

Study on the internal defects of concrete slab on the basis of IES

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Abstract: Empty, segregation etc are the common internal defects of concrete slab, positioning the inner defects of slab is the basic requirement of the engineering detection and repair, in this study, the internal defects of concrete slab were studied based on the principle of impact echo method. Different forms and sizes of defects were set up within the concrete slab, testing with the impact echo scanning instrument, the plane position of the internal defects in the slab were intuitive by the generated 3d graphics. In the defective area, there are three obvious resonant frequency in the spectrum and the depth of the defect can be obtained by the corresponding frequency.

Introduction

Lots of Non-Destructive Testing (NDT) techniques of concrete structure have been developed since the late 1940s, the commonly used Non-Destructive Testing techniques of concrete structure including Rebound Method, Ultrasonic Method that based on the sound wave theory and Impact-Echo Method that based on the stress wave theory. The strength measured by the Rebound Method is estimated value which is not highly accurate, and the Ultrasonic Method needs to set the transmitters and receivers on the separate sides, so there is a higher requirement for working plane and it cannot apply to defect detection for large area. Whereas, the Impact-Echo Method is easily operated, based on the reflection of stress wave at different wave impedance interface, it can finish motivating and receiving signal in the same surface. So the Impact-Echo Method is widely used in defect detection of concrete structure.

Since 1980s, the Impact-Echo Method has been applied in nondestructive testing of concrete structure. Many researchers have studied the application of the Impact-Echo Method in concrete structure [1~4]. In the study of prestressed box girder, the frequency of stress wave is obviously effected by the ratio of channel diameter and web thickness, and the bigger the channel diameter and smaller the web thickness, the better the results of mortar plumpness detection[5]. The Impact-Echo Method was also used to detect the web thickness of prestressed box girder, and the test precision can meet the engineering requirements basically, but since the velocity of stress wave was changed in some individual defective parts, there were relatively larger deviations of the test results[6]. The identification of most defects in concrete by the Impact-Echo Method is accurate, but it is difficult to identify the vertical crack in concrete[7], that is because the vertical cracks are paralleled to the propagation direction of stress wave and stress wave cannot effectively reflect.

Some researchers applied the Impact-Echo Method to evaluate the defects of concrete under anchor in prestressed concrete slab and more than 60% of defects were identified[8], in order to improve the efficiency of the Impact-Echo Method to detect the inner defects of concrete, some new type of device are studied[9]. The data analysis method of the Impact-Echo Method is also complicated, since the peak frequency is difficult to identify, the combination of Fast Fourier Transform (FFT) and wavelet transform in waveform analysis may help [10].

Principle and method

The basic principle of the Impact-Echo Method

The Impact-Echo Method is a kind of nondestructive testing method based on the theory of stress wave. One of the elastic stress wave (P-wave) produced by the instantaneous impact on the surface of concrete slab will have a repeated reflection at upper surface, lower surface and the internal defects where wave impedance changed. The vibration frequency and the amplitude of the slab is received by the sensor and reflected in the spectrum diagram, the resonant echo is not obvious in the time domain but it is easy to identify when the data within the scope of time domain are converted into frequency domain through Fast Fourier Transform (FFT). The thickness of the slab can be obtained through the analysis of the resonant frequency and the relationship between the thickness of the slab, t , and the resonant frequency, f , is as follow:

$$t = \frac{\beta V_p}{2f} \quad (1)$$

Where β is the correction factor of the impact surface, which value is '1' when the surface is ideal, and V_p is the velocity of P-wave. Part of the P-wave diffract when spread to the internal defect of concrete, when come to the lower surface, the P-wave reflect and transmit in the same way to the impact surface and received. The other part of P-wave will directly reflect at the defect surface and received. There are two kinds of resonance frequency at least in the spectrum, namely diffraction frequency that drift to low frequency and reflection frequency that drift to high frequency. As one kind of volume wave, the stress wave repeatedly reflects and transmits that it will arise thickness frequency in the spectrum as well. Among them, diffraction frequency is the main frequency.

The detection method of Impact-Echo

Use the scanning type of Impact-Echo instrument developed by *OLSON* company to detect the concrete slab, and make the wheel scan head go through some strait lines with the spacing of 10 centimeter. The measured thickness of the slab will increase obviously when there is defection in the concrete slab. The location and dimension of the defection is intuitive through the analysis of the vertical view of 3d figure, and the embedment depth of the defect can be obtained through the frequency spectrum.

Experimental procedure

IE testing setup

The test was executed on a precast defective concrete slab with the strength of C30 and size of 1200mm×1000mm, based on the principle of testing concrete thickness by Impact-Echo, the size and position of the internal defects of concrete slab were studied. A plastic pipe with the diameter of 50mm was used to simulate the internal void of concrete and foam board to simulate isolation. Fig.1 and Table 1 present the detail of defections in the slab.

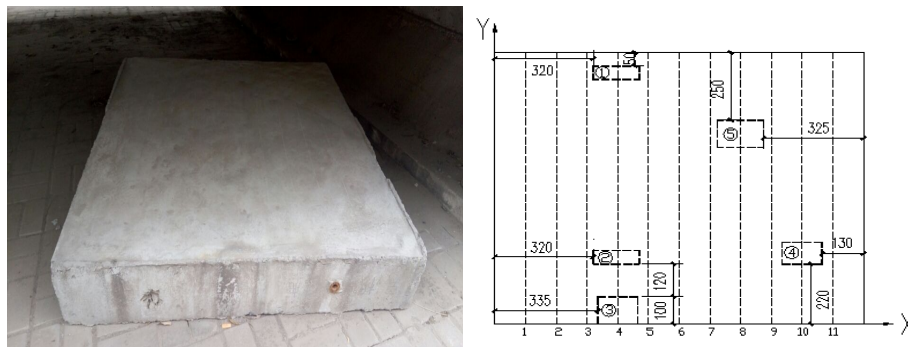


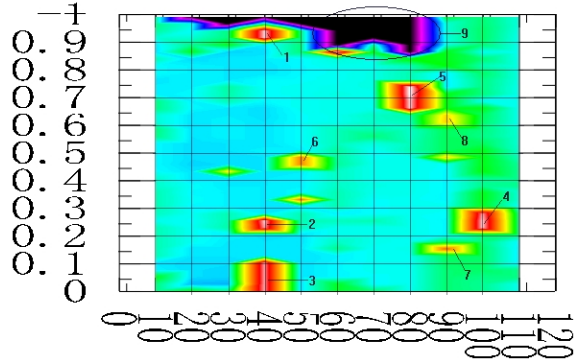
Fig.1 Location of defects and detect lines(Unit:mm)

Table1 Size and location of the defects

Defect no.	Type	X Sides (mm)	Y Sides (mm)	Z Sides (mm)	Diameter (mm)	Depth (mm)
1	plastic pipe	150	—	—	50	135
2	foam board	150	50	50	—	120
3	foam board	130	100	60	—	100
4	foam board	130	80	60	—	125
5	foam board	150	100	50	—	100

IE testing results

The velocity of P-wave was measured with a standard slab designed with calibrate mixture ratio after 28-day standard curing and the calibration results of P-wave velocity of C30 concrete is 3700 m/s. Since the Rebound strength of the testing specimen was 31.2 MPa, took 3700 m/s as the testing P-wave velocity approximately. The results were shown in Table 2 and the position of defects were depicted as Fig.2 (transverse axis unit: cm, vertical axis unit : m), deviation of the designed defects were not more than 5%, and the plane positioning was accurate.

**Table2** Testing results of the IE Method

Defect no.	Velocity of P-wave (m/s)	Diffraction frequency f_1 (Hz)	Thickness frequency f_2 (Hz)	Reflection frequency f_3 (Hz)
1	3700	4031	9302	12868
2	3700	4112	8964	13076
3	3700	4186	9069	14108
4	3700	4108	8992	12326
5	3700	3990	9154	13693

Fig.2 Location map of the concrete slab

Frequency domain analysis and discussion

Before analyzing the spectrum graph, dispose the waveform through band-pass filter first. The filter is designed to reduce attenuation of echo signal as far as possible and keep frequency within a certain range, it is widely used in wireless transmitters and receivers. In the receiver, band-pass filter allows the signal in the selected frequency range received and decoded and let unwanted frequency signal go through.

Frequency domain analysis of the set defects

Detecting inner defects of concrete with Impact-Echo Method is not popular yet, according to the distribution of spectrum of echo signal, the distribution of defects are identified. Analysis of the set defects in the test specimen are as follows:

The testing result of defect 1 was shown in Fig. 3. Fig.3 depicts three kinds of obvious peaks in the frequency spectrum, and the three kinds of frequency and the corresponding thickness were presented in the figure. The corresponding slab thickness of f_2 was 198mm with the deviation of 1%, and the corresponding slab thickness of f_3 was 144mm, which deviation was 6.7%. The results of other defects were shown in Fig. 4 to Fig. 7, and the thickness deviation was presented in Table 3. Referring to Table 3, the thickness deviation were less than 5% which can meet

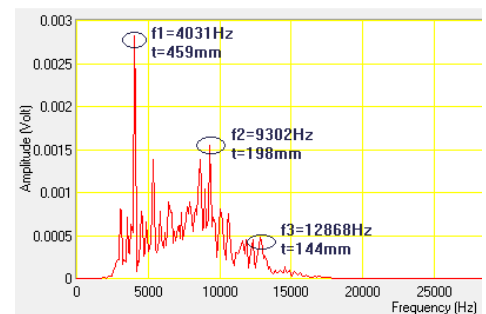


Fig.3 Frequency chart of defect 1

the precision requirement, but as a result of some unclear peak, the reflection frequency was difficult to recognize and the deviation of the depth positioning of defects were more than 10%.

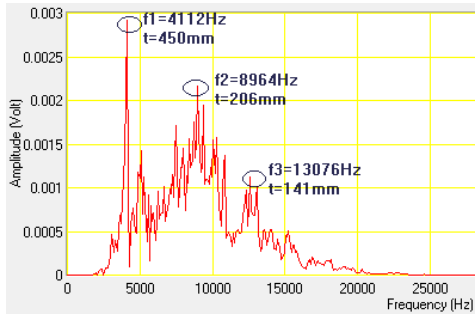


Fig.4 Frequency chart of defect 2

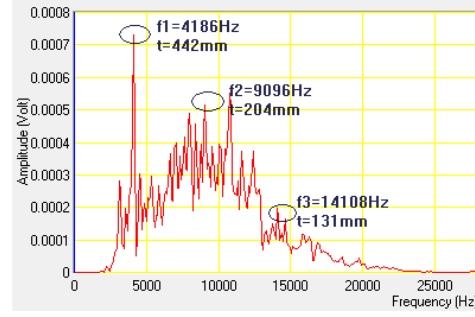


Fig.5 Frequency chart of defect 3

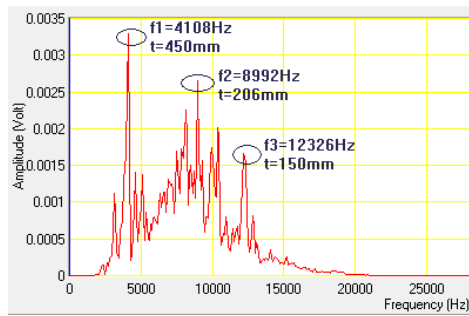


Fig.6 Frequency chart of defect 4

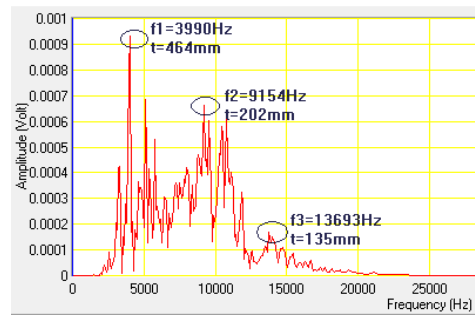


Fig.7 Frequency chart of defect 5

Table3 Table of thickness deviation

Defect no.	Thickness deviation (%)	Depth deviation (%)
1	1.0	6.7
2	3.0	14.9
3	2.0	31.0
4	3.0	20.0
5	1.0	35.0

Frequency domain analysis of the extra defects

Fig. 2 presented some extra defects besides the set ones, Fig. 8 to Fig. 10 showed the frequency spectrum of defect 6 to defect 8 separately, there were three kinds of peaks in each spectrum and the reflection frequency respectively were 16530Hz、13076Hz and 13569Hz with the corresponding thickness of 112mm、141mm and 136mm, which account for the defects in the concrete slab. Another defect presented in Fig. 2 was defect 9, the measured thickness dropped sharply to 0 and the time-domain plot was a single straight line, that was because the wheel scan head did not receive the echo signal at the edge of the slab and that should not be considered as a defect.

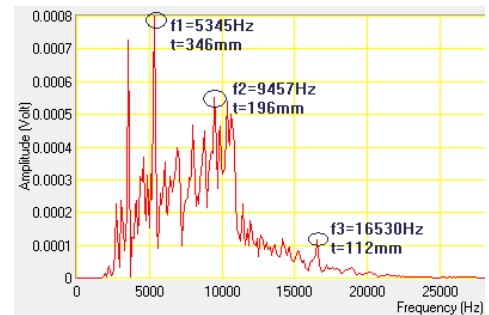


Fig.8 Frequency chart of defect 6

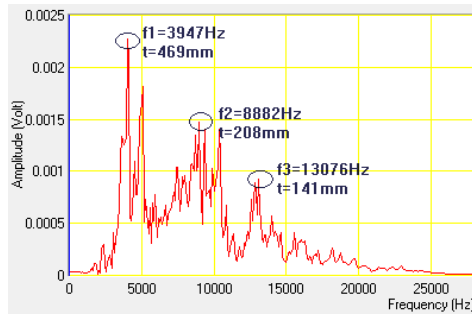


Fig.9 Frequency chart of defect 7

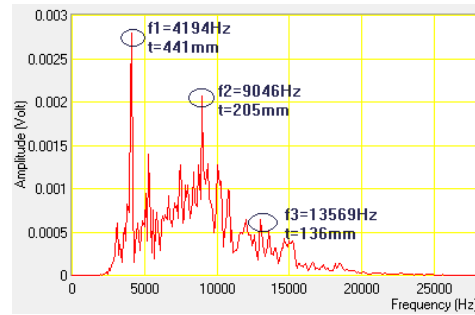


Fig.10 Frequency chart of defect 8

Conclusions

I.The identification of plane position and size of internal defects in concrete slabs by the Impact-Echo Method is relatively accurate, but due to the non-homogeneous features of concrete and too many frequency peaks in the spectrum, the deviation of determining the depth of buried defects is relative bigger.

II.The wave impedance of air and concrete interface is larger than other interface and the stress wave can easily reflect and recognized at these interfaces, the peak of reflection frequency is obvious so that determining the depth of the defects is more accurate.

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