AN INTEGRATION OF THE SEISMIC METHODS IN CHARACTERIZATION OF AN UNSATURATED GRANITIC RESIDUAL SOIL SITE

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ABSTRACT

A comprehensive seismic survey encompassing the seismic refraction and the downhole method have been carried out in order to characterize a site of granitic residual soil. The seismic refraction was found to be useful in the initial modeling of the subsurface and has managed to identify the water table, a bolder and the bedrock level satisfactorily. From the downhole seismic, P-wave velocity was found to be responsived to lithology and the water table, while the S-wave velocity was found to be able to characterise the residual soil in terms of their weathering grades. Correlations between the S-wave velocity (Vs) and dynamic shear modulus (Gseis) were established with the SPT (N) and the static unload reload shear modulus (Gur)of the pressuremeter tests. The relationship of Vs = 2.89N + 167.84 and Gseis (MPa) = 2.39Gur + 36.03 were obtained in this study.

***Keywords** : seismic refraction, downhole method, S wave velocity, P wave velocity, dynamic shear modulus, SPT-N*

INTRODUCTION

The current investigation methods in unsaturated granitic residual soil have not been so successful and have encountered various difficulties as compared to similar tests that have been conducted in transported soil. The limitations of these methods especially in residual soil of high sand content where sampling and in situ testing are difficult has been well acknowledged. As such, there remains a need to supplement the existing ground investigation methods, preferably using indirect methods so as to enable testing to be carried out with minimal disturbance on the soil and providing a wider coverage of information to the site.

Location And Geology Of The Study Area

The study area which is located at Jenalik Hulu, Kuala Kangsar shows in Figure 1. Most of the boreholes and in situ tests are conducted adjacent to the proposed route aligment 1 of the Package II Kuala Kangsar – Grik Road Improvement Project. The geology of the site has been classified as Porphyritic Biotite Granite. It forms part of the Bintang Granite Formation (Foo 1990) that originate from the Triassic period. The geological map indicates that the site is located within extensive areas of highly sheared and fault zones that extend NNE to SSW.

RESEARCH METHODOLOGY

Ground Investigation

Drilling

A total of seven boreholes (Fig.1) along the spread lines L22C2 and L22C3 were drilled to bedrock level with 1.5 m of 54 mm diameter coring. The first two boreholes were conducted using wash drilling with the SPT conducted at every meter depth to the bedrock level. Three of the boreholes were drilled using air-foam to obtain continuous Mazier samples for the purposed of logging and further laboratory test. Two of the boreholes were used to conducted alternate SPT and pressuremeter tests with continuous Mazier samples in between. Logging from the continuous Mazier samples were carried out at the laboratory based on the International Association of Engineering Geologist (Matula 1981).

Pressuremeter

Two of the boreholes were tested with the strain controlled OYO Pressuremeter (Menard type 2). Radial pressures were applied in increments of 0.5 to 1.0 bar and their corresponding radial displacement recorded to a maximum of 10.0 mm. One cycle of unload-reload test was carried out to obtain the unload-reload shear modulus.

Laboratory Test

All the laboratory tests were conducted to confirm with BS 1377 part 1:1990 with modifications made to the drying and sieving of the samples. Air drying of samples was adopted so as not to remove the water of crystallization in the soil structure. Wet sieving was carried out in order to debond the cementation of the residual soil. Soils from weathering grades IV, V and VI were tested for their basic properties involving the classifications, specific gravity, bulk density, dry density, void ration and Atterberg limit. Comparisons were made to the studies carried out by Komoo (1993), Ito et al (1990) and Raj (1985).

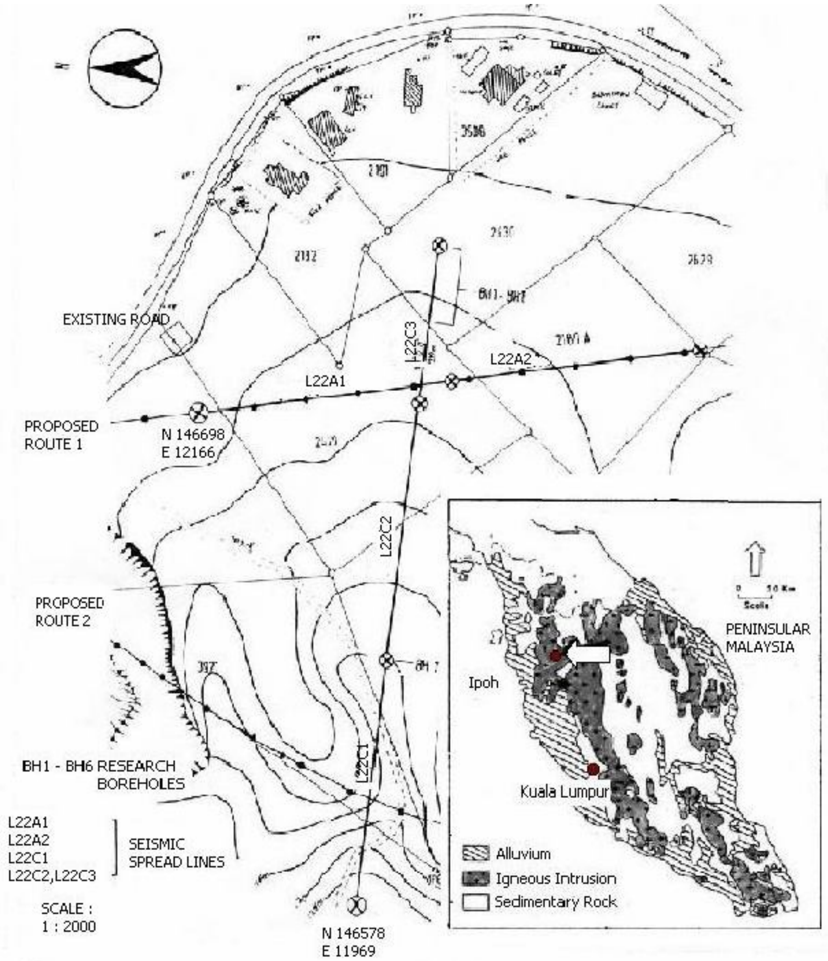

Figure 1. Location of the study area

Geophysical Investigation

Seismic refraction

The seismic refraction survey was carried out by the Geological Survey of Malaysia employing a 24-channel OYO seismograph using dynamite as the energy source. All spread lines were of 115 m length with 5 m geophone spacing except for L22C3, where the spread line is 69 m with a 3 m geophones spacing for a more accurate distance-time plot. Geophones used in the survey were of the vertical P-wave, 14 Hz. Seven shot points were employed for the 115 meters spread lines and five shot points for the 69 meters spread line. The first arrival time of the P-waves were plotted against the geophones distance and the interpretation using the General Reciprocal Method after Redpath (1973) was used to estimate the subsurface velocities and depths.

Downhole Seismic

The test was conducted using a Bison 5012 seismograph and a Bison 1462 (a 3 component geophone) downhole probe at 1 meter interval up to the bedrock level. A small source offset distance (about 2 m) was adopted so as to ensure that the first arrival P and S-waves will be that of direct waves and not that of refracted or reflected waves. A software called Firstpix (Interprex Ltd) was used to magnify the trace records so that a clearer onset of P-wave first arrival is detected. Correspondingly, the S-wave is generated by hammering a weighted timber plank in opposite directions to capture the waveforms in reverse polarity. The waveform generated from his test will be the horizontal components (SH) of the S-wave. The Pseudo-Time Method (Kennet 1981) as show in Fig 2 was used to calculate the respective P and S-waves velocities for every meter depth.

Seismic Refraction

Interpretation of the seismic refraction survey from all the spread lines have managed to represent the subsurface profile into a four layers case as shown by a typical spread line L22C3 (Fig.3). The first layer of depth 2 to 3 m, having P-wave velocity of 300 m/s may be attributed to the residual soil of weathering grade VI and the top soil above it. A second layer of P-wave velocities of 625 to 650 m/s from depths of 2 to 3 m to depths of 10 to 13 meters below the ground level is an unsaturated soil layer and may be attributed to grade V soil material. The third soil layer of P-wave velocity 1,700 m/s to 1,900 m/s at depths from 10 to 13 m to 32-45 m is a saturated layer which has been confirmed by dipmeter measurements. This layer may be attributed to soil of weathering grade II to IV material. The fourth layer of P-wave velocity 4,700 m/s throughout is of fresh rock from weathering grede I based on work done by Komoo (1993) and Irfan & Dearmen (1978).

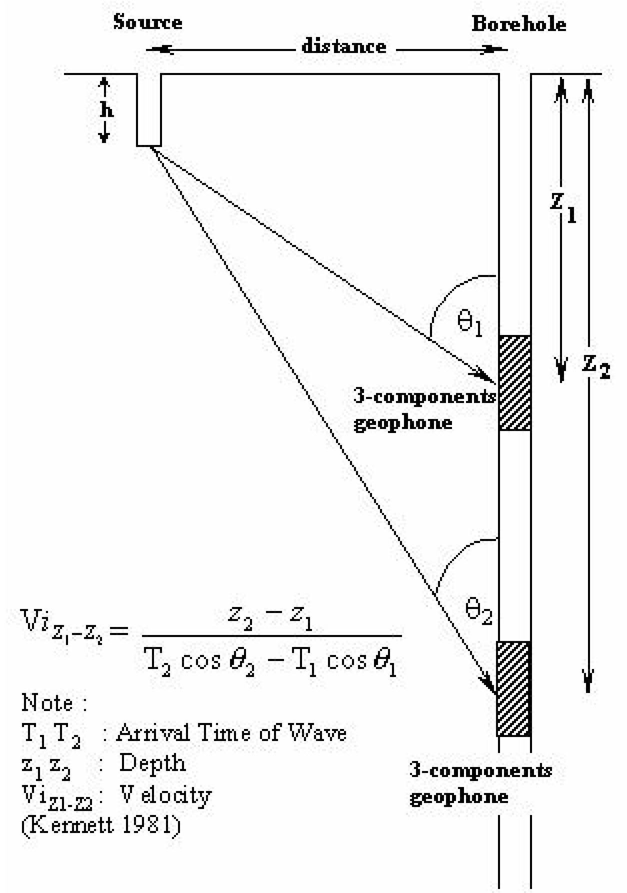

Figure 2. The measurement scheme of downhole method (after Kennet, 1985

ANALYSIS AND DISCUSSION

Bedrock level determined through drilling and the seismic refraction survey are inappropriate for comparison because the boreholes were terminated at the bedrock level of the weathering grade III but the velocity obtained is deeper to that of weathering grade I.

Borehole logging

The logged soil profile (Fig.4) was found that to be divided into three zones comprising the colluvium at the top, the residual soil in the middle and the sheared bedrock at the bottom of the profile. The colluvium was found to be composed of transported material sandwiched between materials of weathering grades V and VI. The texture of the cored rock had shown that the rock mass had been subjected to dynamic structural shear stress with preferred orientations and slicken sided surfaces filled with calcite stringers. As such, the residual soil obtained at the site was found to inherit the structural features of the heavily sheared parent rock.

Basic properties

The distribution of clay, silt and sand (Fig.4) were found to be irregular throughout the depth and is not gradational like a normal weathered residual soil profile (Komoo 1989). This irregular soil distribution is caused by the presence of colluvium and the residual soil that has been a product of highly sheared and hydrothermaly altered bedrock.

There specific gravity were almost constant in the range of 2.55 to 2.75. The bulk and dry densities were found to decrease from grade IV to grade VI in agreement to the work done by Ito et al (1990). There is an increase in void ratio from grade IV to grade VI similar to the trend obtained by Ito et al (1990) with a lower void ratio values. Opposite trends were found from the values of bulk, dry densities and the void ratios from Raj (1985) may be attributed to sample taken from the surface of slope as compared to sample obtained from boreholes for this study and from Ito et al (1990).

Standard Penetration Test

The values of SPT were found not to increase continuously with depth as what would normally be expected of a weathering residual profile (Komoo 1989). The lowest SPT values from depths of 11 to 13 m at the colluvium residual soil interface is observed. This is similar to the trend reported by Tan (1978) from similar results of SPT values obtained over several sites throughout Malaysia. At depth greater than 11 to 13 meters a general trend of increasing SPT blow count is observed which had indicate a normal weathered residual soil profile.

Downhole Seismic Logging

From the results, both P and S-wave velocities (V_p and V_s) were found to be clearly responsive to the soil material, weathering grades, unconsolidated and transported material interface for depths above the water table as shown in Fig.4. Below the water table the response of both P and S-wave were not so distinct as before. At depths of 11 to 13 m, the boundary detected between the transported material from the residual soil is in agreement to the result obtained from other test such as the SPT ad the pressuremeter. The water level (where V_p is approximately more than 1480 m/s) were found to be slightly deeper than the level measured from the dipmeter with an averaged difference of +0.54 meters for four boreholes as shown in the comparison from Fig.4. For saturated or near saturated soil conditions the dynamic Poisson's ratio has been observed to be 0.49 and approaching 0.5.

Generally, the results for V_s were quite consistent and are within the range of 116 to 971 m/s for residual soil in agreement to the study by Ohta and Shima (1967) on transported soil and from the study by Ito et al (1990) on granitic residual soil in Japan. Corresponding plot of the shear wave (G_s) versus V_s has managed to characterize the weathering grades and its summary is given in Table 1 with comparisons to work by Ito et al (1990).

Table 1. Summary of weathering grades to IAEG (Matula, 1981) using the dynamic parameters of G_{seis} and V_s

Weathering Grades	V_S(m/s) This study	V_S(m/s) Ito et al	G_{seis} (MN/m^2) This study	G_{seis} (MN/m^2) Ito et al
VI	116-196	130-250	23-59	36-193
V	179-427	310-450	56-326	131-252
IV	448-876	550-900	385-1033	334-862

From Table 1, it should be noted that the ranges of G_{seis} and V_s obtained from this study have major overlaps to the ranges obtained by Ito et al (1990). The ranges in this study are generally of the lower bound values. The maximum difference are in grade VI where there are insufficient data. The variations can also be attributed to the different of the residual soil involved in the study of Ito et al (1990) which is of the medium to coarse grained hornblend biotite granite with no dynamic sheared or hydrothermal effect reported.

With the S-wave being independent of water saturation it is able to characterize the weathering grades in both the submerged and unsubmerged conditions.

SPT values from two boreholes were correlated to G_{seis} with comparisons from works carried out by Ohsaki & Iwasaki (1973) and Otha et al (1972). Empirical equation obtained from this study with correlation coefficient of r^2 = 0.92 can be expressed as:

$$G_{seis} = 4.71\ N - 9.98 \tag{1}$$

where

G_{seis} = dynamic shear modulus (MN/m^2) and,

N = no.of blows per 30 cm of the SPT test.

From the pressuremeter test, the unload-reload shear modulus (G_{ur}) from BH5 were correlated to the dynamic shear modulus (G_{seis}) with coefficient of r^2 = 0.94 is obtained. Their relationship can be equated using the following empirical equation:

$$G_{seis} = 2.389\ G_{ur} + 36.03 \tag{2}$$

where

G_{ur} = unload-reload shear modulus (MN/m^2).

The inaccuracies in this study can be attributed to the problems in picking the first arrival times of the S-waves. The S-wave velocities obtained averages the bulk of the soil layers in the direction of the travelling waves, where else the SPT and the pressuremeter tests are applied locally in their respective orientation and direction.

CONCLUSION

The shear wave profile obtained in this study has proven that the integration of seismic refraction and downhole logging is useful to the engineering assessment of unsaturated granitic residual soil even for a highly complicated site.

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