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Concrete Acoustic Emission Signal Recognition Based on Concrete Acoustic Emission Energy

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ABSTRACT. *Acoustic emission energy is one of the important characteristic parameters in AE signals. AE energy can reflect the deformation mechanism of materials, AE energy history analysis method can evaluate the activity and development trend of AE sources, AE energy distribution analysis method can be used to evaluate the intensity of AE sources, and AE energy history analysis method and AE energy history analysis method can be used to evaluate the intensity of AE sources The acoustic emission energy distribution analysis method combines the energy, cumulative energy and the change of applied external load with the arrival time, which is used to reflect the basic characteristics of different stages of the acoustic emission signal generated by concrete after external load, so as to realize the recognition of the acoustic emission signal of concrete.*

KEYWORDS: *Concrete damage evolution, acoustic emission signal recognition, Damage characterization of concrete, acoustic emission energy*

1. Introduction

At present, the non-destructive health monitoring of large civil engineering structures has been widely concerned and valued at home and abroad. The research of non-destructive testing technology in this field has become a hot issue in the current academic and engineering field [1] NDT technology mainly includes radiographic testing, ultrasonic testing, magnetic particle testing, penetrant testing, eddy current testing, acoustic emission testing, infrared testing, laser holographic testing [2-4]. Compared with other nondestructive testing methods, acoustic emission technology (AE) has two significant characteristics: ① dynamic detection of damage, dynamic detection can detect crack growth changes, while static damage will not generate acoustic emission signal; ② passive detection, that is, the defect can be detected without external input energy. Therefore, acoustic emission technology has the unique advantages of real-time, dynamic, online detection, etc.,

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in detecting rock failure process [5], composite damage mode [6, 7], rolling bearing fault detection [8, 9], tool wear state detection [10, 11], aerospace [12, 13], water transmission research in plants [1], pressure vessel leakage detection [14, 15] , research on failure and instability mechanism of ceramics and metals, acoustic emission testing of concrete structure [1], wood processing and mechanical property testing have been widely used [16, 17].

2. Methodology

2.1 Basic content of concrete acoustic emission energy recognition

A large number of acoustic emission signals are generated in the process of concrete damage, which can be recorded as a large number of acoustic emission signal parameters. The essence of acoustic emission signal recognition is the process of obtaining, analyzing and applying these data. Concrete acoustic emission parameters contain important information of concrete acoustic emission signals. The research on the basic parameters of acoustic emission has always been one of the basic research on acoustic emission signal recognition technology [50]. A large number of experimental research and engineering applications have adopted the parameter analysis method. The parameter analysis method of acoustic emission signals has also become one of the most commonly used acoustic emission signal recognition technologies. Acoustic emission signals The energy of is directly proportional to the area enclosed by the envelope formed by the signal amplitude peak and the abscissa axis, as shown in Figure 1. From the perspective of its definition, its definition represents the physical quantity of acoustic emission signal, i.e. the size of energy value. As a unified parameter standard, it can be used to monitor the development process of concrete damage. Figure 2 is the flow chart of the concrete acoustic emission energy recognition process.

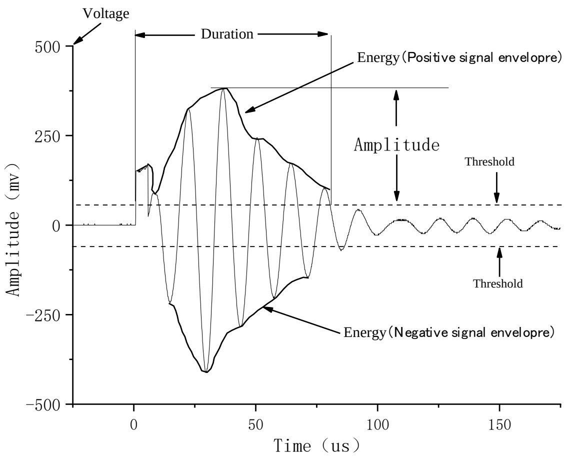

Figure. 1 Typical AE waveform with related parameters.

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2.2 acoustic emission energy

As shown in Figure 1, the area enclosed by the envelope line formed by the energy proportional to the signal amplitude peak and the abscissa axis of the acoustic emission signal is understood from the definition point of view. The definition represents the physical quantity of the acoustic emission signal, i.e. the size of the energy value. It is a unified parameter standard, which is usually represented by the parameters of the piezoelectric signal and can be understood as the energy parameter.

The energy expression is:

$$\mathrm{E} = \frac{1}{R}\int_0^{\infty} V^2(t)\,dt \tag{1}$$

Similarly, the continuous AE signal can be seen as cosine wave with real exponential law, and its expression is as follows:

$$\mathrm{V} = V_p e^{-\alpha t}\cos(\omega t) \tag{2}$$

Take the above formula into the energy expression, and suppose to find the energy from the beginning to t1, the integral can be obtained:

$$\mathrm{E} = \frac{1}{R}\int_0^{t_1} V^2(t)\,dt = \frac{1}{R}\int_0^{t_1} {V_p}^2 e^{-2\alpha t}\sin^2(\omega t)\,dt \tag{3}$$

$$\mathrm{E} \approx \frac{{V_p}^2}{4\alpha(1+\alpha^2/\omega^2)R} \tag{4}$$

3. Results and discussion

3.1 Concrete acoustic emission signal acquisition experiment

In the experiment, the size of concrete compression cube is 150 mm in length, 150 mm in width and 150 mm in height. The concrete materials are made of four different water cement ratios of 0.40, 0.45, 0.50 and 0.55, respectively. The maximum aggregate size corresponding to each water cement ratio is 5 mm ~ 26.5 mm continuous grading, the coarse aggregate is limestone crushed stone aggregate, the fine aggregate is standard sand, and the mix proportion and dosage of each test block are shown in Table 1 below. The concrete is mixed by an electric mixer and vibrated by a vibrating table. After 48 hours, the formwork is removed and then placed in a standard curing room for curing. The test piece is cured to 7, 14 and 28 days before the experiment. During the preparation of test blocks, each group has three test blocks, Six groups of test blocks of different curing age were tested. In order to ensure the consistency of each group of test blocks, considering the material loss during the experiment, in the specific operation process, the coefficient of loss rate is taken as 0.3, and the actual amount of each material is calculated as 130% of the calculated amount. The dry apparent density of ordinary concrete is 2000-2800 kg / m^3, calculated as 2400 kg / m^3 in the experiment.

Table 1 Mix proportion of test block and dosage of each component

w/c ratio	Dosage of each component(kg)			
	Cement	Sand	Coarse aggregate	water
0.40	8.1900	18.2637	32.5143	3.2760
0.45	8.1900	18.2637	32.5143	3.6855
0.50	8.1900	18.2637	32.5143	4.0950
0.55	8.1900	18.2637	32.5143	4.5045

After pouring, the test pieces shall be numbered. After numbering, they shall be put into the curing room for curing. After 48 hours, the formwork shall be removed. The test pieces shall be cured in the standard curing room with the curing temperature of 20 ± 3 ℃ and the relative humidity of 95%. The test pieces shall be tested after curing to the corresponding age, The test site drawing is shown in Figure 2.

Figure. 2 Photograph showing actual test setup

3.2 Testing instrument of acoustic emission acquisition system

In this paper, *RS-2A* wide-band sensor and *DS5* series full-wave acoustic emission signal analyzer produced by Beijing Softland Times Scientific& Technology Co.,Ltd. are used. The appearance of the sensor is shown in Figure 3, and the specific parameters are shown in the Table 2 below. Compared with other existing acoustic emission signal analyzers, DS5 series full information acoustic emission signal analyzer has the advantages of full waveform acquisition Multi channel number, high sampling rate, synchronization of each channel, automatic adjustment of trigger position, etc.

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Figure. 3 RS-2A broadband sensor

Table 2 RS-2A wideband acoustic emission sensor parameters

Model	Diameter	Height	Service frequency	Center frequency	Operating temperature range	Test surface material
RS-2A	18.8mm	15mm	50-400 KHz	150KHz	-20℃~130℃	ceramics

3.3 Damage characterization of concrete based on acoustic emission energy

The change of energy, cumulative energy and applied external load with arrival time is shown in a diagram by acoustic emission, which is used to reflect the basic characteristics of different stages of acoustic emission signal generated by concrete under external load. The energy accumulation analysis diagram of three groups of test blocks with water cement ratio of 0.5 and curing age of 7D, 14d and 28d is shown as follows:

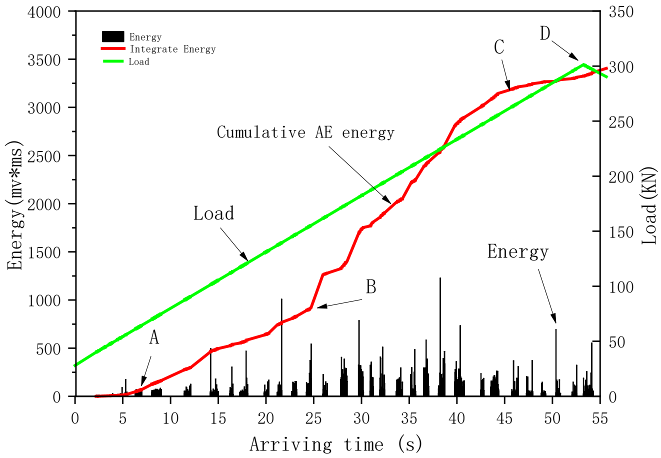

Figure. 4 Test block with curing age of 7D

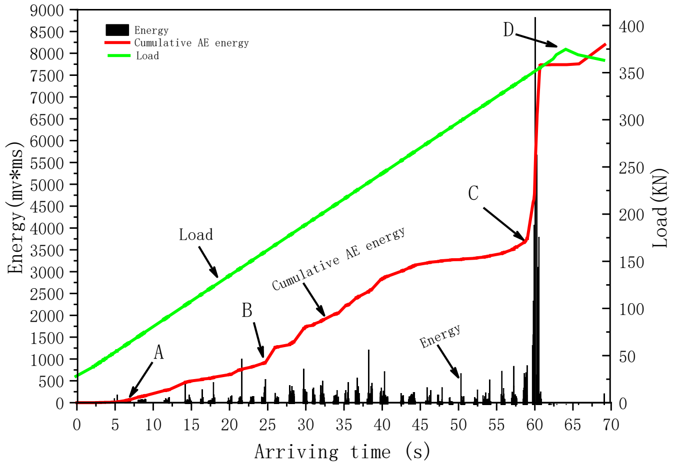

Figure. 5 Test block with curing age of 14D

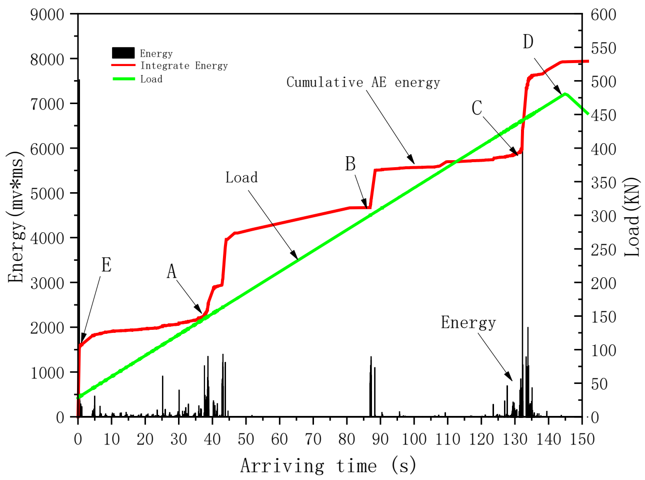

Figure. 6 Test block with curing age of 28D

The cumulative energy and load arrival time relationship of three groups of test blocks with different curing age have some common features. Their load arrival time relationship is composed of linear growth stage and load drop stage. The distribution of energy in the whole loading stage has aggregation phenomenon in different time nodes, and the cumulative energy has jump type sudden increase phenomenon in different time nodes.

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There are different points in the cumulative energy, load arrival time relationship diagram of three groups of test blocks with different curing age. The relationship between the parameters of the cumulative energy, load arrival time relationship diagram of the test block with the curing age of 7d and the test block with the curing age of 14d has different points and similarities. Based on the brief analysis of the test block with the curing age of 14d, from Fig. 6 the curing age is The 14d test block shows that there are two obvious inflexions in the energy accumulation curve. The first inflexion occurs at point B, i.e. near the 25s indicated by the arrival time. The slope of the energy accumulation curve increases greatly and becomes steeper. The second inflexion occurs at point C, i.e. near the 59s indicated by the arrival time. A large amount of energy is released instantaneously and the slope of the energy accumulation curve suddenly changes to 90 degrees. Within 0 ~ 25s of the arrival time, it belongs to the initial loading stage, which takes up 35.71% of the total time, and the cumulative energy increases to 800 (mv * ms)It accounts for about 10% of the total cumulative energy. In this stage, point a (i.e. near 6 s of arrival time display) is the obvious boundary. Before point a, the acoustic emission signal is the most inactive, the energy parameter of the acoustic emission signal is basically zero, and the slope of the cumulative energy curve is almost zero, which indicates that the occurrence of the acoustic emission signal can not be detected basically, and the activity intensity of the acoustic emission source is very weak; point a Between point B and B, the acoustic emission signal starts to be active, a large number of parameters with small acoustic emission signal energy appear, and the slope of the cumulative energy curve begins to change, which indicates that a large number of acoustic emission events with small energy appear, and the activity intensity of the acoustic emission source is in a weak state; within 25s ~ 59 s of the arrival time, it belongs to the medium-term loading stage, and the time used accounts for the total time length 48.58%, and the cumulative energy increased to 3300 (mv * ms)It accounts for 41.25% of the total cumulative energy. Between point B and point C, the acoustic emission signal is relatively active, and a large number of parameters with large acoustic emission signal energy appear. The slope of the cumulative energy curve begins to change significantly, which indicates that with the continuous increase of the load, a large number of acoustic emission events with large energy appear, and new cracks continue to appear in the test block, and the cracks begin to expand stably During the period of 59s ~ 70s of the arrival time, it belongs to the later loading stage, which takes up 15.71% of the total time, and the cumulative energy increases to 8300 (mv * ms)It accounts for 100% of the total accumulated energy. Within 2s after point C, the acoustic emission signal is the most active, and a small amount of parameters with huge energy appear. The slope of the accumulated energy curve shows a straight-line rise, which indicates that the test block releases a large amount of energy instantaneously, and a small amount of acoustic emission events with huge energy appear, and then the accumulated energy curve soon reaches a relatively high level In short, in the whole loading process, before the crack failure of the test block, the intensity of each acoustic emission signal is gradually increased compared with the previous stage, and the change of acoustic emission signal is the most obvious at the moment of failure.

4. Conclusion

The cumulative energy and load arrival time relationship of three groups of test blocks with different curing age have certain commonness. Their load arrival time relationship is composed of linear growth stage and load drop stage. The distribution of energy in the whole loading stage has aggregation phenomenon in different time nodes, and the cumulative energy has jump type sudden increase phenomenon in different time nodes. With curing age The slope of cumulative energy curve keeps straight after experiencing sudden increase.

Acknowledgments

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