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Prediction of Landslides Using Surface Wave Analysis Incorporating with GIS: A Case Study in Selangor, Malaysia

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PREDICTION OF LANDSLIDES USING SURFACE WAVE ANALYSIS INCORPORATING WITH GIS: A CASE STUDY IN SELANGOR, MALAYSIA

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ABSTRACT

Sites Bukit Antarabangsa, Selangor and at Universiti Kebangsaan Malaysia, Selangor were investigated using Multichannel Analysis of Surface Wave (MASW) method. Surface wave method is incorporated with Geographic Information System (GIS) to investigate the hazardous zone for landslides that allows online data to obtain near surface soil profiles. Low frequency seismic signals are used to get 2-D tomography profiles of surface soil near landslides. It is possible to identify landslide risks, if geological and geotechnical properties of soil are known. The effects of different man-made factors for landslides are characteristic properties of soil, slope geometry, road construction etc. The results of analysis of soil properties within the areas are presented in this paper. The GIS interfacing with seismic sensors is capable of showing the shear wave velocity, V_s and shear modulus G_s of risk areas through online seismic records. The aim of this paper is to obtain the online records of risk areas for landslides by getting the soil properties of surface soil using MASW.

INTRODUCTION

Landslides occur regularly and frequently in Selangor, Malaysia with different sizes and shapes due to the country's wet climate and heavy annual rainfall. Landslides occur during earthquake causing saturated soil to lose their strength with ground settlement, lateral spreading, mass movements of the ground and foundation failures. Many landslides are man-made as a result of cutting in roadways and building pad foundations and cutting of natural slopes of hills. Soft Soil with higher clay and compressible organic contents can present settlement and stability problems leading to landslides (Emami & Ghazavi, 2001).

In Selangor, Malaysia, several landslides occur next to road construction at slopes on hilly areas. Roads and highway construction placed on these types of conditions can cause substantial settlement or induce foundation failure. Moreover when vehicle runs away on these conditions, mechanical vibrations generate. These mechanical vibrations also reduce the strength of saturated soil. In addition, building structures or walls located at soft ground conditions are likely to be affected by landslides.

This paper shows the prediction of landslides through the information of near surface soil properties. The method of surface wave analysis is used to obtain near surface soil properties like shear modulus G_s and shear velocity V_s profiles as a non-invasive and robust geophysical testing. Park *et al*. (1999a) shows that the MASW method as an improved technique in surface wave analysis. The MASW method is used in a shallow marine environment (Kaufmann *et al.*, 2005), to determine collapse and subsidence feature (Xia *et al.*, 2004), to represent near surface anomalies (Ivanov *et al.*, 2003) and for pavement feasibility test (Roesset, 1998; Park *et al.*, 2001). On a 2-D shear velocity V_s profile, the bedrock surface is shown with high S-wave velocity gradients (Miller *et al.*, 1999a, 1999b). Fracture zones, voids and buried landfill edges, etc. may be indicated by low velocity of shear velocity V_s profile (Miller *et al.*, 1999a, Park *et al.*, 1999b).

Online measurements of seismic data incorporated for prediction of landslides by Mouazen *et al.* (2003) shows the profile of soil compaction based on real-time measurement of the draught (D) of a compaction sensor. In their research work, the Arcview 3.1 GIS software was used to draw the field maps of bulk density, moisture contents, cutting depth of near surface soil. The electrical system in their research includes basic power supply, travel speed sensor, global positioning system (GPS), signal conditioning system, amplifier and data acquisition system.

Incorporating GIS with seismic geophones would provide the quick view of position of risk zone for landslides. This paper shows the case study of severe landslides at Bukit Antarabangsa, Selangor and at Universiti Kebangsaan Malaysia (UKM). During landslides, buildings and other infrastructures built on top of or in the path of a landslide are also destroyed. Proposed online shear velocity V_s profiles will identify the areas where landslides prone soils may be located. With knowledge of surface soil conditions, many landslides can be prevented through appropriate maintenance and adherence to standard geologic and soil engineering recommendations.

CASE STUDY BACKGROUND

In Malaysia, landslide is a serious disruption in a community or a society causing material, economic or environmental losses. The landslides cause severe hazards, damages, casualties and vulnerability with insufficient capacity to reduce the potential chances of risk. This paper also includes the pictures of vulnerability and damages due to landslides in Selangor, Malaysia.

Landslide at Bukit Antarabangsa is introduced as case study A in this paper. Bukit Antarabangsa is an established residential area for the middle working class living close to the capital of Kuala Lumpur. It is a hillside township in the Ulu Klang district of Malaysia. This area is one of the highly landslide prone areas in Malaysia. One of the disastrous landslides occurred in December 2008.

Fig.1. Landslide at Bukit Antarabangsa, Malaysia

Figure 1 and 2 shows the severity of the landslide affecting the livelihood and endangering the lives in Bukit Antarabangsa. This landslide collapses a number of buildings and the infamous highland tower collapse also took place in the vicinity many years earlier. Hazards due to the landslides create dangerous situations that cause injury to life and damage to property or the environment. Our research group visited the landslide at March, 2009 to obtain the soil condition through MASW method at near of this landslide.

Fig.2. Hazards and destructions due to landslide

In this case study, seismic data was acquired using geophones, seistronix device (RAS-24) shown in Fig.3. Seismic data was transferred to a computer to get a shear velocity V_s profile. Here 24 geophones were used to acquire seismic signals and USB interfacing was used to connect RAS-24 device with computer. We followed the optimum field parameters as suggested (Park *et al.*, 2002) during seismic data acquisitions through MASW method. A 2-D tomography of V_s was obtained after dispersion and inversion analysis using the SurfSeis software.

Fig.3.Seismic data acquisition at near of landslide occurrence

Case study, B was carried out at UKM, Selangor, Malaysia. This landslide occurs at slope of hillsides beside the main access road leading to the offices in the university as shown by the Fig.4. A major fracture zone caused by the landslide is clearly illustrated. A thorough investigation at this landslide area was performed and the MASW method was employed to obtain the soil properties.

Fig.4. Landslide at UKM, Malaysia

METHODOLOGY

GIS technology (Fuhrmann *et al.*, 2008) can be used for investigations of high risk zones for landslide in Selangor, Malaysia. Sims *et al.*, (2008) uses information technology including GIS techniques database networking system for planning activities in disaster prone areas. These criteria would be incorporated to find the landslide risk zones. For surface wave analysis, it is essential to obtain the seismic signal for surface soil investigations. Low frequency geophones were used to get the seismic signal in this case study. These geophones used for seismic data acquisition required frequencies from 4 Hz to 100Hz. For the case study at the two sites in Selangor, we have used a 16 lb. hammer to create the seismic signal. Natural vibration such from vehicle motions would be used as a seismic source signal to get online monitoring of surface soil properties.

Figure 5 shows the block diagram of online measurement of seismic data from the field. Recorded seismic data by geophones will be transferred to a computer server through a wireless networking system as indicated in Fig.5. A GPS data logger is used to receive seismic data through an online system. This seismic data is recorded in storage or database system. There is interfacing between this seismic record and Arcview GIS software to get a 2-D profile of surface soil properties. The microcontroller handles the data acquisition, signal processing, calibration, control and communication in wireless networking. The radio frequency (RF) terminal handles the data transmission and reception. The wireless networking (Yick *et al.*, 2008) with mesh topology has to be configured in obtaining better performance to reduce noises with robustness for transmitting the information.

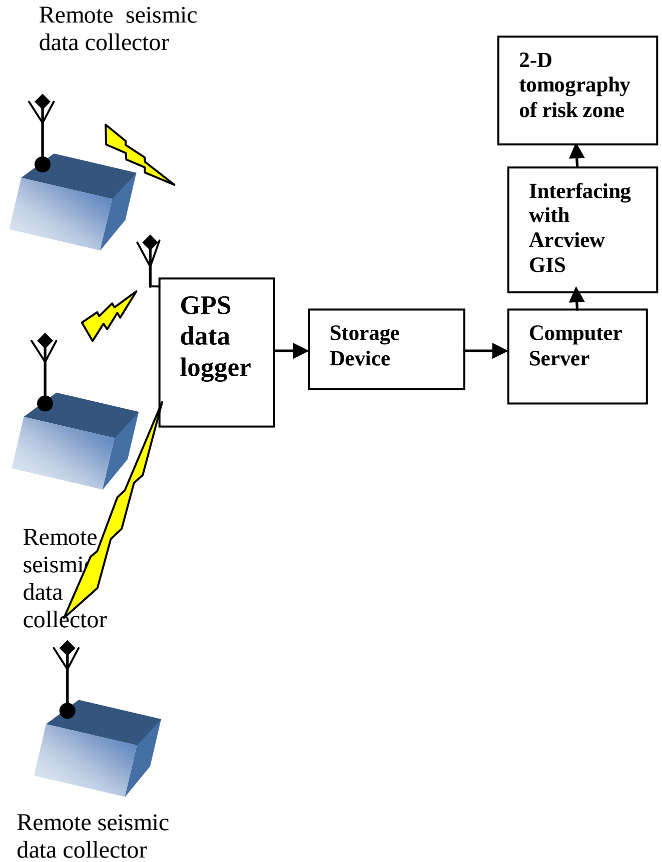

Fig.5. Block diagram of online monitoring of landslide prone area

DISCUSSION

This paper shows case studies on landslides and how landslide prone area can be predicted using surface wave analysis incorporating with online GIS. Introduction of information technology (Yick *et al.*, 2008) in the surface wave analysis enable a potential reduction in destruction and hazards due to landslides. GIS is considered as a modern technology to obtain quicker identification of landslide prone areas according to shear velocity V_s profiles of soil and cracks within soil. It provides a support for an effective and efficient storage and interpretation of remotely sensed seismic data (Fuhrmann *et al.*, 2008). The geo-graphical maps can be created for cities, districts of Selangor, Malaysia through this study.

Results of Surfseis software demonstrate the justification of finding landslide prone areas using surface wave analysis interfacing with Arcview GIS. Recorded seismic signals shown in Fig. 6 for case study A and B are analyzed using the Surfseis software. For case study A at Bukit Antarbangsa, the source station is defined as 5996 where noises are seen in the surface wave analysis. These noises were removed through filtering criteria according to the surface wave method. For case study B at UKM, the source station is defined as 996 where filtering criteria is used to reduce of seismic signal.

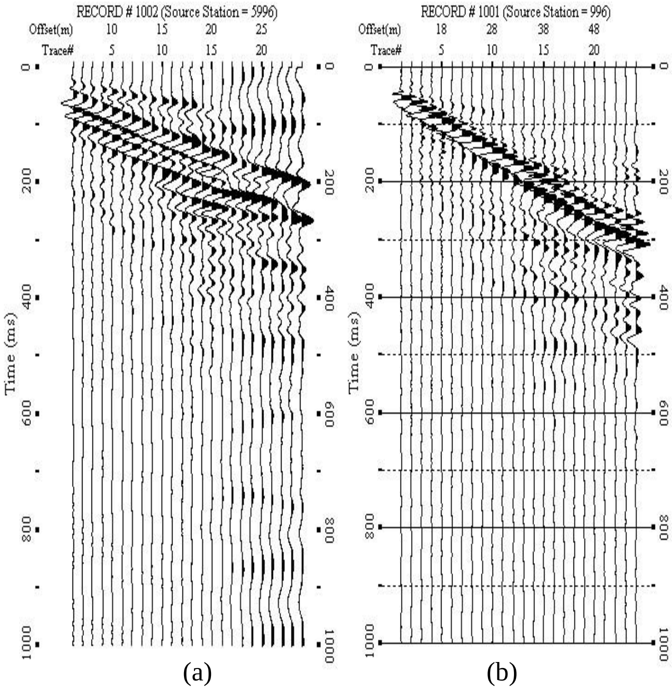

Fig.6. Seismic records for MASW method of (a) case study A (b) case study B

These recorded seismic signals were analyzed as multimodal dispersion curve analysis and inversion analysis in Surfseis software. Frequency-wavenumber (F-K) analyses were included for a better performance in multimodal analysis of the dispersion curve. A 2-D tomography of the V_s profile is obtained after the inversion analysis.

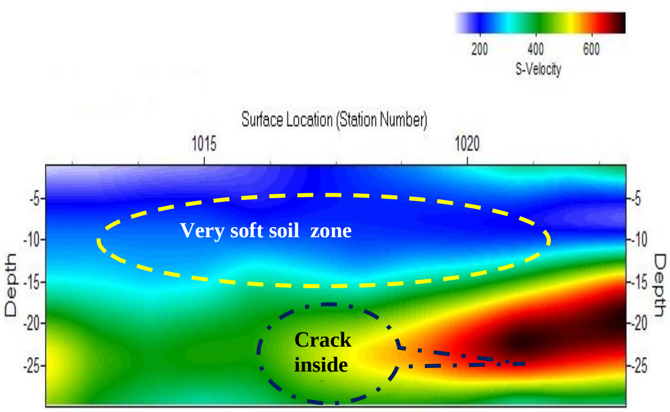

Fig. 7. V_s profile of surface soil for site A

Figure 7 shows the V_s profile at site A where very soft soil is seen until the depth of 15 m in soil. The V_s in this very soft soil zone are about 200 m/s ~250 m/s which can be identified as risk area for landslides at slope of hillsides. Small area at depth of 25 m. shows the V_s of 600 m/s. According to investigative observation on this landslide, illustration of higher V_s marked as circled in black color in Fig.7 was due to cracks inside soil at this site.

Figure 8 shows the V_s profile for site B at UKM, Selangor, Malaysia. According to the results from Surfseis software, a layer of very soft soil is seen within 12 m. deep with the V_s of 200~ 300 m/s. There are the V_s of 400~ 450 m/s from 15 to 20 m depth as well as the V_s of 550 ~700 m/s after 22 m depth in the soil. According to this justification, soft soil with lower V_s at slope of hillside in UKM also contributed to the causes the landslides in the case study B.

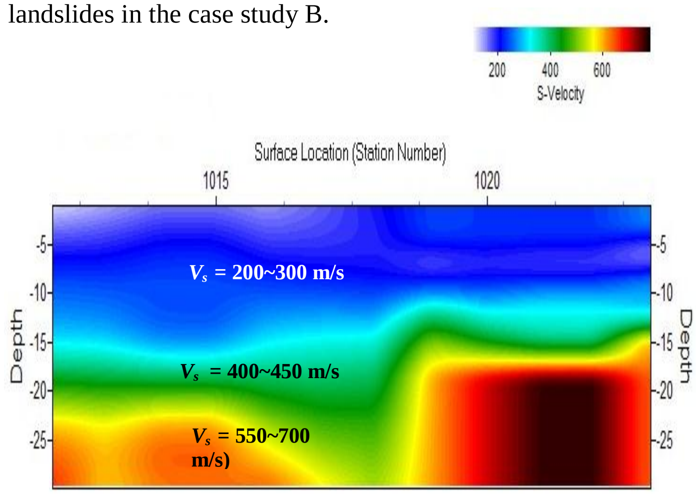

Fig.8. V_s profile of surface soil at site B

Incorporating surface wave analysis with Arcview GIS software is verified with the research study by Mouazen *et al.* (2003). They have used sensor mounted on the three-point hitch of a tractor. GPS is used for interfacing with Arcview GIS to get information of topsoil compaction. They used draught signal as input signal to get dry density distribution in the field. There is also an on-line measurement system of bulk density based on on-line measured draught, depth and soil moisture content (Mouazen & Ramon, 2006). In addition, Rysan & Sarec (2008) uses Arcview GIS to get online soil apparent resistivity profile at crop field. This online monitoring model supports the research methodology landslide prediction through surface wave analysis.

It further facilitates the measurement, mapping, monitoring and modeling of V_s data related to environmental and geo-climate phenomena. The GIS is a tool to enable estimation of geo-environmental information via an online measurement system. The application of GIS shows quicker mapping of landslides prone areas with risk assessment in Selangor, Malaysia.

CONCLUSION

This paper presents the case studies of soil properties within landslide areas in Selangor, Malaysia. Shear velocity V_s profiles of near surface soil were obtained to predict landslide prone areas. Seismic sensor was incorporated with Arcview GIS to get online monitoring of risk zones for landslides. The research on online soil properties monitoring with surface wave analysis is justified through previous research using Arcview GIS applications in other disciplines of engineering. Advances in information technology, GPS logger, radar and satellite communications, mobile etc., are incorporated in the employed methodology. In terms of landslides hazards, this paper is a guide to assist planners in the implementation of emergency preparedness and response action toward geological hazards.

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