Pencirian konkrit berketumpatan tinggi dengan kaedah goniometer ultrasonik

Characterization of high density concrete by ultrasonic goniometer

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Abstrak

Kertas kerja ini menerangkan keputusan ujian goniometer ultrasonic terhadap konkrit berketumpatan tinggi. Batuan bijh besi (hematite) digunakan sebagai agregat bagi mendapatkan konkrit berketumpatan tinggi untuk kegunaan perisai sinar-X dan gamma. Kubus konkrit bersaiz 150mm mengandungi hematite sebagai agregat kasar disediakan dengan mengubah nisbah campuran, nisbah air/simen dan jenis agregat halus. Semua sampel dirawat dengan merendam dalam air selama 7 hari. Kubus konkrit yang berumur 28 hari kemudian dipotong kepada saiz sekitar 10mmx20mmx30mm agar ianya dapat diletakkan pada goniometer. Daripada ujian goniometer, halaju gelombang permukaan (Rayleigh), ricih dan longitude dapat ditentukan. Keputusan pengukuran diterang dan dibincangkan.

Abstract

This paper described the results of ultrasonic goniometer measurements on concrete containing hematite. Local hematite stones were used as aggregates to produce high density concrete for application in X-and gamma shielding. Concrete cube samples (150mm x 150mm x 150mm) containing hematite as coarse aggregates were prepared by changing mix ratio, water to cement ratio (w/c) and types of fine aggregate. All samples were cured in water for 7 days. After 28 days of casting, the concrete cubes were then cut into small size of about 10 mmx20mmx30mm so that it can be fitted into goniometer specimen holder. From this measurement, longitudinal, shear and surface Rayleigh waves in the concrete can be determined. The measurement results are explained and discussed.

Keywords: high density concrete, ultrasonic goniometer, density, radiation shielding

INTRODUCTION

Normal concrete is the most common and cheap materials for construction including radiation shielding bunker. Local hematite was used as an aggregate to produce high density concrete. This will provide an alternative to normal concrete, better and effective radiation shielding.

Compression strength is the main parameter check for determining concrete quality. Other than strength, the parameters such as durability, volume stability and impermeability are also important in evaluating the concrete quality. In general, most people think that by increasing the strength means that other parameters are also increased. However, this assumption is not always true. For example, the use of excessive cement will increase the strength but at the same time it also produces shrinkage and creep (Mindness& Young 1981).

For shielding purposes, density is the main parameter concerned. The high the strength normally implies to higher density concrete. But this is also not always true.

Ultrasonic method has been used to estimate strength, elastic modulus, slab thickness, crack depth, and to detect voids, lamination and bar location [National Seminar on NDE of concrete, 1991]. It is recognized as the only NDT method available at this time, which is capable of determining the crack depth to a certain degree of reliability. The technique was also used to monitor the mixing materials during construction [Elvery, 1976], determine the concrete uniformity [Tomsett, 1980], thickness measurement and to estimate the depth of damage caused by fire [Tomsett, 1980].

Rebound hammer have been used to estimate strength or surface hardness of the concrete [Pauzi, 1996]. At the moment the only available NDT method for measuring density is by gamma backscatter [Adil, 1977]

The research is carried out to characterize concrete using ultrasonic goniometry.

ULTRASONIC GONIOMETRY

Basically ultrasonic characterization of materials can be performed in two ways, firstly by measuring sound velocity and secondly sound attenuation. The theoretical correlation between ultrasonic parameters and material properties are as follow. In homogeneous, isotropic and elastic media, the wave velocity *V* is given by;

$$V_p = \sqrt{\frac{E}{\rho} \frac{(1-\upsilon)}{(1+\upsilon)(1-\upsilon)}} \quad (1)$$

where *E* is the Young modulus, ρ the material density and υ the Poisson ratio.

Ultrasonic waves are also attenuated as they passed through the materials. Basically the attenuation is caused by beam divergence (distance effect), absorption (heat dissipation), and scattering. Only scattering is affected by the characteristic of the materials they passed through. It is affected by the degree of inhomogeneity and frequency of the transducer. The attenuation caused by scattering is given by (Szilard 1982),

$$\alpha_s \propto \begin{cases} 1/D & \text{for diffusion range} \quad \lambda \le D \\ Df^2 & \text{for stochastic range} \quad \lambda \approx D \\ D^3 f^4 & \text{for Rayleigh range} \quad \lambda >> D \end{cases} \qquad (2)$$

where f is the wave frequency, λ the wavelength and D the average inhomogeneity. In gaharu wood, D may be the void or porosity size.

Ultrasonic goniometry is a technique used to study materials surface properties by surface wave ultrasound. The principle of operation is illustrated in figure 1. The solid specimen is immersed in a liquid and a transceiver used to study the echo characteristics of a point in the surface as a function of angle of incidence of acoustic waves. The reflected amplitude measured by the transceiver is illustrated in figure 2.

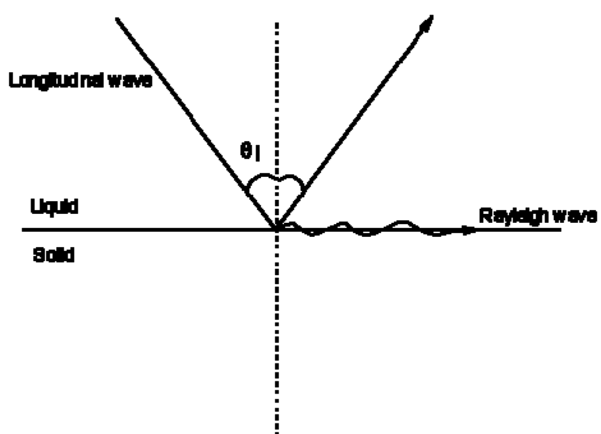

FIGURE 1: Principle of the ultrasonic goniometer. An ultrasonic beam is incident at a critical angle θ_i and Rayleigh wave propagated on the solid surface.

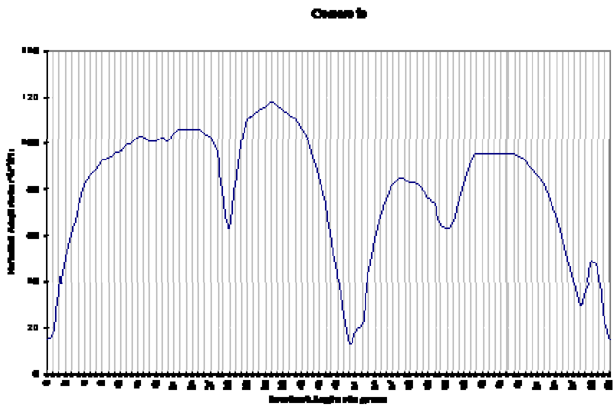

FIGURE 2: Goniometer curve for Steel-Concrete (Mohamad Pauzi Ismail, et al 1996)

EQUIPMENT, MATERIALS AND METHODS

Sample Preparation

The concrete containing hematite cubes were prepared based on JKR methods. The block sizes are 150mm x 150mm x 150mm. The workability is medium. The samples were cured by immersion into water for 7 days. At the age of 28 days the cube samples were then cut to fit into specimen holder of the goniometer.

Table 1 show the mix proportion used in the experiment.

Table 1: The mix proportion

Mix	**Proportion**	**W/C**	**Cement (kg)**	**Hematite sand (kg)**	**Crushed hematite (kg)**
A	1:1:2	0.5	10	10	20
B	1:1.5:3	0.5	10	15	30
C	1:2:3	0.5	10	20	30
D	1:2:4	0.5	10	20	40
D1	1:2:4	0.7	10	20	40
D2	1:2:4	0.75	10	20	40
D3	1:2:4	0.8	10	20	40
E	1:2:6	0.5	10	20	60
Mix	**Proportion**	**W/C**	**Cement (kg)**	**River sand (kg)**	**Crushed hematite (kg)**
F	1:1:2	0.5	10	10	20
G	1:1.5:3	0.5	10	15	30
H	1:2:3	0.5	10	20	30
I	1:2:4	0.5	10	20	40
I1	1:2:4	0.7	10	20	40

I2	1:2:4	0.75	10	20	40
I3	1:2:4	0.8	10	20	40
J	1:2:6	0.5	10	20	60

Ultrasonic Instrument and test procedure

In this experiment velocity of longitudinal is measured by conventional ultrasonic flaw detector using longitudinal probe. The velocity of Rayleigh wave was measured by ultrasonic goniometer. The shear wave velocity is then calculated using the following formula (Szilard 1982);

$$q^6 - 8q^4 + 8q^2(3 - 2u^2) - 16(1-u^2) = 0 \quad (1)$$

where $q = V_R/V_S$., $u = V_S/V_L$, V_L = longitudinal wave velocity, V_S = shear wave velocity and V_R = Rayleigh wave velocity.

The density of samples was also measured by weighing the sample and volume determination using water displacement method.

Ultrasonic goniometer was performed using a ultrasonic pulse-receiver card model attached to computer notebook as a signal display. The immersion transceiver Nortec 5MHz and 3/8" diameter was used for generating and receiving ultrasound through samples. The distance between transceiver and sample is set to 100mm.

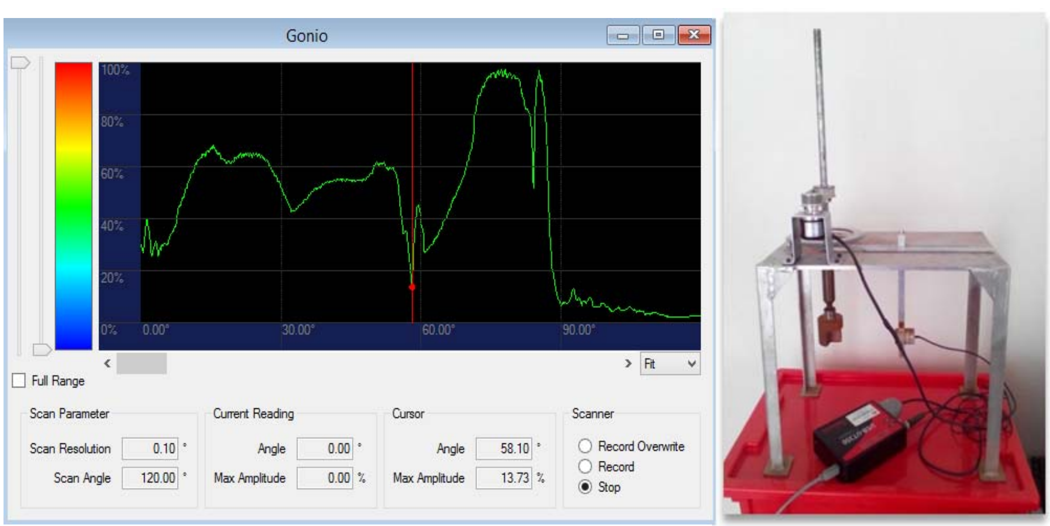

FIGURE 5: Ultrasonic instrument and goniometer

The sample attached to goniometer was rotated from incident angle of 0° to 90° and the amplitudes of reflected signal from the sample were recorded at every one degree of rotation.

RESULTS AND DISCUSSION

Typical goniometer result is plotted as shown in Fig. 6. Rs and Rr are Rayleigh wave critical angles for hematite concrete sample and steel reflector, respectively. Using Snell law, the Rayleigh wave velocity in the samples can be measured.

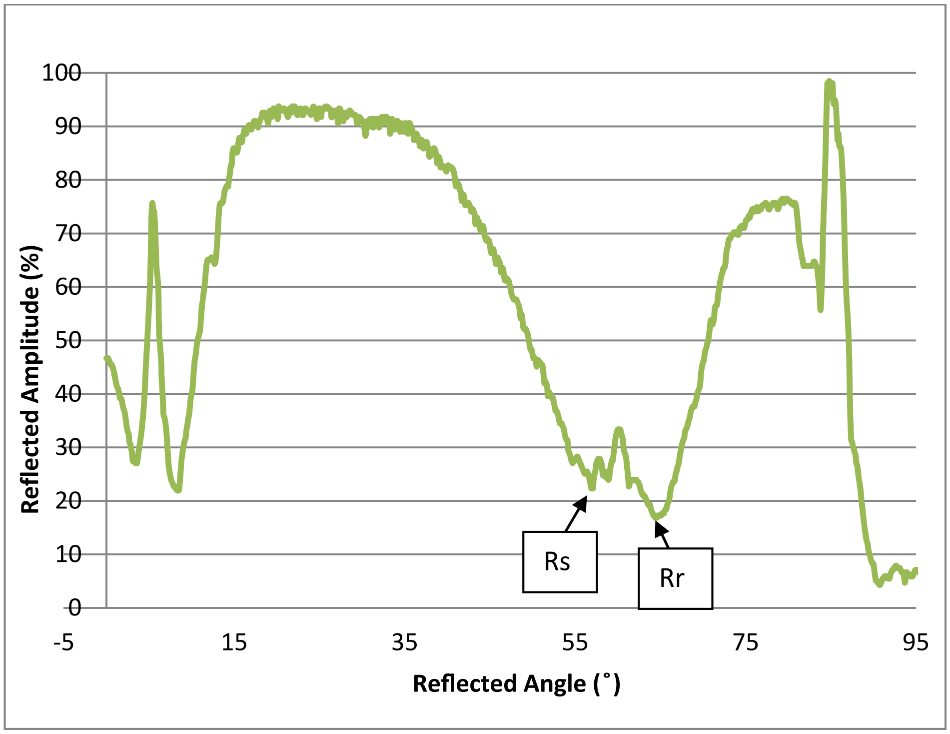

Fig. 6: Goniograph

The results of all measurement are summarized in Table 2. Fig. 7 shows a good correlation between elastic modulus (bulk) and density. Modulus is increased as the density increases.

Table 2: Summarized results

Mix proportion	Density (kg/m3)	Rayleigh velocity (m/s)	Longitudinal velocity (m/s)	Shear velocity (m/s)	Dynamic Young Modulus (GPa)
1:1:2	3741	1731	4195	1844	35.1
1:1.5:3	2417	1715	3833	1834	21.9
1:2:3	2856	1762	3762	1893	27.1
1:2:6	2930	1760	3295	1916	35.1

1:3:6	2465	1753	3670	1884	26.9

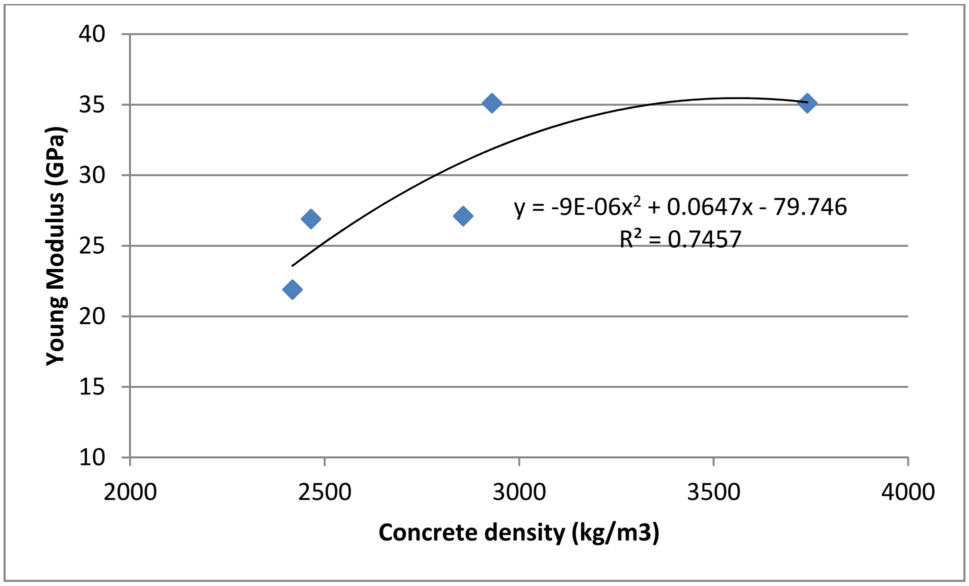

Fig. 7: Elastic modulus versus density

CONCLUSION

Goniometer can be used to measure surface Rayleigh wave velocity in the samples. From this measurement and by combination of conventional ultrasonic pulse echo method a complete sound velocities in the material can be measured and finally a bulk modulus of elasticity (Young Modulus) can be determined.

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