Journal of Civil Engineering and Urban Planning (2022)
Clausius Scientific Press, Canada
DOI: 10.23977/jceup.2022.040407
ISSN 2616-3969 Vol. 4 Num. 4

# Study on Ultrasonic Detection of Concrete Crack Depth

**Yi Wu, Ping Jiang*, Yanfei Yu**

*Shaoxing University, Shaoxing City, China*
**Corresponding author*

***Keywords:*** Ultrasonic nondestructive testing, crack depth, error, improvement scheme

***Abstract:*** According to the basic principle of ultrasonic nondestructive testing, this paper discusses the method of ultrasonic testing concrete cracks, and designs the experimental scheme by using the flat testing method. The crack depth is evaluated by testing the experimental data obtained from the component concrete. On this basis, the experimental data error and experimental improvement methods are discussed.

## 1. Introduction

In the construction engineering, the application of concrete is extensive and important, but it is inevitable that concrete will produce cracks due to many factors such as cement quality, grading, construction conditions, curing, etc., so cracks are extremely common [1-4]. However, when the crack depth reaches a certain degree, it will affect the bearing capacity, waterproof, durability, safety and other performance of the structure, so it is necessary to carry out concrete crack detection in construction. Through the ultrasonic concrete crack depth detection experiment, we analyzed the experimental data and evaluated the concrete crack depth [5-8]. At the same time, we discussed the error of the experimental data and optimized the deficiencies of the experimental scheme to find the applicable scope of the experimental method.

## 2. Experimental Scheme for Ultrasonic Testing of Concrete Crack Depth

### 2.1. Purpose

(1) Understand the basic principle of ultrasonic testing;
(2) Master the method of using ultrasonic to detect the depth of concrete cracks and design the experimental scheme;
(3) Evaluate the concrete cracks of actual members;
(4) The experimental data error is discussed and the experimental scheme is optimized;
(5) Understand the scope of application of experimental methods.

### 2.2. Experimental Equipment

(1) Concrete ultrasonic detector
(2) Reinforced concrete specimen.

## 2.3. Ultrasonic Nondestructive Testing Mechanism

First, place transducers A and B on both sides of the crack. Some of the ultrasonic wave generated by A will spread along the surface, but because of the reflection of the crack, the ultrasonic wave cannot directly reach the receiving transducer B. And the other part of the ultrasonic wave passes through the concrete from A to C, and finally bypasses the crack to B. However, the measured propagation time t should be greater than the surface propagation time, as Figure 1.

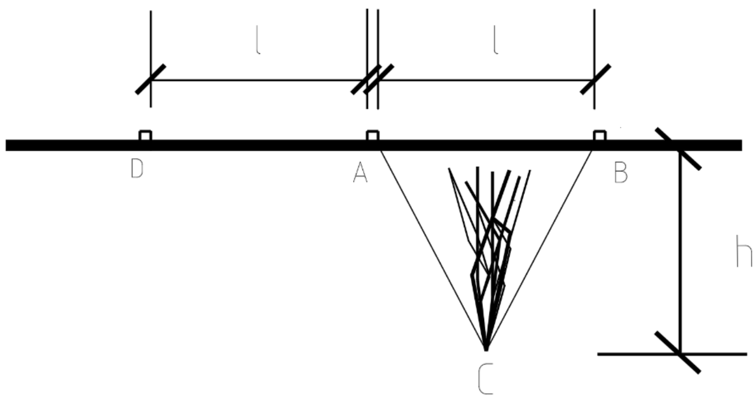


Figure 1: Schematic diagram of concrete crack depth test

Place a transducer near the crack, let AD=AB=$l$, then the measured ultrasonic propagation time along the seamless surface is $t^0$, and let $t^0$ represent the propagation time measured by the transducer at A and B under the assumption that there is no crack.

According to the triangle side length relationship, the crack depth $h$ is as Eq.(1).

$$h = \frac{l}{2}\sqrt{(\frac{t}{t^0})^2 - 1} \tag{1}$$

Where, $t^0$, when measuring sound without crossing the seam; $t$, During cross seam flat sound measurement; $l$, Transducer ranging.

## 2.4. Steps of Ultrasonic Crack Detection

### 2.4.1. Preparation Before Test

(1) Instrument preparation

(2) Treatment of component surface: the component surface shall be clean, flat and free of dirt.

(3) Formulate a plan: according to the situation of the project construction site, develop a testing plan to determine the testing parts.

### 2.4.2. Layout of Measuring Points for Surface Leveling Method

(1) No cross joint horizontal measurement: first, no cross joint measurement shall be conducted near the crack. Draw a straight line at the joint near the crack, and then draw 40, 50, 80mm and other short lines with different distances on the straight line. Place one transducer at point A without moving, and the distance from the other transducer to transducer A (inner edge) is also 40, 50, 80mm... ($l_1$ ', $l_2$', $l_3$ '), when measuring the sound without across the seam.

(2) In the horizontal measurement across the joint, draw a straight line perpendicular to the crack, and take the crack as the center on the straight line, draw equidistant short lines to both ends at the same time. The spacing of each pair of short wires is also 40, 50, 80 mm. Finally, place the transducer on each pair of measuring lines to measure the ultrasonic propagation time around the crack $t_1$, $t_2$ and $t_3$ respectively.

## 3. Data Processing of Ultrasonic Nondestructive Testing

### 3.1. Crack Measurement by Surface Plane Measurement

#### 3.1.1. Time Interval Diagram

Take the acoustic time ($t_1^0$, $t_2^0$, $t_3^0$) of the measuring point without crossing the seam as the abscissa, and the ranging $l_1$ ', $l_2$', $l_3$ ' as the ordinate according to Table 1 and Table 2. Draw the time distance diagram of the points and connect the points into a line, as shown in Figure 2.

Table 1: Distance measurement

| | | |
|---|---|---|
| $l_1$'=4cm | $l_2$'=5cm | $l_3$'=8cm |
| $l_4$'=10cm | $l_5$'=12cm | $l_6$'=14cm |
| $l_7$'=15cm | $l_8$'=16cm | $l_9$'=18cm |

Table 2: Measuring point acoustic time

| | | |
|---|---|---|
| $t_1^0$=27.2s | $t_2^0$=32.4s | $t_3^0$=52.8s |
| $t_4^0$=65.6s | $t_5^0$=72s | $t_6^0$=78.8s |
| $t_7^0$=80.4s | $t_8^0$=84.4s | $t_9^0$=88.8s |

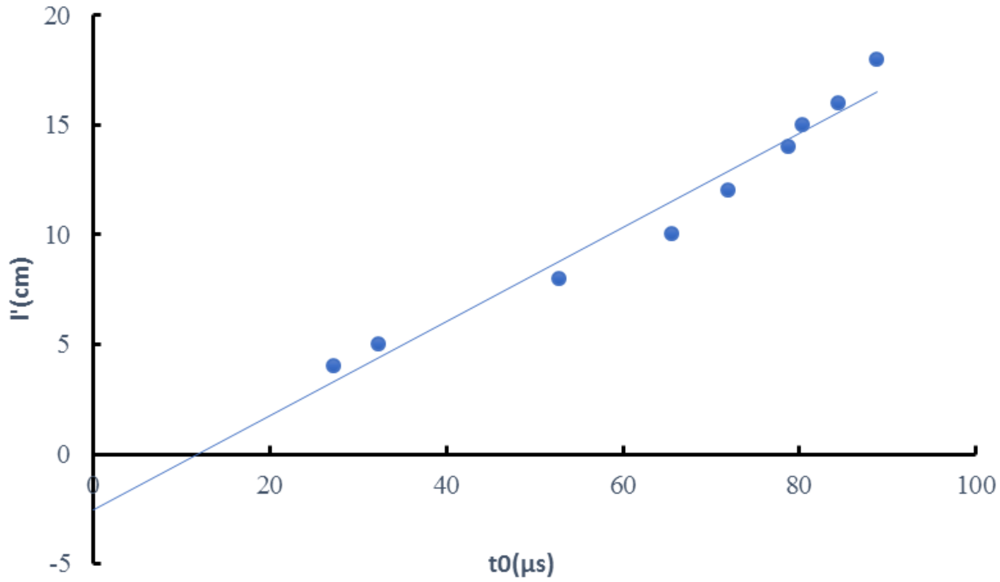


Figure 2: Time interval diagram

The above experimental data are real data measured by using experimental equipment. The equation ($l$ '=a+b$t^0$) is obtained by linear regression from the above data as Eq. (2).

$$l' = -2.36 + 0.21t \tag{2}$$

### 3.1.2. Calculate the Actual Propagation Distance of Ultrasonic Wave

According to Eq.(3), the actual propagation distance of ultrasonic wave is shown in Table 3.

$$l_i = l_i' + |a| \tag{3}$$

Table 3: Actual propagation distance of ultrasonic wave

| | | |
|---|---|---|
| $l_1$=6.36cm | $l_2$=7.36cm | $l_3$=10.36cm |
| $l_4$=12.36cm | $l_5$=14.36cm | $l_6$=16.36cm |
| $l_7$=17.36cm | $l_8$=18.36cm | $l_9$=20.36cm |

### 3.1.3. Calculate the Crack Depth

The sound time ($t_i$) of each measuring point across the seam is shown in Table 4.

Table 4: Measuring point across the seam time

| | | |
|---|---|---|
| $t_1$=39.2s | $t_2$=51.6s | $t_3$=90s |
| $t_4$=108.8s | $t_5$=119.2s | $t_6$=128.4s |
| $t_7$=135.0s | $t_8$=148.2s | $t_9$=151.1s |

According to Eq.(1), Table 2, Table 3 and Table 4, the crack depth $h_i$ can be obtained as Table 5.

Table 5: Value of crack depth

| | | |
|---|---|---|
| $h_1$=3.29cm | $h_2$=4.52cm | $h_3$=7.12cm |
| $h_4$=8.10cm | $h_5$=9.42cm | $h_6$=10.42cm |
| $h_7$=11.58cm | $h_8$=13.17cm | $h_9$=13.99cm |

The average value of $h_i$ can be calculated from Table 5 as shown in Eq. (4).

$$\overline{h_i} = \frac{\sum_{i=1}^{9} h_i}{9} = 9.07cm \tag{4}$$

As $l_1$=6.36cm<9.07cm, $l_2$=7.36cm<9.07cm, So $h_1$ and $h_2$ data are discarded. Average value of $h=(h_3+h_4+h_5+h_6+h_7+h_8+h_9)/7=10.54$cm.

## 3.2. Error Analysis and Improvement of Experimental Data

### 3.2.1. Influence of Concrete Internal Structure on Ultrasonic Testing

(1) Ultrasonic detector is an instrument with waveform display function. The instrument observes other parameters such as wave amplitude and dominant frequency by measuring the propagation speed of ultrasonic pulse in the internal structure of concrete. These parameters can be displayed in the ultrasonic instrument, and the defect in concrete can be judged by the change of these parameters, so as to obtain the crack depth of concrete.

(2) During concrete construction, the internal structure of concrete will be different due to different cement dosage, water cement ratio, aggregate specifications and quality, etc. When measuring the crack depth of concrete at different distances from the crack, the internal structure of concrete is likely to be different, which will lead to errors in ultrasonic measurement data. Similarly, in case of vibration leakage, mortar leakage or stones being overhead on the reinforcement framework during construction, there will be a honeycomb like non dense area or hollow area in the concrete, which will affect the transmission and acceptance of ultrasonic waves by the transducer,

thus causing errors in the experimental data.

From the above analysis, we found that when the internal structure of concrete is different or there are problems, the ultrasonic measurement data will be affected, which will lead to errors in the experimental data.

### 3.2.2. Measurement Error of Ultrasonic Instrument

(1) Accuracy: the error between the measured value and the true value, which is unavoidable and objective.

Error cause: temperature may affect the ultrasonic speed;

After receiving the sound wave, the receiver will inevitably lag;

The timer itself may have errors, etc

(2) Accuracy: multiple measurements are required to avoid accidental data and a series of errors such as data errors caused by human factors.

(3) Ultrasonic instrument and equipment: The ultrasonic detector shall meet the current national standards and be used within the validity period. When the instrument is damaged or takes too long, the sensitivity of the equipment will be reduced and the measurement reading will have errors.

(4) Transducer:

Cracks in concrete will destroy the continuity, integrity and many other properties of concrete, which will reduce the strength and durability of concrete. Therefore, when conducting experimental operations, we should use higher frequency transducers under the condition that the display of wave amplitude and dominant frequency is clear and accurate, which can make the ultrasonic detection data more accurate.

### 3.2.3. Data Error Caused by Contact Problem

The amplitude and dominant frequency of ultrasonic wave need to be obtained through coupling agents such as toothpaste, vaseline, etc. to make the test surface of concrete closely combined with the transducer. Only when the coupling agent is closely combined with the ground and the transducer can the ultrasonic instrument transmit good sound waves. When the coupling layer is mixed with sand and air, the transducer will have poor contact with the ground, which will affect the amplitude and dominant frequency. At this time, the amplitude may be disordered, and the dominant frequency cannot be displayed, resulting in inaccurate experimental data.

## 4. Experimental Improvement

Through the above ultrasonic testing of concrete crack depth experiment and the processing of experimental data, we know that there are many factors that cause experimental errors. How can we make the measured data results more accurate and true? This is what we need to discuss next.

In the above experiments, we have identified the advantages and disadvantages of the experiment of ultrasonic detection of concrete crack depth, so we can further optimize and improve on the basis of the experiment of ultrasonic detection of concrete crack depth.

In today's nondestructive testing of concrete, radar technology and ultrasonic technology have been widely used.

Because the speed of ultrasonic pulse propagation has a great relationship with the compactness of concrete, when the concrete has cracks or voids, the ultrasonic pulse can only bypass the crack area or void area to propagate to the receiving converter, which will lead to an increase in the propagation distance, which will inevitably lead to a decrease in the final measured time or the sound speed, and ultimately lead to experimental data errors.

And how can we reduce the data error caused by the internal structure of concrete? We can use the bottom detection radar technology to measure the concrete depth on the basis of ultrasonic testing. By combining these two methods, we can not only reduce the data error to a large extent, but also measure the crack depth more accurately.

We know that the radar system measures the concrete crack depth through electromagnetic pulse (the propagation speed of the radar depends on the electromagnetic property of the material). It determines the depth and position of the target through the time when the electromagnetic pulse propagates to the target and reflects back. Unlike ultrasonic, the bottom detection radar uses different electromagnetic properties of different media to cause the radar reflected echo to change in wavelength and waveform, then the crack depth of concrete is measured in this way, independent of the internal structure of concrete.

Therefore, to sum up, the combination of bottom detection radar technology and ultrasonic technology, and the measurement of concrete crack depth through their different measurement principles, can make the experimental data more accurate and the experimental scheme more perfect.

## 5. Conclusions

Nowadays, concrete has been widely used in projects, and the quality of concrete has become the top priority of construction projects. Therefore, it is necessary to study the depth of concrete cracks, which not only affects the beauty, but also determines the safety of users. So now people pay more and more attention to the research of concrete crack depth, and there are more and more methods to detect concrete cracks. For example, the ultrasonic technology, bottom detection radar technology, borehole detection method and other methods introduced above, but we need to know that each method has its own advantages and disadvantages, and each method will have its own errors. To make the data more accurate, we need to combine the advantages of each method and optimize the experimental methods as much as possible, so as to measure the true crack depth as possible, In this way, the safety of concrete will be more guaranteed, which is not only responsible for the project, but also responsible for yourself. Therefore, only by learning professional knowledge, combining professional knowledge with practice, and constantly exploring, can we get a truly practical scheme.

## References


*[1] Li, W., Zhu, B., Zhou, Z., & Jin, W. (2022). Simulation and experiment of ultrasonic phased array for additive manufacturing titanium alloy with columnar crystal structure. Insight: Non-Destructive Testing and Condition Monitoring (5), 64.*

*[2] Umanskii, A. A., Simachev, A. S., Golovatenko, A. V., & Dumova, L. V.. (2022). Nature detection of internal defects in railroad rails produced by evraz zsmk company using ultrasonic control in mill flow. Metal Science and Heat Treatment, 64 (5), 350-354.*

*[3] Tang, B., Fu, B., Zhang, S., & Meng, J. (2022). Clinical effect analysis of radial extracorporeal shock wave therapy with compound ultrasonic treatment for frozen shoulder. Journal of North Pharmacy, 2 (1), 1-4.*

*[4] Wang, Z., Yang, F., Zhang, W., & Yang, S. (2022). Quantitative and anatomical imaging of human skin by noninvasive photoacoustic dermoscopy. Bio-Protocol, 12, 4372.*

*[5] Sunil, K. T., Venkata, R. K., Balaji, M., Murthy, P. B. G. S. N., & Vijaya, K. D. (2022). Online monitoring of crack depth in fiber reinforced composite beams using optimization grey model gm (1, n). Engineering Fracture Mechanics, 271.*

*[6] Costa, E. C., Weingaertner, W. L., & Xavier, F. A. (2022). Influence of single diamond wire sawing of photovoltaic monocrystalline silicon on the feed force, surface roughness and micro-crack depth. Materials science in semiconductor processing, 143.*

*[7] Ali, A. Y. F., El-Emam, H. M., Seleem, M. H., Sallam, H. E. M., & Moawad, M.. (2022). Effect of crack and fiber length on mode i fracture toughness of matrix-cracked frc beams. Construction and Building Materials (Jul. 25), 341.*

*[8] Wang, Z., Chen, D., & Gong, J. (2022). Pose error analysis method based on a single circular feature. Pattern Recognition: The Journal of the Pattern Recognition Society, 129.*