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Material Evaluation by Using Impact Echo Test

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Abstract: Tests were performed to evaluate the feasibility of using Impact-Echo Method (IEM) in detecting defect and determining its depth during the early age concrete. Five Reinforced Concrete (RC) slabs grade 30 and 40 specimens respectively at day 3, 7, 14 and 28 with a fabricated void at a known location were used. The results obtained were analyzed to determine the accuracy of the method hence the effectiveness of it. Impact Echo method detect defects in specimens during the early age. Porosity has significant effect on the accuracy since lower porosity yield accurate determination of the depth of defect. Tests were also performed to examine the relationship between the porosity and strength of concrete at each stage with the accuracy of void depth detected. The test results indicate that the method can be used to assess the in-situ properties of concrete or for quality control on site. Impact Echo Test method showed better accuracy in detecting defect with stronger concrete with the accuracy ranging from 60.75-99.05% from day 3-28 (full strength) respectively.

Key Words: Concrete, Impact-Echo Method, Porosity, Defects Detection and Accuracy

Introduction

The deterioration of concrete in a structure is a result of several degradation mechanisms that caused a decreased in the integrity of the structure. The state of deterioration is often invisible and is only evident when there is a significant reduction in the load carrying capacity. Ensuring better performance of concrete structures requires early defects detection. Defects are often introduced during casting and detection during in-service life is often too late to remedy the situation. In the past years great improvement has been made in the field of Non-Destructive Testing in Civil Engineering (NDT-CE) and this trend will certainly continue and even accelerate (Bungey,1982) . Base on the information obtained for both Impact-Echo Method (IEM), all the work that have been done in relation to defect detection and depth of defect determination are limited to in-service structures for case-study and on laboratory research specimens that are more than 28 days of age. None of them are done on early age structures or specimens except for the monitoring of strength development in concrete (Lin and Sansalone,1992; Sansalone and Carino,1986; Sansalone and Street,1997; Sansalone and Carino, 1998).

The scope of this study is to test and compare the accuracy of this method by using the Germann Instruments DOCter Impact Echo System (IEM) (Germann Instruments,1999) for detecting the location and depth of defects. The main interest is to correlate concrete properties with age and how it affects the accuracy of defect detection.

Materials and Methods

Five Reinforced Concrete (RC) slabs grade 30 and 40 with prerecorded location of defect namely the actual void depth (i.e. 37.5mm) were prepared. The proportions of the concrete mix are summarized in Table 1 and 2.

Table 1: Grade 30 RC Slab (500 x 300 x 75)

Cement	Fine Aggregate Sand	Coarse Aggregate 20mm	Water
4.706 kg	13.858 kg	17.680kg	2.340kg
1.000	2.940	3.760	0.500

Slump = 10-30 mm cured at room temperature

Table 2:Grade 40 RC Slab (500 x 300 x 75)

Cement	Fine Aggregate Sand	Coarse Aggregate 20mm	Water
4.500kg	8.07 kg	12.105kg	2.25kg
1.000	1.79	2.6900	0.50

Slump = 10-30 mm cured at room temperature

All the specimens were tested from day 3, 7, 14 and 28 with and IEM. The accuracy of the testing methods was determined by comparing the prerecorded location and depth voids. The methods of testing and determining the void location, void depth and porosity of concrete at different age are as follows.

Impact Echo Method (IEM): Fig. 1 showed the spectrum for RC Grade 30(Slab 1) at day 14 from which the void depth was determined. The void depth T was determined by using the following equation,

$$T = C/2f_v \qquad (1)$$

where is f_v the void frequency in kHz, T is the void depth in mm, and C is the true wave speed in m/s. A typical calculation for determining the void depth and

Table 3: Impact Echo Test Results: Slab 1 (Grade 30) and Slab 6 (Grade 40)

Concrete Age Days	f_T (KHz)		C (m/s)		f_v (KHz)		Void Depth (mm)		Accuracy %	
	G30	G40	G30	G40	G30	G40	G30	G40	G30	G40
3	27.20	26.73	4250	4172	89.55	73.65	22.78	27.19	60.75	72.50
7	26.11	25.80	4078	4031	71.81	65.54	27.26	29.52	72.69	78.72
14	28.63	27.21	4469	4250	66.72	60.61	32.15	33.66	85.72	89.77
28	27.81	26.50	4344	4140	56.30	53.51	37.00	37.14	98.67	99.05

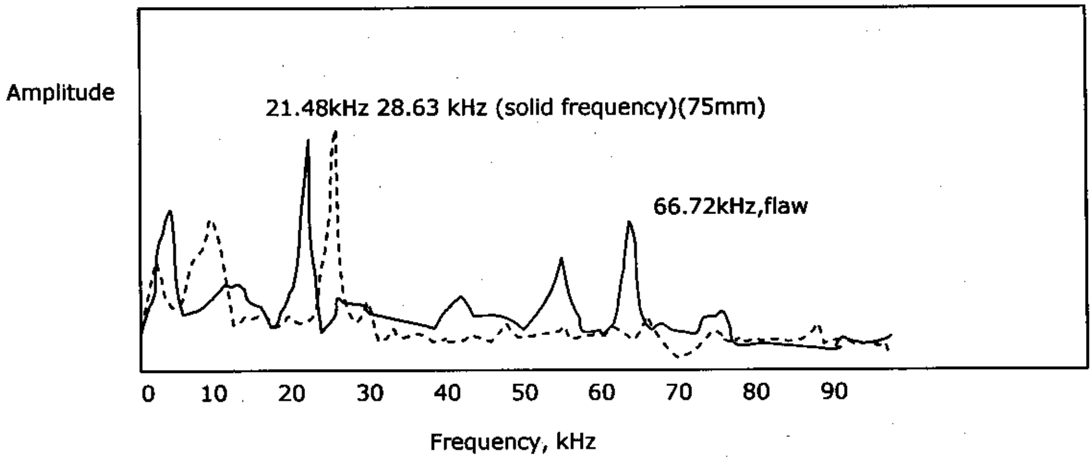

Fig. 1: Spectrum for RC Grade 30 (Slab1) at day 14

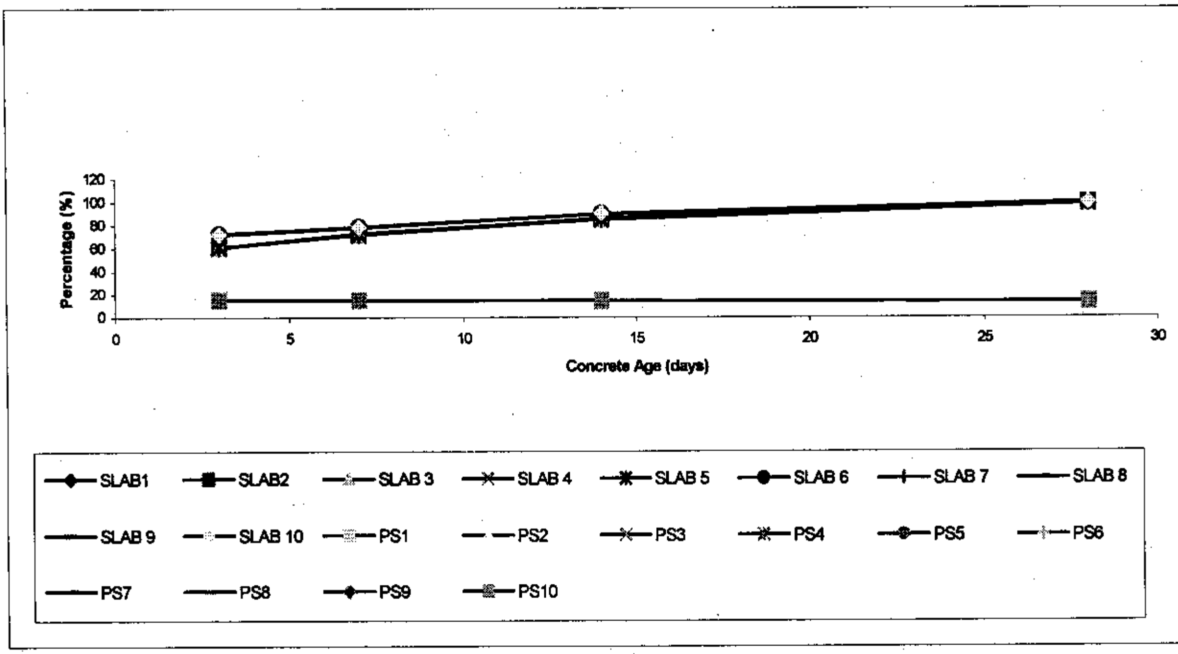

Fig. 2: Correlation of Accuracy and Porosity with Concrete Age for GD30 and GD40

accuracy for RC Grade 30(Slab 1) at day 14 using equation 1 are presented.

$$T = 4469/2(66.72)$$
$$= 32.15\text{mm}$$

Accuracy= (Detected void depth/Actual void depth)×100
= (32.15/37.5)×100=85.72%

Results and Discussion

The use of stress wave propagation to monitor the development of early-age mechanical properties is not a new idea. In this study, two parameters namely void location and void depth are used to determine the accuracy of IEM. Changes in strength of concrete with age that are influenced by porosity are the significant factor affecting the accuracy of readings since all other properties are similar for both specimens.

Fig. 2 showed the accuracy versus age for RC Grade 30 and 40 using IEM. From Fig. 2, the accuracy of the method increased as the specimens matures. The results indicate that changes in aggregate, moisture and air void affects the readings of this as shown by the 2 different grade specimens. Grade 30 specimens yield less accuracy than grade 40 specimens. Impact Echo wave of reinforced concrete is affected by changes in the hardened cement paste. The changes in the water/cement ratio affect the modulus of elasticity of the hardened cement paste. Therefore the moisture condition of concrete affects the wave reading. As the concrete age, the moisture content decreases and it can be observed from Fig. 2 that as the concrete mature the detection of void is more accurate.

Another reason is due to the mix design of both concrete specimens. Referring to Table 1 and 2 for both mixes, Grade 30 has more coarse aggregate than Grade 40 and this explained why Grade 40 specimen is more accurate in determining the depth of the void for both methods. Less homogeneous specimen yield less accurate reading since coarse aggregate can diffract the ultrasonic wave.

Fig. 2 also showed the correlation between percentage of accuracy and porosity of IEM for RC Grade 30 (Slab 1-5) and 40 (Slab 6-10) with concrete age respectively. As the concrete strengthened, the percentage of porosity decreased. Porosity is expressed as a fraction of volume of voids to the total volume of concrete. The porosity was determined from the relationship between compressive strength and porosity graph(Neville ,1987).

It was observed that the decreased of porosity as the concrete matures increase the accuracy of the test. The reason for this is based on the testing principle for the method i.e. where the presence of void on the path will increase the path length as it goes around the void. Concrete with higher porosity acts like bigger voids and this will affect the readings of both methods.Since the changes in porosity with age are based on theoretical calculations, the relationships between the accuracy and porosity are recommended for further experimental investigations.

Conclusion

For the purpose of quality control on site, the use IEM enable detecting defect in concrete structure as early as day 3. Based on the present study it is concluded that detection of defect location is possible as early as day 3 after the removal of form work. The defect depth determination is possible with accuracy ranging from 60.75-99.05%. Stronger concrete gives better accuracy in determining the depth of defect. Theoretically, porosity of concrete has significant effect on the accuracy of the defect depth. It was observed that decrease of porosity with age increase the accuracy. The actual performance of in-situ concrete during early age is yet to be fully understood. Therefore, more studies and further research on actual bridge structure should be conducted. The effect of porosity should be done experimentally. Besides porosity, other effects that changes concrete properties during early age should also be taken into consideration for further research.

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