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Effect of microcapsule layout on crack repair

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Abstract: Similar rock specimens without microcapsules were prepared on the basis of similarity principle, and uniaxial compression tests were carried out to obtain the general law of rock fracture propagation. Microcapsules were mixed into rock specimens in three ways. The first way is uniform mixing. The second method is to add microcapsules at different levels. The third way is to add microcapsules along the crack propagation angle. The uniaxial preloading tests were carried out to obtain the compressive strength of the microcapsules. After the curing of 7d and 14d, three specimens were subjected to compressive test again and the strength recovery rate was calculated. Draw the following conclusions: after pre-compression repair, the compressive strength increases, indicating that microcapsules play a repair role; adding microcapsules along the average angle of crack propagation is the best way to repair the crack; the stress-strain curves show good elastic-plastic, the pressure relief curve is stable, and the residual strength is stable.

Keywords: Microcapsule; similar simulation; layout method; fracture; compressive performanc.

1. Introduction

Coal plays an important role in social development, but with the increase of coal mining, safety accidents caused by mine pressure are more common. In the past seven years, with the deepening of mining level, the complication of rock pressure, the development of roadway side cracks [2,3], the stress concentration factor at crack tip and the stress concentration factor at crack tip increase. With the further expansion and penetration of cracks, the side of roadway is more likely to produce shear slip damage and lead to debris [6,7], which affects the stability of the lateral roof equilibrium structure and leads to larger arm roof accidents.

Therefore, enough attention should be paid to the maintenance of rock roadway support. Predecessors have done a lot of research on the application technology of microcapsules. In this paper, the law of crack propagation in rocks is observed through the uniaxial compression contrast experiment of similar specimens. We studied the effect of microcapsule layout on crack repair [4], and compared the advantages of microcapsule layout along the damage track.



2. Experimental theoretical basis

2.1. Experimental theory of uniaxial compression

The uniaxial compression experiment is carried out on a computer controlled electronic universal testing machine. The specimen is placed in the center of the bearing plate of the testing machine, and then the disc at the bottom is adjusted repeatedly to the equilibrium state. The axial stress is loaded at 0.01 mm / min displacement velocity to the specimen deformation. Record failure load and calculate compressive strength according to formula (1).

Strength calculation formula:

$$\sigma = f / a \quad (1)$$

σ — Compressive strength of similar rock specimens. (MPa)

f — test-piece failure load(N)

a — test-piece carrying area(mm²)

The axial stress is applied at the displacement velocity of 0.01mm / min until the similar rock specimen is completely destroyed. The stress-strain curves and the test force-deformation curves were recorded and the uniaxial compression curves of similar rock specimens were analyzed.

Pre-damage and self-repairing maintenance were carried out on the prepared specimens, and then compressive tests were carried out to obtain the compressive strength. According to the formula (2), the strength recovery rate of similar rock samples with micro cracks is calculated.

Strength recovery rate formula:

$$Q = 100 \times \frac{f_h}{f_i} \quad (2)$$

Q — Strength recovery rate based on compressive strength test, %

f_i — Compressive strength of specimens not repaired and maintained, Pa

f_h — Compressive strength of specimens after repair and maintenance, Pa

2.2. Determination of experimental parameters

The contents of microcapsules and curing time in cement samples were determined by consulting data.

According to the results of orthogonal experiment analysis of Zhangming research group [1], the dosage of fixed microcapsules in this experiment is 6.0%, the curing time is 7 days. We preloaded the specimens with 60% σ max damage degree, and self-repaired the specimens for 7 days and 14 days.

3. Experimental process

3.1. Preparation of microcapsules

The preparation of urea-formaldehyde resin coated epoxy resin microcapsules includes five stages: preparation of prepolymer, preparation of wall materials, emulsification, acidification and curing [5,9].



Fig.1 Cement sample

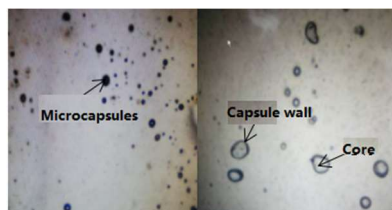


Fig.2 Microcapsule under microscope

3.2. Preparation of similar cement specimens without microcapsules

The cube specimen is selected for the specimen, and the geometric size is 9cm×9cm×9cm.

Steps for preparing specimens:

- (1) According to the required dosage, weigh well, add quartz sand, cement, gypsum in turn, mix evenly, add 1% borax solution, mix evenly, finally add microcapsules, continue to mix evenly.
- (2) Pour evenly stirred mixture into the mold, shock and compacting.
- (3) After 1 days at room temperature, remove from the mold. Maintain in standard constant temperature and humidity curing box for 7 days.

3.3. Uniaxial compression test

3.3.1. Observe the law of fracture distribution. Similar cement specimens without microcapsules were compressed uniaxially. According to the specific testing system, two-dimensional graphs of broken specimens were obtained. A region of 38 mm×68 mm was selected on the surface of the specimens. The general direction of crack propagation and extension during rock failure was observed. Each specimen had a main crack penetrating through the whole specimen during failure. Secondary cracks around the main cracks aggravate the destruction of [8]. The experimental parameters of crack growth are obtained as shown in Table 1.(where the crack growth length is the length of the main crack and the crack propagation angle is the angle between the crack and the axial.)

Table 1. Experimental parameters of five sets of samples

Sample number	Main crack length/mm	Main crack propagation angle/(°)
sample1	71.3	37
Sample2	69.5	35
Sample3	73.4	47
Sample4	70.1	45
Sample5	69.2	41

The average expansion angle is 41°.

3.4. Preparation of microcapsule cement specimen

Ten cement specimens mixed with microcapsules at the average angle of crack propagation, 10 cement specimens mixed with microcapsules by layer distribution and 10 cement specimens mixed with microcapsules uniformly were prepared. The content of fixed microcapsules was 6%, and the curing time was 7d.

3.5. Determination of compressive strength of specimens

3.5.1. Determination of compressive strength of specimens under three layout methods. Three groups of specimens were preloaded and the experimental data were recorded.

3.5.2. Determination of compressive strength of specimens after preloading and repair. Three groups of cement specimens were self-repaired for 7 days and 14 days respectively. After self-repaired and cured, compressive tests were carried out on the specimens, experimental data were recorded, and the strength repair rate of matrix with different pre-damaged degree was calculated by formula (2).

4. Results and discussion

4.1. Compressive strength of similar specimens

The compressive strength of similar rock specimens without microencapsulation was tested. The experimental results are shown in Table 2.

Table 2. Compressive strength of specimens without microcapsules

Mixture ratio	Sample number	Maximum failure load(KN)	Compressive strength of 7d(MPa)
573	I-1	14.880	2.977
	I-2	14.276	2.856
	I-3	14.996	3.000
	I-4	15.228	3.047
	I-5	14.256	2.852
	I-6	15.063	3.014

The simulated compressive strength of similar sandstone specimens ranges from 1.09 MPa to 3.30 MPa. As can be seen from Table 2, the average compressive strength of similar rock specimens with ratio 573 is 2.957 MPa.

4.2. Analysis of compressive strength of specimens under three layout methods

Fixed microcapsule content is 0.5%. The similar rock specimens of 9cm×9cm×9cm are made according to 3.3 method. After 7 days of curing, the compressive strength of three groups of specimens is tested according to 2.1 loading mode. The experimental results are shown in Table 3.

Table 3. Compressive strength without pre damage

Mixture ratio	Layout methods	Sample number	Maximum failure load	compressive strength(Mpa)	Mean value of compressive strength(Mpa)
5 7 3	Microcapsules were added along the average angle of crack growth.	I-1	22.388	2.764	2.904
		I-2	23.045	2.845	
		I-3	23.539	2.906	
		I-4	24.584	3.035	
		I-5	24.057	2.970	
	Mix microcapsules at different levels	II-1	23.660	2.821	2.768
		II-2	22.647	2.796	
		II-3	22.704	2.803	
		II-4	21.643	2.672	
		II-5	23.149	2.758	
	Uniform addition of microcapsules	III-1	23.846	2.944	2.932
		III-2	23.320	2.879	
		III-3	23.458	2.896	
		III-4	24.033	2.967	
		III-5	24.017	2.965	

It is known that the average compressive strength of similar rock specimens is 2.957 MPa. Therefore, when microcapsules are added along the average crack growth angle, the compressive strength of the sample remains basically unchanged, and when microcapsules are added uniformly, the compressive strength of the sample remains basically unchanged, while when microcapsules are added along the layer, the compressive strength of the sample decreases.

4.3. Influence of layout method on strength recovery rate

After self-repairing for 7 days and 14 days respectively, the three specimens were repaired. The specimens were tested under 2.1 loading mode. The experimental data were recorded and substituted into formula (2) to obtain the strength repair rate of matrix under different microcapsule layouts [10]. The experimental results are shown in table 4.

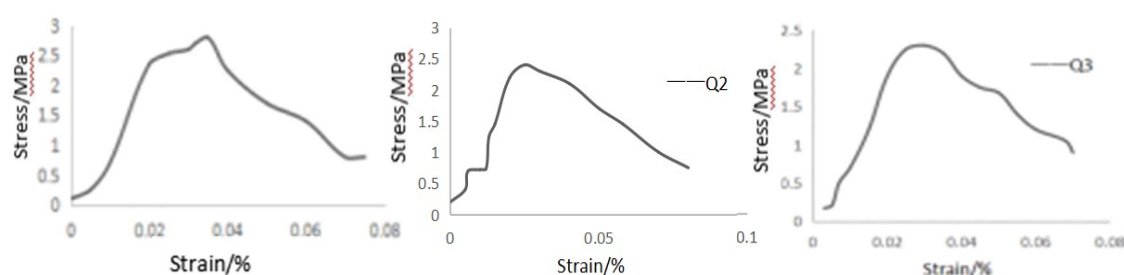
Table 4. Comparison of compressive strength of specimens after self-repairing

Layout methods	Sample number	compressive strength(Mpa)	Compressive strength after preloading(Mpa)		Strength recovery rate(%)	
			7d	14d	7d	14d
Microcapsules were added along the average angle of crack growth.	I-1	2.764	2.602	2.632	94.13	95.24
	I-2	2.845	2.737	2.771	96.22	97.39
	I-3	2.906	2.780	2.815	95.65	96.86
	I-4	3.035	2.935	2.959	96.71	97.49
	I-5	2.970	2.823	2.856	95.04	96.17
Mix microcapsules at different levels	II-1	2.821	2.336	2.336	81.43	82.80
	II-2	2.796	2.386	2.311	85.32	86.46
	II-3	2.803	2.363	2.388	84.32	85.18
	II-4	2.672	2.271	2.314	84.98	86.64
	II-5	2.758	2.390	2.424	86.67	87.88
Uniform addition of microcapsules	III-1	2.944	2.680	2.716	91.34	92.27
	III-2	2.879	2.534	2.617	89.93	90.92
	III-3	2.896	2.705	2.742	93.42	94.68
	III-4	2.967	2.711	2.752	91.39	92.74
	III-5	2.965	2.678	2.710	90.32	91.41

It can be seen from table 4 that the strength recovery rate after preloading is as follows: along fracture distribution>uniform distribution>Distribution along layer. The average angle of crack propagation with microencapsulation has the highest rate of matrix strength repair, and the lowest rate of matrix strength repair with microencapsulation along the layer distribution.

4.4. Analysis of stress-strain curves for similar rock specimens

The stress-strain curves of similar rock specimens without microcapsules(Q1), rock specimens with microcapsules distributed along cracks (Q2) and similar rock specimens repaired 7 days(Q3) after pre-compression damage are analyzed respectively (see Fig. 3).

**Fig 3.** Stress-strain curve

From Figure 3, it can be seen that the stress-strain curves of similar rock specimens in three cases are complete, and the growth laws of the stress-strain curves in three cases are similar, showing better elastic-plastic properties before the peak value, and the stress-strain curves are approximately straight lines. Continue loading, the plastic section of Q1 specimen appears pressure stability curve before peak value. The strength of Q2 specimens is lower than that of Q1 specimens. Q3 specimens appear pressure-stabilized zone, indicating that the specimens began to appear micro-cracks, but did not affect the compressive strength, the pressure-relief curve is relatively smooth.

5. Conclusion

In this paper, the layout of microcapsules in rocks is taken as a variable, and the compressive strength tests of the original similar rock specimens, the similar rock specimens mixed with microcapsules and the similar rock specimens after pre-compression damage repair are carried out. The strength repair rate is calculated, the stress-strain curve and the test force-deformation curve are recorded, and the repair situation of microcapsules on the surrounding rock cracks are studied. The following conclusions are drawn:

(1) The repair rate of matrix strength in the three specimens is as follows: Along fracture distribution>uniform distribution>Distribution along layer. Therefore, we should use the highest intensity repair method to mix microcapsules;

(2) The strength of specimens with microcapsules at the average angle of crack propagation is basically unchanged compared with that of similar specimens without microcapsules, so the damage of the matrix of similar rock specimens can be neglected by the incorporation of microcapsules;

(3) After the specimen was pretreated, the compressive strength increased for a period of time, indicating that the microcapsule played a role in repair;

(4) Under the three conditions, it shows good elastoplastic, stable pressure relief curve, stable residual strength and stable physical and mechanical properties.

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References

- [1] Zheng ming. A study on microcapsule based self-healing method and mechanism for cementitious composites[D]. Zhongnan university, 2013, 05: 118-134.
- [2] QIAN qihu, LI shuchen. A review of research on zonal disintegration phenomenon in deep rock mass engineering[J]. Chinese Journal of Rock Mechanics and Engineering, 2008, 27(6): 1278-1284.
- [3] XIE heping, GAO feng, JU yang. Research and development of rock mechanics in deep ground engineering[J]. Chinese Journal of Rock Mechanics and Engineering, 2015, 34(11): 2161-2178.
- [4] Hilloulin B, Tittelboom K V, Gruyaert E, et al. Design of polymeric capsules for self-healing concrete[J]. Cement & Concrete Composites, 2015, 55: 298-307.
- [5] WANG mingcun, ZHU hiying. Progress in the self-healing mechanisms of polymers materials, 2012, 26(6): 89-95.
- [6] Cui J, Jiang Q, Li S, et al. Estimation of the number of specimens required for acquiring reliable rock mechanical parameters in laboratory uniaxial compression tests[J]. Engineering Geology, 2017.
- [7] Manouchehrian A, Sharifzadeh M, Hamidzadeh M R, et al. Selection of regression models for predicting strength and deformability properties of rocks using GA[J]. International Journal of Mining Science and Technology, 2013, 23(4): 495-502.
- [8] Wang Yongyan, Zhang Jinlong, Zhang Yubiao. The experimental investigation of single fracture rock strength characteristics and creep model by experiment[J]. Science Technology and Engineering, 2018, 18(18): 94-100.
- [9] XU fei, LING xiaofei, XU haiyan, et al. Review of Self-healing Smart Coatings: Definition, Self-healing Mechanism and Application[J]. China Coatings, 2014, 29(8): 38-45.
- [10] LIU chao. Numerical simulation of failure process intact rock specimens containing crack rock specimens under uniaxial compression[J]. Coal Technology, 2014, 33(8): 249-251.