stability of the existing site conditions.

Failure of providing enough information from site investigation will cause the contractor to encounter a lot of problems during the design stage as well as during construction period. In addition, construction works will be delayed due to several unforeseen circumstances due to insufficient information gathered from the site investigation reports.

After the construction, routine maintenance is necessary to keep the slope safe. Lack of maintenance of the slopes and retaining wall will contribute to disaster like landslide. Routine maintenance inspections should be done in a certain time period to ensure that the slopes are in a safe condition. The drainage system must be maintained so that it works well to drain the water out from the slopes.

1.2 Background

Landslides always happen especially during the rainy season. Many cases have been recorded as landslides in Malaysia that made a big impact to the society. One adverse events that is still remembered until today is a tragedy of Highland Tower on December 11, 1993 in Park Hillview, Ulu Klang, Selangor, Malaysia . The incident has claimed the lives of 48 citizens when one of the apartment building collapsed due to slope failure. This failure is caused by the rapid development in the hilly area known as Bukit Antarabangsa Development Project. Factor of water from surrounding development and monsoon rains at the end of the year is the major cause of this catastrophe. After the tragedy, a series of landslides occurred around there in which it also has claimed many lives. *(Refer Table 1)*

Landslide on 21 May 2011 once again led to tragedy tears. The adverse events that killed 16 peoples with 15 people from them are residents of orphans Hidayah Madrasah Al -Taqwa in Hulu Langat. This incident was also caused by the heavy rains that occurred a few days before the incident.

Figure 1.1: The Landslides at Hulu Langat Have Killed 16 People, of Whom 14 were Children Resident in the Orphanage. *(www.dailymail.co.uk/news)*

Table 1.1: Historical of Major Landslide in Malaysia 1993 - 2013

Date of Occurrence	Landslide Location (Name)	Fatality (Nos)	Injury (Nos)	Highway Closure
11 December 1993	Highland Towers	48	-	-
30 Jun 1995	Genting Sempah	20	22	-
6 January 1996	Km 303.8, Gua Tempurung	1	-	Yes
29 August 1996	Pos Dipang, Perak	38	-	-
26 December 1996	Keningau, Sabah	302	-	-
20 November 2002	Taman Hillview	8	-	-
26 October 2003	Km 21.8, Bukit Lanjan	-	-	Yes
12 October 2004	Km 303, Gua Tempurung	-	1	Yes
31 May 2006	Kg. Pasir, Ulu Kelang	4	-	-
6 December 2008	Bukit Antarabangsa	4	15	-
21 May 2011	Hulu Langat	16	-	-

There are many types of instruments that have been used for monitoring the slopes at high risk. One of the instruments used is inclinometer. Inclinometer is used to monitor the lateral earth movements (deformation) especially in landslide area and embankment. They are also used to monitor the deflection of retaining wall and piles under load. Other instrumentation that been used nowadays is a Robotic Total Station. This is a new technology by integrating high precision land surveying instrument with proven real time communication technology. The main function of this instrumentation is to provide a total integrated deformation monitoring solution, operating continuously with analysis intelligent and early warning system. This system (source from *http://www.tmcsis.com/?loc=news)* will be able to:

i) Monitor all the selected critical monitoring points
ii) Measure continuously at a specified interval
iii) Send the observed data automatically to main server
iv) Calculate automatically the differences to identify movement
v) Send out warning to personals thru SMS once the movement exceeded the permitted tolerance.

1.3 Problem Statement

As of today, slope failures still occurs despite various improvement done in the design, taking into account the factor of safety and maintenance work routinely performed. Although mistakes have been learnt, fatal accidents due to slope failures can't be prevented. One of the factors is lack monitoring work primarily on high-risk slopes. Besides, the occurrence of heavy rain is something that cannot be avoided to control the landslides. However, by monitoring the high risk slopes it will be a precaution to prevent the loss of life. Unfortunately, there is no such works of installation slope monitoring instrumentation as detectors and preventive actions before the slope failure.

There are few techniques to determine the performance of slope by monitoring the initial movements that cause deformations just before the slope collapsed. However, current practice in Malaysia and the implementation of slope monitoring work is often neglected as the cost and maintenance of instrumentation is high. Conventional instrumentation for monitoring deformation have a limitations such as a factor of geomorphology at the area, physical obstacles, different climate conditions, and the on-going construction work on the site. These limitations will cause an expensive of the equipment to be purchased. Besides that, the transmission of the data is a main problem with addition to the absence of electricity supply since most slopes are isolated and away from the power source. This method also needs a team to supervise, monitor and take a readings manually.

1.4 Importance of Study

This research is intended to develop a monitoring instrumentation for slope. This instrumentation will give a benefit on the monitoring of deformation that occurs on slope area. The objectives for this thesis are:

i) To propose the concept of automatic and wireless by using an accelerometer for monitoring system.
ii) To conduct a small-scale physical laboratory testing to calibrate the system and detect the signal of failure.
iii) To introduce a new product of slope monitoring system with less cost, friendly user and more effective.
   - ✓ Automatic Wireless Accelerometer Monitoring System (AWAM)

1.5 Scope of Study

Automatic wireless accelerometer monitoring (AWAM) system will implement an early warning system that can be achieved by using real-time data that is programmed to send a signal when it reach a critical value to cause slope failure. The main components (hardware and software) of the system are as follows:

i) Data provider Accelerometers
ii) Communication provider
iii) Data acquisition and analysis devices
iv) Data acquisition and analysis software

Physical model test was constructed in the laboratory to obtain an appropriate variable factor for the system. The tests were carried out with the concept of load increment until it reach a failure.

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