Ultrasonic monitoring of cement setting based on embedded sensor

Xianyong Pei [1, a, *], Qianqian Wang [1, b], Peng Zhao [1,c], Yinghui Lv [1,d]

[1]School of Civil Engineering and Architecture,University of Jinan,Jinan 250022,China；

[a] cea_peixy@ujn.edu.cn, [b] 1957189418@qq.com, [c] cea_zhaop@ujn.edu.cn,

[d] cea_lvyh@ujn.edu.cn

Abstract. The hydration property of cement directly affects the performance index of concrete, so it is necessary to monitor the hydration setting process of cement. The aim of this paper is to monitor the process of cement hydration setting by ultrasonic wave. Ultrasonic monitoring is a kind of dynamic non-destructive testing technology, which has the advantages of real-time, on-line and continuous. In this paper, an in-situ monitoring technology of cement hydration setting based on embedded piezoelectric ceramic sensor is introduced. The monitoring results show that the amplitude change of ultrasonic signal received by the sensor can indirectly reflect the change process of cement hydration solid and liquid, especially the initial setting node has a high catching ability.

Key words: hydration, ultrasonic, piezoelectric, embedded, initial setting time.

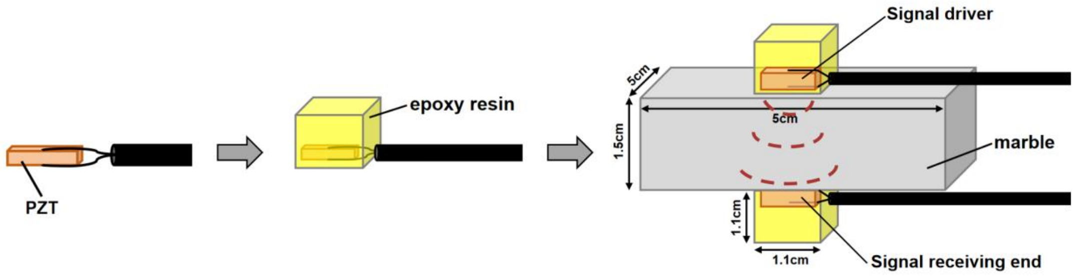
1. Introduction

Concrete structure is widely used in practical engineering, and cement hydration directly affects the mechanical properties of concrete, so the monitoring of cement hydration is of great significance to the application of concrete [1]. Systems with the ability to perform continuous monitoring are one of the important sources of structural quality information to provide effective hydration process information (initial setting) to prevent failures such as mold removal time due to hydration time delays. At present, there are many methods [2,3,4] that can monitor the hydration process of concrete, including thermogravimetry, XRD analysis, hydrothermal method of hydration, chemically combined water method, hydration kinetics, image method, microscope observation, etc., but these methods cannot form engineering standards in engineering. At present, the setting time of concrete materials is generally determined by the penetration resistance method [5]. The principle of this method is that in the process of hydration reaction of newly mixed concrete, due to the formation of hydration products and the change of structure, the mortar forms a cohesive structure from colloid and then changes to a crystalline structure, and the sample of newly mixed concrete gradually loses work ability and then begins to develop strength. An electronic penetration resistance meter was used to measure the change of the penetration resistance of the mix, and the penetration resistance of 3.5MPa and 28MPa was determined to correspond to the initial and final solidification of the concrete, so as to judge the coagulability of the mix. The penetration resistance method is the most widely used method in practical engineering, but it has some defects: the parameters obtained by the measurement method can not directly reflect the physical characteristics of the material, which belongs to the empirical type of judgment; The test result points are discrete and cannot be continuously monitored. It's a lossy detection method. The principle of ultrasonic method [6] is that the propagation of ultrasonic wave is affected by the medium, and the nature of its propagation medium can be deduced by monitoring each ultrasonic characteristic quantity. The use of ultrasonic technology to monitor the coagulation process of concrete has the following advantages: Ultrasonic testing [7,8] is a non-destructive testing method, which can realize in-situ monitoring with the help of sensors, and its detection process has a high degree of automation and can realize continuous monitoring; The physical basis of ultrasonic method is clear, and the relationship between ultrasonic parameters and the properties of the material itself can be directly established.

In view of this, this paper will prepare a kind of embedded piezoelectric sensor which can monitor hydration condensation in real time, in order to realize continuous in-situ monitoring of cement hydration condensation.

2. the production of embedded piezoelectric ceramic sensor

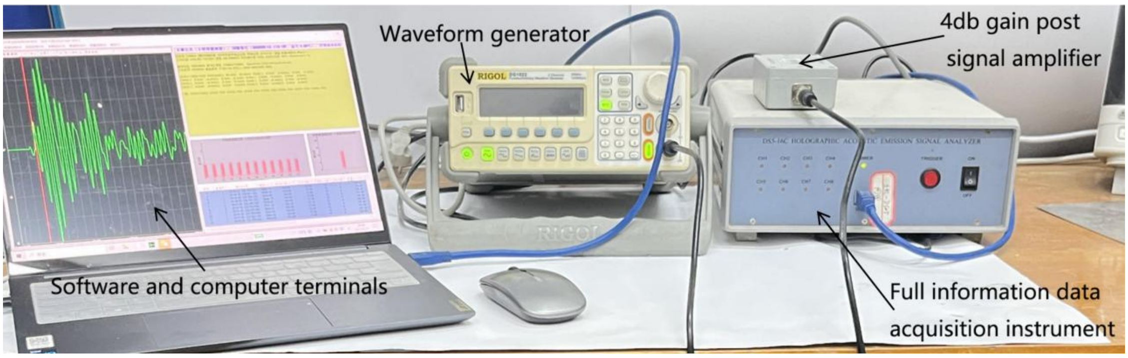
Piezoelectric material selection size of 10mm × 10mm × 2mm piezoelectric ceramic sheet. The coaxial conductor is welded on the positive electrode and the negative electrode of the piezoelectric ceramic plate respectively. In order to shield noise, in the process of welding the receiving sensor, the wire can be left in advance to shield noise. The BNC can be welded to the other end of the wire for easy contact with the signal generator and oscilloscope. The piezoelectric sensor is packaged with a mixed material with a weight ratio of epoxy resin and curing agent of 2:1, and the size of the package is 12.7mm × 12.7mm × 12.7mm. The two piezoelectric sensors are glued to the opposite surface of the marble with a packaging material, and the marble size is 50mm × 50mm × 15mm. The manufacturing process and signal propagation path of piezoelectric ceramic sensor are shown in Figure 1:



Flg. 1 Manufacturing process of piezoelectric ceramic sensor

3. Procedure of the experiment

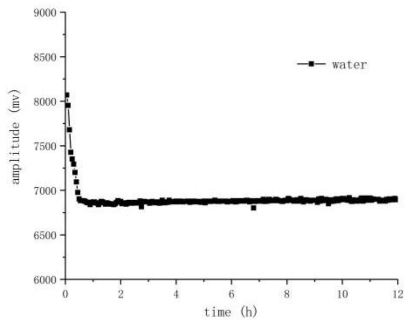
Using the PO42.5 cement produced by Shanshui Group, the water-cement ratio is 0.4. The size of the specimen is 100 mm x100 mm x100 mm. The piezoelectric sensor is fixed in the center of the grinding tool, and the two ends of the piezoelectric sensor are connected with the signal generator (DG1022) and the full information data acquisition instrument (DS5-8A). After the cement paste is mixed, it is immediately injected into the grinding tool, and then the modulated sine wave is generated by the signal generator and applied to the piezoelectric sensor. The signal voltage amplitude is +20V, the frequency is 200khz, the number of sine wave cycles is 1, and the pulse is emitted every 60s. This voltage amplitude value is normalized with the input pulse amplitude obtained from the full information data acquisition instrument. The signal is collected intermittently and continuously, the threshold is 1000mv, and the signal is continuously monitored for 24h. Considering that marble has a certain water absorption, the preparation comparison group immersed the sensor in water and continuously monitored it for 12h. The experimental equipment is shown in Figure 2:



Flg. 2 Schematic diagram of ultrasonic guided wave experimental equipment

4. Results and discussion

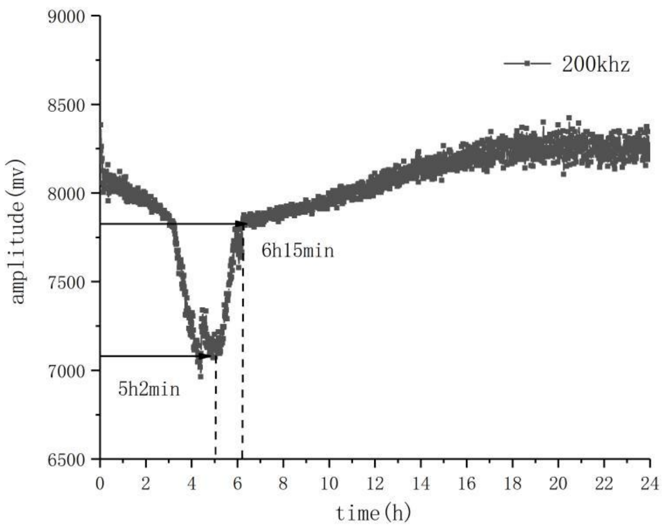
The sensor was immersed in water for continuous monitoring for 12h, and the signal acquisition of the sample was carried out with the full information data acquisition instrument. The ultrasonic pulse signal from the signal generator (DG1022) was received every 180s, and the change trend of the ultrasonic amplitude was shown in Figure 3.



Flg. 3 Variation trend of amplitude in 12h immersed in water

As shown in Figure 3, after the sensor is immersed in water, the received ultrasonic amplitude decreases sharply within 30min, and then the amplitude shows a stable state. This is because the marble has a certain water absorption, the marble after water absorption, the ultrasonic signal has a certain degree of attenuation leading to a reduction in the amplitude, and the water absorption is saturated after half an hour, so the amplitude is stable after 30 minutes.

The sensor was buried in 0.4wc cement paste for continuous monitoring for 24h, and the initial setting time of the mixed cement paste was 4h50min measured by VicA instrument. The full information data acquisition instrument was used to collect the signal of the sample, and the ultrasonic pulse signal from the signal generator (DG1022) was received every 60s. The variation trend of ultrasonic guided wave amplitude within 24h of signal acquisition was shown in Figure 4. Time domain waveform diagrams of two special moments (5h02min/6h15min) were selected for comparative analysis. The representative waves were shown in Figure 5.



Flg.4 Amplitude variation trend of cement paste 24h after embedding 0.4 water-cement ratio

As shown in Figure 4. The degree of hydration can be determined by changes in amplitude. The decrease of amplitude corresponds to the first stage of hydration induction. A few hours after the cement paste is mixed, it is basically liquid, at this time the moisture content of the slurry is higher, the marble water absorption phenomenon, and the marble water absorption will lead to a decrease in amplitude. Therefore, the ultrasonic amplitude shows a decreasing trend.

When the amplitude reaches the lowest point, the hydration reaches the initial setting state. The initial setting time measured by Vicar instrument (4h50min) is basically consistent. With the progress of hydration, the hydration products increase, the cement slurry changes from fluid state to solid state, and the water content of the cement paste decreases rapidly. Therefore, the ultrasonic amplitude shows an upward trend.

According to the time domain analysis of the received signal, the amplitude of the ultrasonic guided wave signal is related to the initial setting time of hydration. The amplitude parameter is more sensitive to the process of hydration condensation, and the initial coagulation node of hydration can be caught by the variation trend of amplitude.

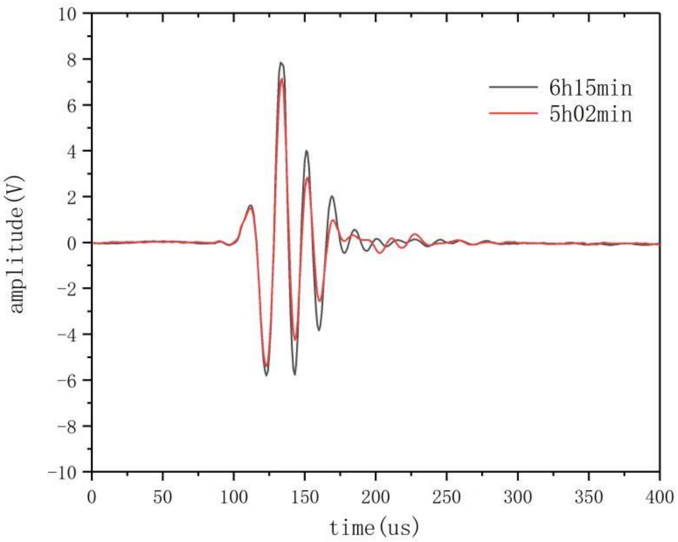


Figure 5 Time domain waveform of 5h02min/6h15min

5. Conclusion

Based on the self-made embedded piezoelectric sensor, the paper adopts ultrasonic method to continuously monitor the hydration process, and draws the following conclusion: The self-made embedded piezoelectric sensor can catch the initial setting point of cement hydration by the trend of ultrasonic amplitude change. The trend is divided into two parts: down and up. The decreasing stage of amplitude means that cement has not reached the initial setting stage, and when the amplitude change curve reaches the minimum value, the cement paste reaches the initial setting. The amplitude rises and gradually becomes stable, which means that the cement paste completes the initial setting and develops to higher strength.

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