

# Rock Breaking Law Under the Condition of Multi-row Drilling of Static Crushing Agent and Its Application in Roadway Expansion

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**Abstract:** Static crushing agent (SCA) has the advantages of good safety, no harmful gas and no vibration. It is widely used in rock crushing engineering of mine or underground engineering. Aiming at the performance of static crushing agent with different water-cement ratios, based on the engineering and environmental conditions of roadway side protection in a mine of Shanxi coking coal, the stress-time curve of SCA and the fracturing law of SCA on roadway side rock under the condition of multi-row drilling were studied by means of laboratory test and numerical simulation. The results show that: the smaller the hole spacing, the better the fracturing effect of SCA, the smaller the required fracture initiation stress and penetration stress, and the existence of the free surface contributes to the development of the fracture, and the fracture around the hole extends along the direction of the incoming pressure under the peripheral pressure conditions; the porous SCA fracturing can be used for the high efficiency of underground rock fracturing projects such as rocky roadway spreading and other underground rock fracturing projects. The research results of the project provide a new method for non-blasting roadway expansion, roof picking and other rock-breaking projects in underground coal mines.

**Keywords:** Static crushing agent; rock fracturing; drilling arrangement; numerical simulation; construction process.

## 1. Introduction

Static crushing agent (SCA) is a kind of grayish white powder admixture, which is mixed with water in a certain proportion and filled into the borehole that needs to be cracked. After a certain period of reaction, it expands, and the expansion pressure is generated in the borehole to achieve the purpose of fracturing borehole. The SCA reaction process is relatively peaceful, and there are no open fire, no smoke, no explosion impact, no flying stone and no noise in the cracking process<sup>[1-6]</sup>. At present, SCA is widely used in ground concrete, rock structure and building demolition, and its application in coal mine still needs further research. Especially when the use of explosives is limited, it is difficult to break hard rocks such as sandstone and limestone by using air picks and air drills, and the progress of rock roadway expansion project in underground coal mine is very difficult. Therefore, the method of using static crushing agent to crack the rock of roadway side is proposed, and the dosage of static crushing agent, the selection of hole spacing and the arrangement of construction technology are studied.

## 2. Engineering Background

Shanxi Coking Coal Fenxi Mining Liangdu Coal Industry

needs to expand the 2 # coal centralized transportation roadway. The roadway expansion position is located at 2m-32m behind the H6 # point, and the roadway is advancing to the right hand side. The centralized transportation roadway is a rectangular section with a width of 5.3 m and a height of 3.3 m. Due to the need to add a transportation track in the centralized transportation roadway, the width of the existing roadway fails to meet the erection requirements. Therefore, it is decided to carry out the expansion operation at the right hand side in the forward direction of the centralized transportation roadway. The expansion specification is 2.3 m high, 1.5 m deep, and the length of the expansion section is 30 m.

The two sides of the roadway are sandstone. The standard rock mechanics test samples are made from the on-site rock processing. The RMT150 microcomputer-controlled electro-hydraulic servo rigid pressure testing machine is used to carry out triaxial compression, uniaxial compression and Brazilian splitting experiments. The basic mechanical parameters of rock specimens are measured. The test results of rock physical and mechanical properties are shown in Table 1.

Table 1. Parameters of rock physical and mechanical properties

Name of rock	Density kg / m <sup>3</sup>	Compressive strength MPa.	Tensile strength MPa.	Elastic modulus GPa	Poisson 's ratio	Internal friction angle °	Cohesion MPa.
Sandstone	2720	67.4	5.82	16.874	0.25	36.2	14.3

### 3. Theoretical Study on Static Fracture Agent Fracturing

#### 3.1. Static crushing agent parameters

The properties of static crushing agent are mainly affected by its material ratio, mixing water temperature, ambient temperature and water cement ratio. Due to the limitation of underground conditions, it is difficult to change the material ratio, mixing water temperature and ambient temperature. Only the water-cement ratio of the static crushing agent purchased on the mine can be tested to obtain the optimal water-cement ratio. The remaining factors refer to the existing research results.

Due to the large difference in the relationship between the volume expansion rate and water-cement ratio of different types of static crushing agents and the ambient temperature, it is necessary to test the expansion stress of static crushing agents used underground with different water-cement ratios, and use the constant temperature water tank to monitor the expansion stress-time curve of static crushing agents according to the underground temperature. The expansion stress is measured by the resistance strain gauge measurement method. The method is strictly implemented in accordance with the ' silent crushing agent : JC506-2008 ' standard. The expansion stress of the static crushing agent is calculated according to Formula ( 1 ) :

$$P = E_s \cdot (K^2 - 1) \left[ \frac{\varepsilon_\theta}{2 - \nu} \right] \quad (1)$$

Where : P - expansion stress, in MPa ; es-elastic coefficient, Q235 steel pipe is  $2.060 \times 10^5$ MPa ; the coefficient of K-steel tube is  $\gamma\delta / \gamma\iota$  ( the outer diameter of  $\gamma\delta$ -steel tube, the unit is

mm, mm ; the inner diameter of the  $\gamma\iota$ -steel tube, in mm, mm ) ;  $\varepsilon_\theta$  - circumferential strain of steel tube ;  $\nu$ -Poisson 's ratio is 0.3.

The expansion stress-time curves of different water-cement ratios measured by the static crushing agent are shown in Figure 5. From the results, it can be seen that the expansion stress-time curve of the static crushing agent is divided into three stages : the first stage is the buffer stage. The retarder and water reducing agent in the static crushing agent play a role in delaying the reaction time within 0 ~ 3h ; the second stage is the stage of rapid development. The rate of expansion stress rise is faster in 3 ~ 30 h, and the gap between different water-cement ratios is gradually widened. The third stage is a stable stage. After 30 h, the expansion stress increases slowly with the increase of reaction time, and the reaction rate of expansion stress decreases gradually, and finally tends to be stable and can be maintained for a long time. By measuring the expansion stress of static crushing agent slurry with water-cement ratio of 0.26,0.3,0.34 and 0.38, after fitting and comparison, it can be concluded that when the water-cement ratio is 0.3, the static crushing agent slurry has the fastest rate of expansion stress rise in the second stage. In the third stage, the expansion stress value can reach 75.9 MPa after the expansion pressure tends to be stable, that is, when the water-cement ratio is 0.3, the greater the expansion stress of the static crushing agent, the more obvious the cracking effect. This test can also be concluded that the expansion stress of static crushing agent will increase with the extension of time. Therefore, in the roadway expansion project, the number of boreholes can be increased according to the actual drilling time. After many expansion stress test tests and field construction tests, it is verified that it is difficult to spray holes in 42 mm diameter boreholes. When using static crushing agent to crack rock, there must be a free surface in the construction site.

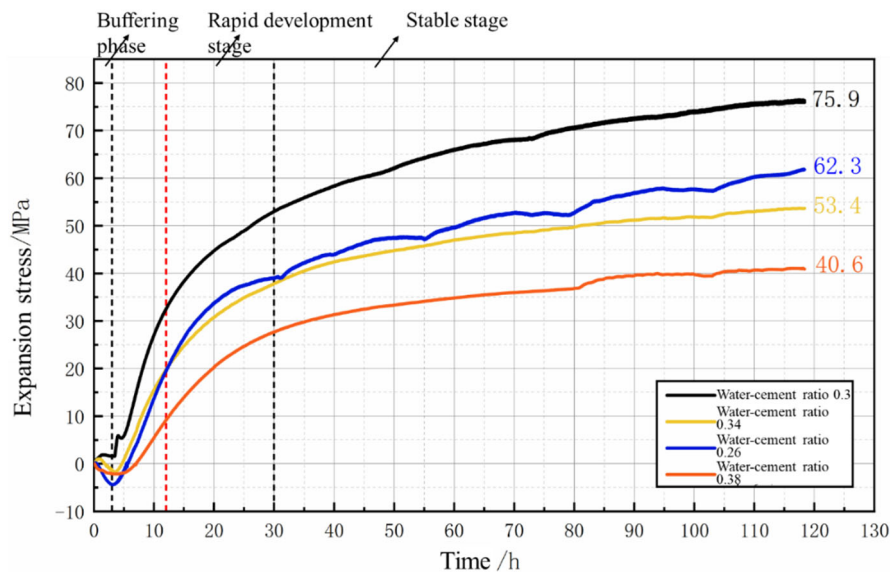


Figure 1. Expansion stress-time curve of static crushing agent

## 4. Numerical Simulation

The hardness of different rocks is different, and the required cracking stress is different. The selection of hole spacing greatly affects the cracking effect of static crushing agent. The smaller the hole spacing is, the better the cracking effect is. The larger the hole spacing is, the worse the cracking effect is. Based on the background of the expansion of the car yard in the centralized transportation lane of Shanxi coking coal Fenxi Mining Liangdu Coal Industry, Abaqus numerical simulation software zero-thickness cohesive element is used to simulate the cracking effect of static crushing agent with different hole spacing. The simulation is matched with the

field situation. The model size is set to be 2000 mm high and 4000 mm long. The drilling holes are arranged on the right side of the model to simulate the construction of the roadway. The hole spacing is 300 mm, 400 mm and 500 mm respectively, with a total of 25, 16 and 9 holes. The right boundary of the model is the free surface, and the distance between the right hole and the free surface is equal to its hole spacing. According to the stress of the overlying strata on the construction site, the confining pressure is set to 5MPa. The triangular mesh is used to divide the model elements, the global seed size is 0.01, the number of mesh elements around the hole is set to 12, the total time length is set to 1, and the global cohesive element is inserted through the triangular mesh.

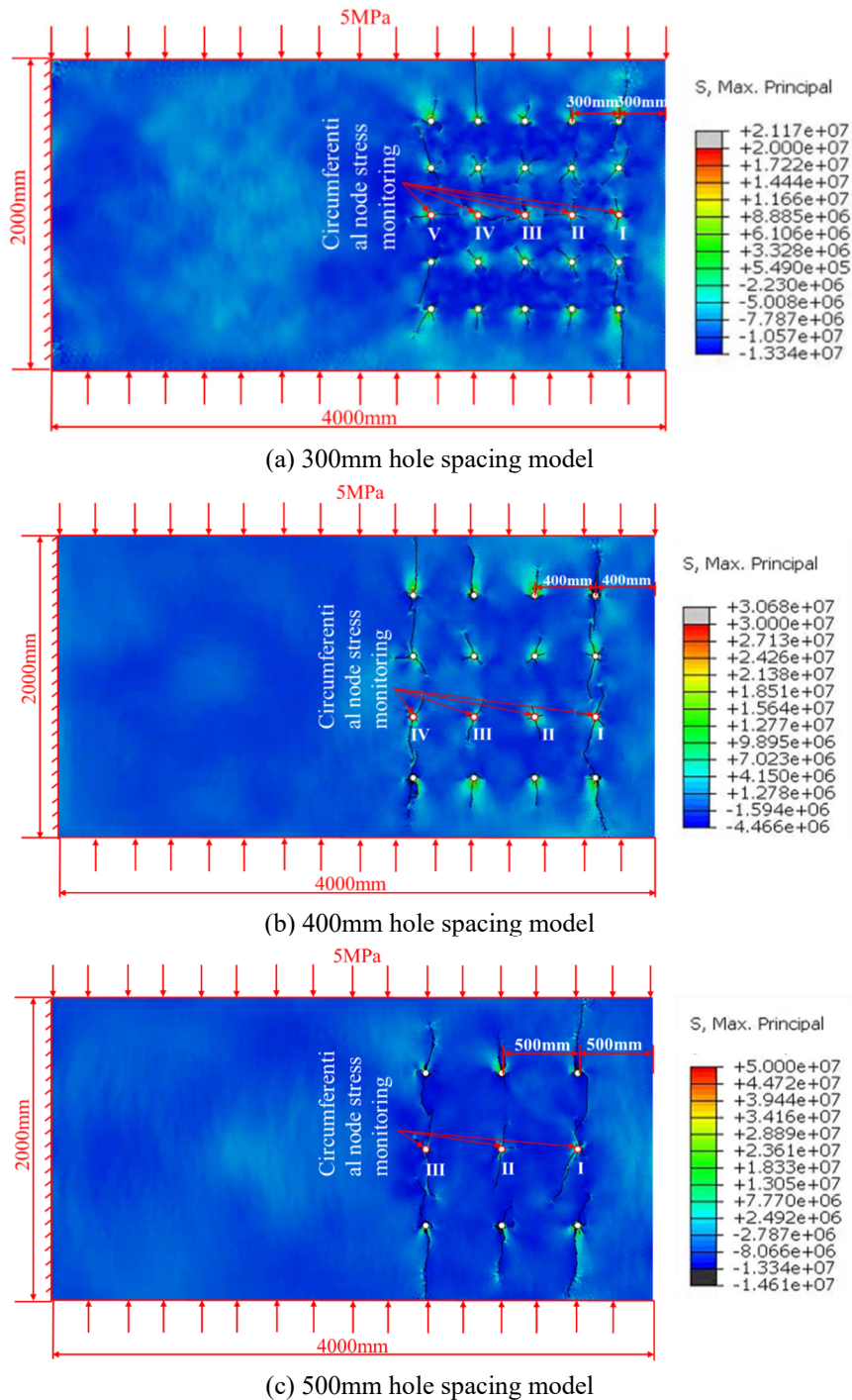
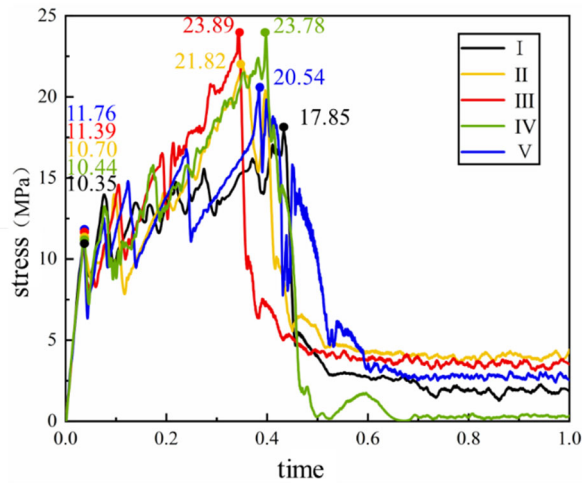


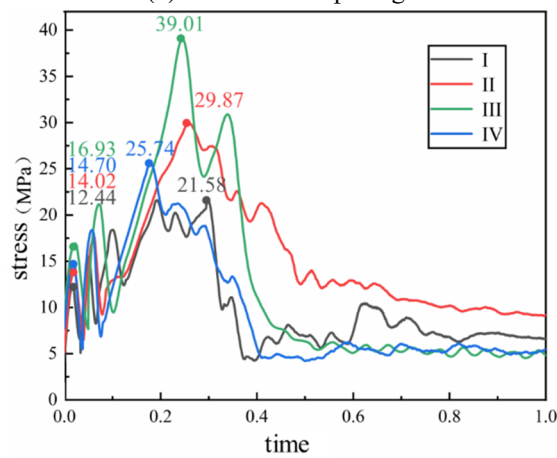
Figure 2. Cracking stress cloud diagram of different hole spacing

As shown in Figure 2, the stress around the middle row of holes in different hole spacing models is monitored, and marked as I, II, III, IV and V from right to left. As shown in Figure 3, the average crack initiation stress and average penetration stress of the stress around the middle row of holes are 10.93 MPa, 14.52 MPa, 21.81 MPa and 21.58 MPa, 29.05 MPa, 46.98 MPa, respectively. According to the stress around the middle row of holes, the crack initiation stress and crushing stress required for drilling increase with the increase of hole spacing, and the sudden drop of the peak value of the stress-time curve around the hole indicates the occurrence of

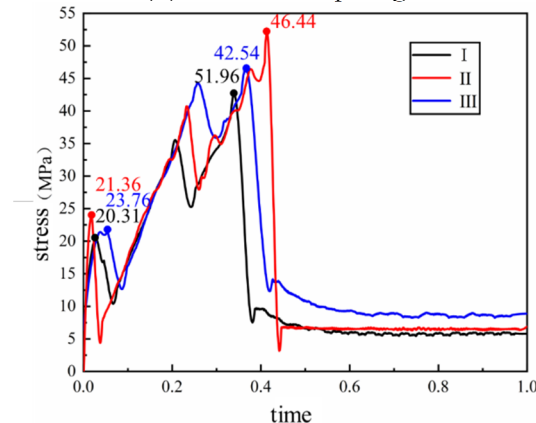
cracks. By comparing the fluctuation times of the stress-time curve, it can be seen that 3 ~ 4 large cracks and a large number of small cracks are generated around the hole when the hole spacing is 300 mm, and the number of cracks is large. The 400 mm hole spacing mainly generates 2 ~ 3 large cracks around the hole, and there are few small cracks. Most of the 500 m hole spacing only generates 2 ~ 3 large cracks. From the above results, it can be seen that the smaller the hole spacing, the more the number of cracks generated around the hole, and the better the cracking effect.



(a) 300mm hole spacing



(b) 400mm hole spacing



(c) 500mm hole spacing

**Figure 3.** Stress-time diagram around the hole

## 5. Summary

The static crushing agent is used to crack the roadway side of multi-row boreholes. By studying the properties of static crushing agent, laboratory tests and numerical simulation analysis, the following conclusions are obtained :

(1) The best water-cement ratio and stress-time curve are determined by studying the static crushing agent, and the construction technology of static crushing agent grouting method is put forward.

(2) Through the numerical simulation of static cracking agent fracturing scheme simulation, the drilling hole spacing setting optimization research, according to the situation of Liangdu coal industry to determine the optimal fracturing scheme.

## References

- [1] Yan Changbin. Study on cumulative damage effect and stability of rock mass under blasting [D]. Central South University, 2006.W. Strunk Jr., E.B. White, The Elements of Style, third ed., Macmillan, New York, 1979.
- [2] Luo Yong, Cui Xiaorong, Shen Zhaowu. Application of shaped charge blasting in rock controlled blasting [J]. Mechanics Quarterly, 2007, (02) : 234-239.
- [3] Zong Qi, Liu Jinghua. Research on the application of deep hole blasting cutting technology in rock roadway of coal mine [J].Blasting, 2010,27 (04) : 35-39
- [4] Li Gang, Niu Lei, Li Wenlong. Research on rapid excavation technology of hard rock roadway in coal mine [J].Coal Science and Technology, 2018,46 (11) : 13-20.
- [5] Yang Renshu, Li Chengxiao, Chen Jun et al. The development history and new technology research progress of rock roadway blasting excavation in coal mines in China [J].Coal science and technology, 2023,51 (01) : 224-241.
- [6] Duan Kexin. Maintenance of soft rock roadway by pressure relief blasting of roadway side [J].Coal Journal, 1995, (03) : 311-316.