Detection Technology and Application of Three-Dimensional Ultrasonic Imaging of Concrete

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Abstract: Concrete is a very important structural material in engineering buildings and it is of great significance and practical value to visually describe the internal components and defects of concrete structures by means of imaging. In this paper, a three dimensional imaging detection technology for concrete has been introduced, which employs special techniques such as point contact, dry coupling, array and shear wave observation, and the result of the test block experiment and engineering practice shows that this method can accurately detect abnormal parts of steel bar and void in steel fiber reinforced concrete.

1. Introduction
Concrete is a very important structural material in engineering buildings and it needs to be inspected to ensure the safety, reliability and durability of concrete structures in service after the construction. It is of great significance and practical value to visually describe the embedded targets and damages in concrete structures by means of imaging[1-2].

Radar detection and ultrasonic detection imaging are the main detection and imaging methods. Ultrasound detection has many advantages, such as strong penetration ability, large thickness, and simple equipment. It has good prospects in the application of concrete structure imaging[3]. However, concrete is a heterogeneous anisotropic composite material with porous and viscoelastic plasticity. During the propagation of ultrasonic wave, complex reflection, refraction and transmission phenomena will occur. The energy attenuation will be very large. The received signal will be doped with structural noise, reflection of boundary surface and reflection of defective target, which makes the signal-to-noise ratio very low, thus increasing the difficulty of concrete structure imaging[4-5]. In this paper, a three-dimensional imaging detection technology for concrete has been introduced, which employs special techniques such as point contact, dry coupling, array and shear wave observation and processing with synthetic aperture focusing imaging algorithm the small transducer can get high resolution at a lower working frequency. Finally, the imaging detection technology is applied in engineering.

2. Detection Principle
The technology of ultrasonic three-dimensional imaging detection uses an array dry-coupled probe to excite an ultrasonic shear wave to penetrate the concrete structure. Fig. 1 shows the array probe scanning mode, synthetic aperture focusing algorithm is used to image the scanning data to obtain the internal information of the detected structure. Finally, the two-dimensional or three-dimensional image of the completely concrete section is drawn[6].
The ultrasonic imaging principle of synthetic aperture focusing technology is shown in Fig. 2. There is a defect $P(i, j)$ in an object, the vertical distance from $P$ to the surface of the object is $R$. The transmitting probe is fixed on the surface of the object $N_1$. The receiving probe moves along the scanning straight line with a certain step starting from the distance from the transmitting probe $x$, and receives a defect reflection signal and stores it every time. Then, the received defect signal is delayed superimposed according to the spatial location of the defect. The advantage of synthetic aperture focusing technology is that small aperture transducers can be used to synthesize large aperture transducers, which can detect distant objects with high azimuth resolution at low operating frequencies [7].

3. Experimental methods

The size of steel fiber reinforced concrete prism is 100cm*50cm*50cm, and a layer of 20mm steel bar has been prefabricated. The formula of steel fiber reinforced concrete material is shown in Table 1. The ultrasonic frequency is 35 KHz and the ultrasonic velocity is 2850 m/s. The MIRA-A1040 ultrasonic transverse wave reflection-imaging detector is used to detect concrete blocks and tunnel lining respectively. The surfaces of the concrete blocks and lining are divided into meshes according to the size of 20cm*10cm and scanned point by point. Finally, the test result is processed by analysis software.

| Cement | gravel | sand | expansive agent | water | steel fiber | water reducer |
|--------|--------|------|-----------------|-------|-------------|---------------|
| 460    | 700    | 1000 | 45              | 5     | 80          | 165           |

4. Result analysis

The test result of concrete blocks is shown in Fig. 3. The red in the figure shows abnormal areas, there are many parallel strip Red areas on the upper part of the blocks, which are analyzed as embedded steel bars. There is a strip of red areas in the depth of 500mm, from the analysis of the depth position; it can be seen as the reflection of the bottom of the blocks. The imaging results reflect the internal structure characteristics of the test block, which shows that the method is effective and intuitive for the measurement of concrete thickness and the air reflection signal of the steel bar inside the concrete and the bottom of the test block is obvious.
Figure 3. Test results of steel fiber reinforced concrete blocks

The structural integrity of the steel fiber reinforced concrete lining is testing in the tunnel, shown in Fig. 4. Meshing is carried out on the lining surface, and then the three-dimensional information is scanned and drawn point by point.

Figure 4. Testing of Steel Fiber Reinforced Concrete Lining in Tunnel

The test result is shown in Fig. 5. Within the depth range of 500mm-800mm, there is an anomalous area of continuous reflection about 3m in length. Combining with the depth position of B-section image, the trend of anomalous area is basically consistent with the outline of surrounding rock during construction. It is analyzed that the anomalous area of reflection is the air reflection signal of the interface between concrete lining and tunnel rock mass, and the concrete lining solidifies and shrinks after casting. Cavitation defects occur in rock mass of the same tunnel.

Figure 5. Lining test results

Fig. 6 shows the result of borehole coring and borehole photography and the ultrasonic three-dimensional imaging detection in the void lining area, which confirms the accuracy of the concrete three-dimensional imaging detection technology.
Figure 6. The result of lining detection and borehole coring and borehole photography

5. Summary
In this paper, three dimensional imaging detection technology for concrete has been introduced, which employs special techniques such as dry coupling and synthetic aperture focusing imaging algorithm. Experiments and engineering examples show that the detection method can accurately detect the abnormal parts of steel bar and void in steel fiber reinforced concrete. The results show clearly and intuitively, which provides a new technical means for the detection and evaluation of the safety, reliability and durability of concrete structures after construction and during service.

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