Study on the factors of acoustic emission wave velocity in concrete

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Abstract. Concrete is frequently used as construction material, because of its favourable properties. However, concrete material is a kind of artificial multiphase composite material, which has the inevitable flaws, such as the anisotropy. As a result, it is necessary for structure to make real time monitoring. The wave speed has a significant effect on the AE location results. The experiments between AE wave velocity and different distances condition under concrete was conducted. With the increase of distance in concrete, the wave propagation speed will have a little reduction. However, the acoustic emission location system adopts constant wave velocity, so the error will be tremendous. For this reason, this paper utilizes the thought of mutative speed and find a influence between wave velocity and propagation distance, max aggregate and water-cement ratio.

1. Introduction
Acoustic emission (AE), which is the transient elastic waves generated by the rapid release of internal energy, such as structural deformation or a micro-fracture in elastic material. For structural health monitoring (SHM), the AE technique is considered as one of the most popular NDT method [1]. Compared to other non-destructive techniques, AE technique can determine the position of the cracks or monitor the entire structure without damaging the structure. The advantages of AE method also include real time capability, high sensitivity and global monitoring capability. There have been conducted many researches among the damage localization in concrete by means of AE. Shah and Li applied the AE source location to identify the fracture process zone of the cementitious materials. Ohtsu M carried out further studies to determine the crack location in concrete structures [2,4]. Cheng et al. [5] used Shuffled Frog Leaping Algorithm to Wavelet Neural Networks for acoustic emission source location. Researchers located the AE sources in concrete by the first arrival times of the P-waves of the emitted signals. Modified earthquake source localization is the principal of AE source localization [6]. The 3-D locations of the AE sources can be performed by taking into account arrival time differences of AE (TDOA) waveforms at each AE sensor [7]. Instead of improving the accuracy of onset time, a varying velocity to different distance was used and the results show that the localization accuracy was greatly improved by using mutative speed [8,9]. Measured velocity curves according to the distance from AE source to the sensor were obtained. Experiment results show that the localization accuracy was greatly improved.
2. Velocity test

2.1. Experimental Specimens
To determine the relationship between the inhomogeneity of concrete and velocity attenuation, a velocity test was conducted. It is necessary to extend the acoustic wave propagation path as far as possible in concrete. All of the concrete beams were 150×150×550 mm. In Figure 1, the water-cement ratio is 0.40, and the maximum aggregate size of the concrete beams is 25mm, 19mm, 12.5mm and 4.75mm respectively, the curing age is 28 days.

2.2. Experimental Procedure
The beams with AE sensors were used to measure the wave velocity determined by the onset time. The velocity measurement schedule was shown in Figure 2. When measuring the velocity using surface bonded WSa sensor, the position of sensor 1 was fixed. In Figure 3, the posititng of sensor 2 moves with the AE source which is simulated by pencil lead fracture. The pencil with a Nielson shoe was fractured just at the edge of the sensor. The distance from the AE source to sensor 1 was 10, 20, 30 and 40 cm respectively. Five points were tested for each distance. The distance and AE source are all the same as the above test. The wave velocity was calculated using the onset time difference of the two sensors. The software determine the onset time of the wave through a preset threshold, which is 5 dB higher than the background noise level.

3. Test Results and Analysis
The velocity was plotted against the distance. It could be seen that, with the increasing of the distance, the velocity decrease gradually [10], and there are similar laws in all concrete blocks. Under the same distance, the larger the water-cement ratio, the smaller the average velocity of the concrete measured in the same maximum aggregate size. For example, Figure 5 shows that the largest aggregate is 4.75 mm and the distance is 100 mm, we select water-cement ratio is 0.4, the wave velocity of acoustic emission is 4750 m/s, when the water cement ratio is 0.55, the velocity is 4250 m/s, the velocity decreases 10.5%. The same rule was found in several other groups of maximum aggregate size in concrete.  Under
the same distance, the larger the maximum aggregate size, the smaller the average velocity of the concrete measured in the same water-cement ratio. For example, Figure 4 shows that water-cement ratio is 0.4 and the distance is 300 mm, we select the largest aggregate is 4.75 mm, the wave velocity of acoustic emission is 4350 m/s, when the largest aggregate is 25 mm, the velocity is 3750 m/s, the velocity decreases 9.5%. The same rule was found in other groups of water-cement ratio in concrete. Figure 6 shows that with the increasing of the aggregate, the velocity increased obviously. It is easy for the larger the particle size of the aggregate to form interface defects and a series of holes after concrete hardening. In other words, it were these defects that produced the AE signal in the process of velocity test.

**Figure 4.** The measured velocity in different water-cement ratio
Figure 5. The measured velocity in different aggregate

Max aggregate: 4.75 mm

Max aggregate: 12.5 mm

Max aggregate: 19 mm

Max aggregate: 25 mm

Figure 6. The measured velocity in different aggregate and water-cement ratio

Distance: 100mm

Distance: 300mm

4. Conclusion

In this paper, the velocity in concrete obtained decreased obviously with increased distance. Moreover, under the same distance, the larger the water-cement ratio, the smaller the average velocity of the concrete measured in the same maximum aggregate size, and the maximum particle size has the same rule.
Acknowledgments
This work was financially supported by the National Natural Science Foundation of China (51678277) and Key R & D project of Shandong Province (2017GGX90107).

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