Determination of Seismic Wave of Consolidated Granite Rock in Penang Island: Ultrasonic Testing Method Vs Seismic Refraction Method

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Abstract—In seismic survey, the information regarding the velocity of compression wave (Vp) as well as shear wave (Vs) are very useful especially during the seismic interpretation. Previous studies showed that both Vp and Vs determined by above methods are totally different with respect to each other but offered good approximation. In this study, both Vp and Vs of consolidated granite rock were studied by using ultrasonic testing method and seismic refraction method. In ultrasonic testing, two different condition of rock are used which is dry and wet. The differences between Vp and Vs getting by using ultrasonic testing and seismic refraction were investigated and studied. The effect of water content in granite rock towards the value of Vp and Vs during ultrasonic testing are also measured. Within this work, the tolerance of the differences between the velocity of seismic wave getting from ultrasonic testing and the velocity of seismic wave getting from seismic refraction are also measured and investigated.

***Keywords*—**Compressional wave, Granite, Shear Wave, Velocity

I. Introduction

Nowadays, non-destructive Ultrasonic Testing Method (UTM) is commonly used in various field especially in geology and geophysics. The advantages of this method is because it can yield both seismic velocities (Vp and Vs) as well as ultrasonic elastic constants that are very useful in characterizing the dynamic properties of rock. Because of this, UTM are widely applied in field as well as in the laboratory. Previous works showed that UTM have been used in rock characterization [1] by seismic velocity determination, blasting efficiencies in the rock mass [2], the prediction of rock mass deformation and stress [3]-[4] and many more. A number of studies utilizing the application of UTM in investigating the value of Vp. Reference [5] studied the correlations between the saturated and dry P-wave velocity of rocks and strong linear correlation between the dry-and wet-rock P-wave velocities were found. Reference [6] estimating the direct P-wave velocity value of intact rock from indirect laboratory measurements. Most researchers [7]-[11] studied the relations between rock properties and sound velocity and found that the sound velocity is closely related with rock properties. Vp can be measured both in laboratory as well as in field. Seismic refraction method, SRM are utilizing in this work as a field method and direct ultrasonic testing method, DUTM as a laboratory method. Reference [12] stated that the value of seismic wave getting by using both methods are different but will offer good approximation. So, if strong correlations can be established between both methods, the value of Vp yield from the seismic refraction can be easily predicted from the DUTM and the measurements thus made easier. In this study, the correlation between the Vp getting from DUTM and SRM were investigated. Also, the effect of water content towards the Vp and Vs measured in DUTM were studied.

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II. Rock Sampling

This study covered only one location inside Penang Island. 4 rocks are drilled out from different point below the seismic survey line by using diamond core driller. The depths of all samples were approximately 10 m. All samples were calibrated to be in cylindrical shape with approximate length is around 6 cm-8cm and approximate diameter is 4.4 cm. The sample code, the location and the type of the collected rocks are given in Table 1.

TABLE I
LIST OF TESTED ROCKS

Sample Code	Position	Length, m	Rock Type
BJ1	G1	0.07	Granite
BJ2	G8/9	0.063	Granite
BJ3	G12/13	0.068	Granite
BJ4	G20/23	0.076	Granite

Abbreviations: G = geophone location.

III. Ultrasonic Testing Method

SOWAN (Sonic wave analyzer) made by controls and two transducers (transmitter and receiver) having a frequency 1-500 KHz were used in this method. Direct method is applied in UTM and couplant was used to provide good coupling between transducers and samples. At first, time delay of the SOWAN were observed so that accurate value of Vp can be measured during the measurement. Then, before starting the core sample measurement, clamp was used to diminish the space between the transducers and sample so that fully energy are recovered in the sample. The pulse rate and receive gain are set to be maximum to get a clear data. Bandpass type filter was used with low cutoff 100 Hz and high cutoff 200Hz. The filtered data then windowed by using Hanning type window. Proper data processing was done to get the precise arrival time which in turn yield accurate Vp. The final value of Vp were measured by using equation 1.

$$Vp = L / (tp - td) \quad (1)$$

Where L is the rock sample length, tp is the arrival time for P wave and td is the time delay experienced by SOWAN. All the procedures done in DUTM were followed [12].

IV. Seismic Refraction Method

In seismic refraction, two spread of approximate total length 50 m survey lines are done atop of granite strata with the geophone spacing is 2 m and total geophone is 24. There were 7 shot points while doing this method and an average 10 to 15 successive stacks were taken at each shot points. The data then interpreted at the laboratory and velocity values at same point as rock samples point were extracted out to compare with the ultrasonic testing method. The signal processing in this method are done carefully especially in picking the first arrival at each geophone. Table 2 shows the values of Vp measured during SRM at each geophone and the locations of rocks sample.

V. Result And Discussion

Based on the SRM, only Vp can be observed in this study. So the correlation can be done only between the values of Vp measured in both method. In DUTM, measurements of Vp were done first at room temperature (27°C). In preparing this conditioned, all rocks were dried in the oven with 60°C and exposed them to the room temperature for 2 days. Then the temperature was increased up to 90°C in steps of about 10°C-20°C over 1 hour’s periods. Table 3 showed the values of Vp measured at each temperature.

Table II
Vp values measured in SRM at each geophone

Geophone	Velocity (ms-1)	Sample location
1	2417.6	BJ1
2	2387.8	
3	2387.8	
4	2387.8	
5	2387.8	
6	2422.9	
7	2422.9	
8	2295.0	BJ2
9	2295.0	
10	2295.0	
11	2295.0	
12	2334.1	BJ3
13	2334.1	
14	2175.9	
15	2175.9	
16	2175.9	
17	2175.9	
18	2128.9	
19	2128.9	
20	1954.2	BJ4
21	1954.2	
22	1954.2	
23	1954.2	
24	2005.9	

A. Temperature effect

The measurement were done at each temperature with the conditioned of rocks are dry. Figure 1 shows the change of Vp for all rocks as a function of temperature. Surprisingly, at early 27°C the values of Vp measured using DUTM were almost same with the values of Vp measured during SRM. The deviations between both values are just around 7.79%-28.37%. The values of Vp decrease with the increasing in

Table III
Vp values for SRM and DUTM at various temperature

Sample Code	Vp, SRM (ms-1)	Vp, DUTM, (ms-1)					
		27°C	30°C	40°C	50°C	70°C	90°C
BJ1	2417.6	2621.7	2127.66	1917.81	1678.66	1670.64	1654.9
BJ2	2295	2342.0	2258.06	1962.62	1754.87	1680.0	1698.1
BJ3	2334.1	2369.3	2079.51	1757.11	1748.07	1687.34	1622.9
BJ4	1954.2	2241.8	1974.03	1831.33	1771.56	1715.58	1685.1

temperature. There is a tendency for a linear decreasing in Vp for all rocks from 27°C to 50°C. During measurement at 50°C, the variation of Vp are approximately constant for all samples. Generally, the variation of Vp towards the increasing in temperature were negative exponentially.

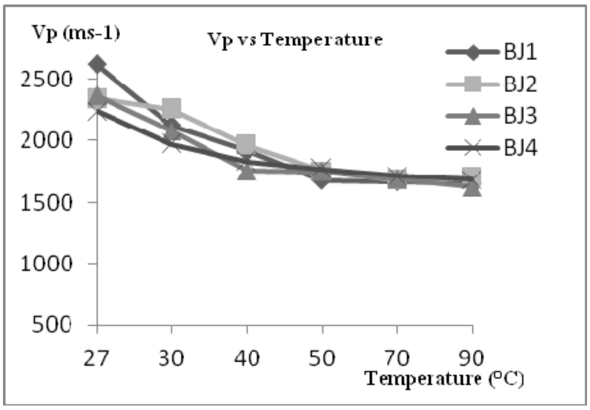

Fig 1. Overview of Vp for all rock sample at various temperature starting from 27°C to 90°C

B. Correlation of Vp Values between DUTM and SRM

Comparisons were performed by studying the reduction of Vp in DUTM in figure 1. Based on figure 1, Vp values getting from both methods were approximately same at temperature ranging from 27°C to 30°C. After 30°C, the Vp start to deviated more from the value of Vp measured in SRM. So, this work suggests that the controlling factors for DUTM in measuring the approximate values of Vp in SRM of consolidated granite rock was a temperature. In order to get the approximate Vp of dry granite rock in SRM from DUTM, the temperature should be set at 27°C to 30°C and the sample should be free from any external pressure.

C. Effect of Wet Rock towards Vp and Vs In DUTM

Effect of wet conditioned towards the values of Vp and Vs in DUTM for granite rocks were studied based on figure 1. Generally, the increasing in temperature caused the water content decreasing or in other words, the level of wet condition inside the rock sample was reduced as well. By analyzing the graph of Vp in figure 1, wet condition of rock will increased the value of Vp. Theoretically, Vs is slower than Vp and cannot propagate in fluid medium. So, wet conditioned of rock will reduced the value of Vs inside rock sample.

VI. CONCLUSIONS

Vp of dry granite rock measurements of DUTM were carried out on 4 rock sample and comparison had been made with the values of Vp at same point of rock sample measured by using SRM. In DUTM, Vp values varies in negative exponential with the increasing of temperature. From the result, it was observed that around 50°C, Vp values for all samples behave approximately constant. Finally, the temperature should be set to 27°C to 30°C during DUTM in order to predict the respective Vp measured by using SRM. The effect of wet condition of rock will increase the values of Vp and reduced the Vs. However, these conclusions are valid only for granite rocks. Further research is necessary to check the validity of this conclusion. Also, the correlations between the Vp getting by DUTM as a function of pressure with the Vp getting from SRM needs to be evaluated.

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