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Study on Three Point Bending Features of Sandstone Based on Acoustic Emission

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Abstract. The three-point bending experiment of sandstone from a coal mine roof under different loading rates based on acoustic emission was carried out. Through analyzing the AE phenomenon, found that the sandstone fracture is brittle fracture. The number of AE counts under low loading speed is more than it under high loading speed, indicated that internal crack is more fully occurred and expanded at low loading speed. The AE energy presents as solitary earthquake type. The flexural strength of sandstone is not high, the failure load and flexural strength increase with the increasing of loading speed, and then decline gradually after reaching the extreme value.

1. Introduction

China is a resource consuming country, with the increasing demand for energy and mining intensity increasing, China's coal mining gradually turned to deep, so the under goaf coal seams mining has gradually into people's vision. The roof accident of goaf area is a serious disaster threatening coal mine safety, which accounts for a large proportion of coal mine safety accidents [1].

As the roof or floor of underground engineering or mine, rock is subjected to bending stress, which is prone to bend and fall. Three-point bending test is the standard method to test the bending strength of rock. But from the existing literature, most of the studies focused on the acoustic emission of crack propagation. For the study of acoustic emission behavior of bending feature is less, and using it to guide the practical application of materials, accident prevention is much less involved. Roof caving and floor impact will cause serious safety problems, so is particularly necessary to study rock bending fracture features so as to provide theoretical support for mechanism of surrounding rock burst, roof and floor failure, rock burst and other mine pressure phenomenon. This paper intends to use three point bending test combine with acoustic emission to study the bending strength of the key stratum sandstone in a coal mine, analysis the bending properties of sandstone.
2. Test scheme

2.1. Sample preparation
The test adopts fine sandstone which is taken from the key stratum of a coal mine roof. The large sample is finish machined into 50×50×250mm cubes that meet the standard [2]. Through testing, the physical parameters of rock is as follows: the uniaxial compressive strength is 44.2MPa, the elastic modulus is 16.8GPa and the Poisson's ratio is 0.34.

2.2. Test equipment and method
The test load system adopts microcomputer control electronic universal testing machine, calibrates and sets the instrument before testing, and installs supporting base at the bottom, sets the pivot span as 200mm.

Acoustic emission probe type is R6α, according to the principle of trying to eliminate environmental interference and maximize receiving AE signal, the threshold value of acoustic emission system is set to 40 dB, the sampling rate is 2MHz. The test uses 2 acoustic emission probes, symmetrically placed on both sides of the center line at the back of specimens, bottom coated with Vaseline as couplant to ensure closed-up to the surface, and tape fixed to prevent shedding and displacement.

The strain gauges are adhered to the front of the specimen face along the center line. From top to bottom evenly distributed 4 strain gauges and stacked with 502 glue. Single strain gauge resistance is 120Ω, the strain gauges and dummy gauges consists of half bridge circuit and is linked with dynamic resistance strain instrument. Testing arrangement is as shown in Fig.1. The sampling rate of dynamic strain instrument is 5000HZ, the maximum strain change is controlled within 1000.

![Testing arrangement](image)

Figure 1. Testing arrangement

Loading with load control mode, loading rates select 10N/s, 20N/s, 30N/s, 40N/s, 50N/s, 60N/s, a total of 6 loading speed. Before the test slightly contacts squeeze head of the electronic universal testing machine and steel rod placed at test specimen axis wire. Ensure the loading system, the acoustic emission and the dynamic strain instrument start and stop recording at the same time.

3. Test result analysis

3.1. Acoustic emission features of sandstone
The AE phenomenon of rock can reflect the damage process and damage degree of rock to a certain extent, so as to reflect the evolution law of rock strength [3]. The essence of acoustic emission is the stress concentration in the partial region of the material, and fast release strain energy with the transient elastic wave when micro fractures happens. The AE phenomenon was recorded by the instrument, AE counts less than 60 can be considered as background noise, not as the analysis object,
discarded the AE counts below 60. After filtering the AE counts less than 60, as well as the pre-contact effect, Kaiser effect point data, just focus on the AE near the bending fracture time, the relationship among AE ring-down counts, AE accumulative count and time as shown in Fig. 2, the relationship among AE energy as shown in Fig. 3.
Figure 2. Relation among AE counts, AE accumulative counts and time
Fig. 3. Relation between AE energy and time

Fig. 3, Fig. 4 shows that the regularity of acoustic emission under different loading speed is almost the same, there is no obvious counts at early time, counts and energy suddenly increases when the fracture load is counted, the knee point of cumulative AE counts is just before bending fracture. It shows that the test fine sandstone occurs brittle fracture and the crack propagation time is short. AE counts represent the number of oscillations over the signal, which can better reflect the evolution process of sandstone internal damage. When the loading speed is slow, the number of AE is large, but it decreases when the loading speed increases. This phenomenon also illustrates that under low speed the the cracks in rock generation and propagation has more time than under high loading rate, therefore, under low loading rate the AE activity is more intense, relatively, under high loading rate, the brittle fracture directly occurs before internal crack developing, thus the AE signal is relatively weak.

It can be seen from Fig.4 that the AE energy varies little under different loading speeds. It shows that the time period of the internal crack of sandstone begins to break completely is short, and the internal energy is released instantaneously. AE energy release mode is similar to seismic energy, so it is classified according to the earthquake sequence characteristics, it can be divided into: main shock type, swarm type, isolated type. The main-shock type: large magnitude of main-shock, small magnitude of foreshock and aftershock, corresponding to AE, it released high energy at a time, low in other time zones; swarm type: the main energy released by many similar magnitude, as AE, the energy peak uniform appeared at lest twice and has close peak energy value; isolate shock type: almost no foreshocks and aftershocks, corresponding to the AE, the AE phenomenon only occurs at the maximum load point, less AE energy releases before and after the peak[4]. According to the energy time curve of sandstone, the energy release type is considered as isolated type, AE energy release is concentrated before rock failure moment.
3.2. Bending strength of sandstone

Bending strength of rock $R_t$ is\[5\]:

$$R_t = \frac{3P_t L}{2ba^2} \times 10$$ (1)

In the formula, $P_t$ is the bending failure load, kN; $L$ is the bending span, cm; $a$ is cuboid section width, cm; $b$ is cuboid section height, cm.

The bending strength of each group is the average bending strength of 3 specimens. The flexural strength of sandstone at each loading rate are calculated, as shown in Table 1.

| Loading speed N/s | Fracture load kN | Flexural strength Mpa |
|-------------------|------------------|----------------------|
| 10                | 2.93             | 7.032                |
| 20                | 3.21             | 7.704                |
| 30                | 3.35             | 8.04                 |
| 40                | 3.51             | 8.424                |
| 50                | 3.58             | 8.592                |
| 60                | 3.56             | 8.544                |

According to the Eq.1, the flexural strength is proportional to the failure load, and the flexural strength increases with increasing failure load. Similarly, the flexural strength also increases with the increase of loading rate, the growth rate at previous stage is far greater than the later period, but peaked at the point of slightly higher than uniaxial compressive strength, then the flexural strength began to slow descend. Loading speed is the cause of the failure strength and flexural strength enhance, but it is controlled by the critical value of uniaxial compressive strength. When the loading speed is accelerated, the sandstone damage is slightly delayed, and the failure strength and flexural strength of the sandstone are higher. So in a short period of time, the flexural strength of sandstone has a time effect.

4. Conclusion

(1) With the increase of loading rate, the three-point bending failure load and bending strength of sandstone increased significantly at earlier stage, when exceeding a certain value, the failure load and bending strength decreased. The rock failure has time-lag, therefore, the flexural strength of sandstone has time effect.

(2) The AE counts can reflect the rock damage process. Under different loading rates, AE counts variations are roughly the same, with the increase of loading rate AE counts decreased.

(3) The AE phenomena of sandstone under different loading speeds show similar characteristics to isolated earthquake type, and the fracture of sandstone is inclined to brittle fracture.

(4) The flexural strength of sandstone is not such high, and under the dynamic load disturbance, the fracture prone to brittle failure. There is no obvious precursor information before broke, so in the coal mine with sandstone roof should strengthen the support, mining speed can not be too fast to prevent roof caving.

Acknowledgments

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