The influence of different factors on acoustic emission signal in the process of monitoring steel corrosion

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Abstract. Corrosion of steel reinforcement is one of the reasons affecting the durability of building structures. In this paper, acoustic emission technology is used to monitor the corrosion of steel reinforcement. The two influencing factors of concrete strength and water-cement ratio were compared and analyzed, and the influence of different factors on monitoring acoustic emission signal was summarized.

1. Introduction
Reinforced concrete is widely used in building structures. With the increase of service time, the durability problem of reinforced concrete structure, especially the problem of steel corrosion is obvious.[1,4] Acoustic emission (AE), as a kind of real-time, continuous and online nondestructive testing technology, plays an important role in the monitoring of steel corrosion.[5,8] In this paper, the acoustic emission technology is used to monitor the corrosion of steel reinforcement, and the change curve of cumulative impact number is obtained. It can be seen that the process of corrosion of steel reinforcement is divided into three stages. The influence of different factors on acoustic emission signal was observed by experiments on reinforced concrete test blocks with different concrete strength, water cement ratio.[9,13]

2. Monitoring reinforcement corrosion by using AE

2.1. Specimen preparation and accelerated corrosion process
The size of the specimen used in this experiment is 100mm × 100mm × 400mm, and the diameter and length of the embedded steel reinforcement are 10mm and 400mm respectively. The pouring and curing of concrete shall be carried out in accordance with the standards. The completed test block is shown in figure 1. The specimen was soaked in 5% NaCl solution and was accelerated corrosion by using electrochemical method.[14,15] The positive pole of the power supply was connected to the steel bar, and the negative pole of the power supply was connected to the copper bar. The corrosion current was maintained at 0.1A. The schematic diagram of accelerated corrosion and acoustic emission monitoring of reinforcement corrosion is shown in figure 2.
2.2. The results and analysis of experiment

The cumulative impact number change curve and the energy-time curve obtained through experimental monitoring are shown in figure 3.

(a) The curve of cumulative number of impacts

(b) The curve of energy-time

Figure 3. Variation curve of acoustic emission parameters
As can be seen from figure 3 (a), the slope change of the curve in stage 1 is not obvious. The slope of the curve in stage 2 increases. The slope of the stage 3 continues to change, but not as much as the slope of stage 2. It can be seen from the analysis of figure 3 (b) that the energy density is not large at stage 1. The energy density is high at stage 2, and the highest energy concentration is at the junction of stage 2 and stage 3. Therefore, the process of steel reinforcement corrosion can be divided into three stages according to the change curve of the cumulative impact number and the change curve of energy-time.

The first stage is the initial stage of steel corrosion. It can be seen from the figure that the number of impacts of ae in this stage is very small, and the energy released is also very small. The curve of cumulative number of impacts is relatively flat. The second stage is the development stage of concrete internal cracks. With the increase of electrification time, the corrosion of steel bar and the corrosion products increase continuously. Corrosion products constantly fill the interface between steel and concrete, resulting in micro-cracks. In the process of fracture development, energy will accumulate continuously and finally be released in the form of acoustic emission when blocked by cement stone and aggregate. Therefore, the second stage of steel reinforcement corrosion corresponds to the generation and development stage of concrete internal cracks. The number of ae impacts increases continuously and the energy generated is relatively high.

The third stage is the stage after concrete cracking. It can be seen from figure 3 (a) that there is a break point before the macro cracks, and the curve tends to be stable at the end of the corrosion. The break point can be regarded as the characteristic point of the appearance of cracks, providing a reference moment for damage warning.

3. The influence of different factors on acoustic emission signal

3.1. Different strength of concrete
There are many factors affecting the strength of concrete, such as aggregate, mix ratio, curing condition, water-cement ratio and so on. In this study, three types of concrete strength C30, C40 and C50 are designed, and the mix proportion of concrete is shown in table 1.

| materials    | Strength | C30 | C40 | C50 |
|--------------|----------|-----|-----|-----|
| cement(kg)   | 5.3      | 4.13| 4.5 |
| sand(kg)     | 5.75     | 7.6 | 6.84|
| aggregate(kg)| 10.79    | 10.9| 11.11|
| water(kg)    | 2.39     | 1.65| 1.575|

The detected AE signals are shown in figure 4.5.6.
Figure 4. Variation curve of acoustic emission parameters of C30

(a) the change curve of cumulative impact number

(b) The change curve of energy over time

Figure 5. Variation curve of acoustic emission parameters of C40

(a) the change curve of cumulative impact number

(b) The change curve of energy over time
By comparing the change curves of the cumulative number of impacts, it can be seen that under the same experimental condition, with the continuous increase of concrete strength, the number of impacts decreases, and the time of occurrence of characteristic points increases, indicating that high-strength concrete produces less AE activity and the time of crack generation increases. However, compared with the energy-time curve, as the concrete strength increases, the acoustic emission energy generated also increases. The main reason is that the stronger the concrete is, the greater the energy absorbed and released when the concrete is damaged.

3.2. Different water cement ratios
Experiments were carried out using water-cement ratios of 0.4, 0.5, and 0.6, respectively, to observe the effects of different water-cement ratios on acoustic emission signals. The matching of materials under different water-cement ratios is shown in table 2.

| Water cement ratios | Water (kg) | Cement (kg) | Aggregate (kg) | Sand (kg) |
|---------------------|------------|-------------|---------------|-----------|
| 0.4                 | 2.11       | 5.28        | 10.56         | 6.34      |
| 0.5                 | 2.64       | 5.28        | 10.56         | 6.34      |
| 0.6                 | 3.17       | 5.28        | 10.56         | 6.34      |

The relation curve between peak frequency and energy obtained from acoustic emission monitoring is shown in figure 7:
It can be seen from figure 7 that when the water-cement ratio is 0.4, 0.5 and 0.6, the corresponding peak frequencies are 170KHz, 140KHz and 120KHz, respectively. As the water-cement ratio increases, the corresponding peak frequencies decrease, and the energy also decreases. The reason for this phenomenon is that when the concrete water-cement ratio is small, the internal structure of the concrete is relatively compact, and the porosity is small, which makes the strength of the concrete increase, and the bond strength between the cement gel and the aggregate is also relatively high. Therefore, when the concrete is destroyed, the energy absorbed and released is high, and the peak frequency of the corresponding acoustic emission signal is also increased.

4. Conclusion
In the acoustic emission monitoring process of steel corrosion, the process of steel corrosion can be divided into three stages according to the change curve of cumulative impact number. The first stage is the initial stage of steel corrosion. The second stage is the expansion stage of internal micro cracks. The third stage is the development stage of macroscopic cracks, and the acoustic emission activity eventually flattens out. In addition, by summarizing different influencing factors, concrete strength and water-cement ratio, it can be seen that with the increase of concrete strength, the cumulative number of impacts is reduced. Meanwhile, energy and the time increases when the peak occurs, and the time of rust expansion and cracking becomes longer. With the increase of water-cement ratio, the number of acoustic emission signals which are monitored increases, the acoustic emission activity is intense, and the time of rust expansion and cracking becomes shorter.
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