Study on Nondestructive Test Method for Inner Defects of Mass Concrete

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Abstract. Due to the large geometric size and the influence of dense embedded steel bars, it is difficult to use the traditional nondestructive testing (NDT) method for evaluation the inner defects of mass concrete. A comprehensive nondestructive testing method for internal defects of mass concrete was proposed, which used elastic wave Computed Tomography (CT) scanning for general survey, ultrasonic tomography and ground penetrating radar (GPR) technology for fine investigation. The method was applied to the defect detection of a bearing platform concrete belonging to an interchange bridge. Finally, the reliability of this method was verified by the results of core drilling. The results show that the proposed method can effectively detect the distribution of defects in concrete, provided a new solution and practical guidance for the internal defect detection and reinforcement of mass concrete structure.

Keywords: Mass concrete, Defect detection, Nondestructive method, Elastic wave CT, Ultrasonic tomography, Ground penetrating radar

1. Introduction

Due to the large geometric size and the influence of dense embedded steel bars, embedded pipes, concrete cooling pipes, etc. the defects such as honeycomb, segregation and voids are easily generated caused by poor vibration and long layered pouring time. In order to ensure the good long-term performance, it is very important to evaluate the internal quality of mass concrete.

There are many methods for nondestructive testing of concrete internal quality. The detection depth of ground penetrating radar (GPR) is large, which can reflect the internal defects of concrete. Wu [1] studied using f-k migration to improve the imaging quality of concrete inner defects. Xiao Du [2], George Morcous [3], Nicolas Gagarin [4], Guo Shili [5] improved the imaging effect of the weak reflection signal under the steel mesh by different way.

Elastic wave Computed Tomography (EWCT) and ultrasonic tomography (UT) methods are often used in concrete defect detection too. But, Zhu Wenzhong [6] proved the limitation of this method by examples.

Generally speaking, it is difficult to accurately determine the concrete defects by single detection method. Some scholars try to use a combination of multiple methods to detect the defects. Sherif Yehia [7] compares infrared thermal imaging, impact echo and GPR in detecting defects of concrete bridge deck, found that infrared thermal imaging was suitable for detecting surface cracks, GPR was suitable for detecting internal holes, and impact echo had higher requirements for testing surface. Hoda Azari
[8] studied the characteristics of intact and defective concrete slabs in the impact echo and ultrasonic surface wave test, considered that the combined use of the two methods can improve the accuracy of the detection. Sahil Garg [9] compared GPR, ultra sonic pulse velocity (UPV) and infrared thermography in the detection of grouting holes in pipelines, found that UPV signal was obviously shielded by pipelines, and the other two methods were relatively ideal.

In this paper, a comprehensive non-destructive testing method for internal defects of mass concrete was proposed, which uses EWCT scanning technology for general survey, combined with UT imaging technology and GPR technology for fine investigation. The method was applied to the defect detection and evaluation of a mass bearing platform concrete at an interchange bridge, and verified by core drilling method.

2. Nondestructive Testing Technology of Concrete

2.1. Elastic Wave CT Scanning Technology
The propagation speed of elastic wave in concrete is related to the density, strength and other physical and mechanical parameters of concrete. In hard and dense concrete, elastic wave has high speed and slow attenuation, while in loose and broken concrete, it has low speed and fast attenuation. If there is a defect in the concrete structure, the elastic wave velocity will decrease, so the elastic wave velocity can be used as an index to evaluate the internal defects of concrete structure.

2.2. Ultrasonic Tomography
Ultrasonic tomography is a non-destructive testing method to reconstruct the velocity distribution of ultrasonic wave. It can also be used for 3D reconstruction to visually display the internal defects of concrete structure.

2.3. Ground Penetrating Radar
Ground penetrating radar (GPR) is often used to detect underground targets. It transmits high-frequency electromagnetic waves through the transmitting antenna and receives interface reflected waves through the receiving antenna. When it is used to detect the concrete structure, due to the difference of electromagnetic properties between the concrete medium and the defect medium, the reflected wave will be generated at the defect location, and then the internal defects of the concrete structure can be inferred from the received reflected wave image.

3. Detection Scheme

3.1. Project Overview
The No. 21 bearing platform pier in a road project is 25 m × 13 m in plane and 3 m in height (see figure 1). A large amount of gas escaped from the bottom of the cast-in-place concrete during the pouring of concrete. The investigation confirmed that some shield excavation and grouting were carried out when the gas escaped. In order to evaluate the influence of gas escape on the compactness of concrete bearing platform and confirm whether there are serious defects in concrete, as sampling test was not enough, comprehensive tests were needed.
3.2. Test Methods
The scheme of the test includes: (1) general survey the defects of the bearing platform: appearance inspection, the EWCT method; (2) inspect the suspected defects of the bearing platform, including abnormal wave velocity area, gas escape area, honeycomb and pockmarked area on the surface, and carry out fine detection by using the GPR and UT imaging technology (see figure 2). (3) Sampling and testing the strength of concrete in defect area using core drilling to verify the effectiveness of the testing method.

Due to the connectivity of the defects caused by the slurry leakage, dense steel bars and cooling pipes on the top and ground of the pile cap, the EWCT scanning sections was set up at the position of 1 m above and below the middle of the pile cap.

4. Elastic Wave CT Results
Thirteen measuring points are arranged on each side of the pile cap, and the elastic waves are excited one by one on the opposite side. The EWCT scanning image of elastic wave of two-layer test section at 1 m and 2 m height of No. 21 bearing platform is shown in figure 3. In the figure, the blue area with low elastic wave velocity, and the red area with fast elastic wave velocity, in unit km/s.
Figure 3. Elastic wave CT results.

It can be seen that the area with low wave velocity is larger, and the wave velocity distribution of the upper and lower sections is basically similar, which indicates that the concrete quality defects are distributed vertically, which is consistent with the gas escape path. The elastic wave CT test results, due to the complex structure in the concrete, have detection blind area, need to be combined with higher resolution detection method for verification and data analysis.

5. Ground Penetrating Radar and Ultrasonic Tomography Tests

Using GPR and UT, the defects in the blue low wave velocity area, the gas escaping area on the top and the honeycomb and pockmarked area on the side of the pile cap were further investigated.

It can be seen from figure 4 that the radar image at 21-1 had strong reflection locally, and there are many reflection areas in the red frame of UT image. There were cavities and non dense areas in the concrete, with the range of 2 m × 0.4 m and the depth of 0 ~ 0.35 m.

(a) Image of ground penetrating radar results. (b) Image of ultrasonic tomography results.

Figure 4. NDT results at 21-1 on the side of pile cap.

6. Defect Inference and Verification

Based on the EWCT, UT and ground GPR technology, 11 defects were found in the pile cap, which were mainly distributed in the gas escaping area on the top of the pile cap and the honeycomb and pockmarked area on the side. In order to verify the comprehensive evaluation results, some defect areas were coring. The core sample photo is shown in figure 5. The core sample at 21-a is difficult to take out the complete sample at the deepest point. There are many short spacing fractures and many holes in 21-b. The maximum compressive strength of core sample is 30.2 MPa, which is far lower than the design strength of 50 MPa. The test results of core drilling show that the comprehensive nondestructive testing method proposed in this paper can better identify the internal defects of
concrete.

(a) 21-a on the top of pile cap.

(b) 21-b on the top of pile cap.

Figure 5. Photos of core sample.

7. Conclusions
Elastic wave CT technology is suitable for large-scale rapid survey of elastic wave velocity of reinforced concrete structure. According to the wave velocity image, the low wave velocity region of concrete can be quickly identified, but the detection resolution of defects is relatively low. Phased array ultrasonic method can accurately identify the surface defects and reinforcement distribution, but the ultrasonic reflection signal in deep area is weak, so it is difficult to detect the defects effectively. In Ground penetrating radar (GPR) test electromagnetic wave signal is easily shielded by the surface steel mesh, but combined with phased array ultrasonic method for steel positioning can enhance the ability to identify internal defects. In this paper, the comprehensive use of the above three non-destructive testing technology to detect the internal defects of mass concrete effectively overcomes the difficulties of limited detection accuracy or low detection efficiency when using a single detection method. The successful application of this method provides a new way to solve the construction quality detection and evaluation of mass concrete.

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