

Research on High Efficiency Charging and Mechanized Sealing Technology of Deep Hole Presplitting Blasting in Roof

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Abstract: In order to solve the problem of long sealing time and poor effect in the deep-hole presplitter blasting technology, the inorganic two-component blasting sealing material with a fixed water-cement ratio of 0.8:1, with "cement, gypsum and lime" as the main, "quick-setting agent, water-reducing agent and early-strength agent" as the auxiliary, and the matching double-bag sealing device were developed, and a set of rapid sealing process suitable for deep-hole blasting was designed. The field test was carried out in 43153 multipurpose roadway of Chengzhuang Mine. The application results show that the blasting sealing material with fast setting speed and high strength can meet the needs of sealing holes, and the perforation rate is far less than 4-8% of the blasting mud sealing hole. The fast sealing process designed and developed to complete a hole sealing operation only takes 14min, which not only improves the sealing efficiency, but also reduces the labor intensity of workers and realizes the mechanization of the sealing operation.

Keywords: Deep hole blasting; grouting sealing technology; sealing materials; bag type sealing hole.

1. Introduction

Coal seams with thick hard roof in China account for more than 30% [1], and thick hard roof strata have high bearing capacity and are not easy to break and collapse. With the advance of the working face, the roof cannot collapse in time, forming a large hanging roof in the goaf and accumulating high elastic energy [2]. The stress disturbance caused by roof breaking and instability increases the risk of dynamic disasters such as rock burst, coal and gas outburst. The application of deep hole pre-split blasting technology in the prevention and control of rock burst has been relatively mature [3-7], but there are still problems of low efficiency and poor effect.

The sealing materials used at home and abroad mainly include three types: solid particle sealing, chemical material sealing and cement material sealing [8]. Solid particle sealing materials mainly include sand gravel, yellow mud, clay, etc. Although the material has a wide source and low price, it has low sealing efficiency and poor effect, and is generally only applied to short hole sealing. Chemical materials have polyurethane sealing, etc., the advantage is that the sealing speed is fast, the working intensity is low, the disadvantage is that the price is high and the reaction temperature is high, there is the risk of igniting the detonating wire; Cement materials have good fluidity and good sealing effect, but wait for curing time is long and the efficiency is not high [9-11].

In order to solve the defects of traditional sealing materials and technologies, a new type of blasting sealing materials and technologies is developed based on the application of the deep-hole presplit blasting technology in Chengzhuang Coal Mine, which can effectively simplify the traditional sealing technology, reduce the labor intensity of workers, improve the efficiency and effect of sealing holes, and solve the problem of sealing holes in the deep-hole presplit blasting.

2. Blasting Hole Sealing Material

2.1. Advantages of blasting sealing materials

Traditional blasting sealing materials mainly include solid particles, cement and chemical materials, and the related processes of various materials have been relatively perfect. Table 1 shows the advantages and disadvantages of each material and its processes.

Table 1. Advantages and disadvantages of sealing materials

Materials	Technology	Advantage	Shortcoming
Solid particle	Manual use of cannon rods to feed section by section	Low cost, simple process	High labor intensity, sealing quality
Cement	The orifice is sealed by a single bag or a hole packer, and grouting is injected into the hole sealing section by a grouting pump	Low labor intensity and good sealing effect	Long curing time and low early strength
Chemical materials	The orifice was sealed with organic material combined with a single bag, and the sealing section was injected with high pressure grouting	Quick response and low labor intensity	The reaction temperature is high and the cost is high

With the increase of the length of the sealing section, the difficulty of filling mortar increases, the labor intensity of workers increases, and the sealing quality is difficult to guarantee. The loss of flow hardening of the composite

cement is slow, and it takes a long time to reach the strength required for sealing. Organic polymer materials are expensive and have a high reaction temperature, which has the risk of igniting the detonating wire. Therefore, an inorganic two-component material with rapid loss of flow hardening was developed. The main component of material A is sulphoaluminate cement clinker, the main mineral component is calcium sulphoaluminate, the content is more than 45%, is dark gray powder; The B material is mainly composed of gypsum and lime, in which the effective SO₃ of gypsum is 46% and the CaO content of lime is 69%. After the two components are separately stored for a long time without consolidation, they are mixed with each other and quickly lose flow hardening, which has the characteristics of short setting time and high early compressive strength, and can meet the needs of rapid hole sealing.

2.2. Material preparation and performance test method

Blasting hole sealing material consists of two parts: A and B. The material preparation process and performance test method are shown in Figure 1.

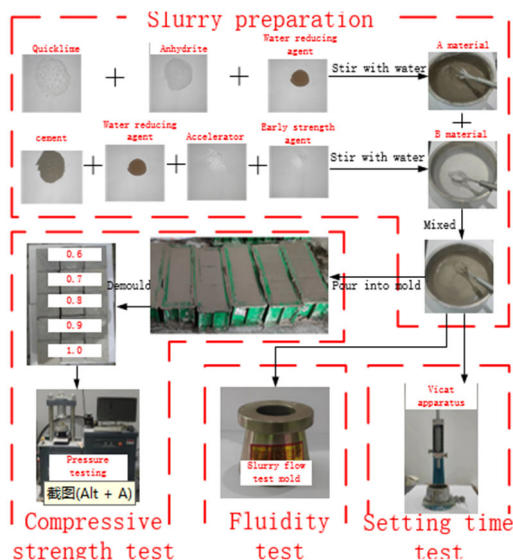


Figure 1. Material preparation process and performance test method

2.2.1. Material preparation

Superfine sulfoaluminate cement clinker as the main component of A, adding homemade additives (water reducing agent, early strength agent, accelerating agent) mixed evenly, A can be obtained; B material can be obtained by mixing natural gypsum and quicklime with the mass ratio of 4:1 and adding the corresponding water-reducing agent to mix evenly.

2.2.2. Performance test method

A metal cutter-cone die with an upper diameter of 36mm, a lower diameter of 60mm, a height of 60mm and a smooth, jointless inner wall was used to test the slurry flow. The glass plate was placed in a horizontal position and moistened with a wet cloth, and the truncated cone mold was placed in the center of the glass plate. The prepared slurry was poured into the truncated cone mold and smoothen with a scraper, and the truncated cone mold was lifted quickly. After 30 seconds, the diameter of the cement paste in two directions perpendicular to each other was measured with a ruler, and the average value was obtained. Repeat the experiment three times and take the

average value.

The setting time of the blasting sealing material was tested with the Vicar instrument. Adjust the contact between the test needle of the Vika instrument and the glass plate, check the zero point, fill the circular mold with the prepared slurry, record the initial time at this time, when the depth of the initial coagulation needle into the slurry is 4mm±1mm, record the initial coagulation time at this time, change the final coagulation needle, when the final coagulation needle does not leave a ring mark on the sealing material, record the final coagulation time at this time.

The uniaxial compressive strength of materials was measured by the automatic hydraulic testing machine. Prepare a triple mold with a size of 70.7mm×70.7mm×70.7mm in advance, brush oil inside, pour the prepared slurry into the mold, release the mold after the final solidification of the test block and put it in the curing box, and choose to test the uniaxial compressive strength of the test block.

2.3. Properties of blasting sealing materials

The performance parameters of blasting sealing materials are shown in Table 2:

Table 2. Performance parameters of blasting sealing materials

Water-cement ratio	Single liquid flow /mm	Setting time of two-liquid mixture		Uniaxial compressive strength	
		Initial setting time /min	Final setting time /min	0.5h/MPa	1h/MPa
0.6:1	235	2.5	8	5.6	8.5
0.7:1	250	3	10	4.2	6.6
0.8:1	260	4	12	2.8	5.4
0.9:1	280	5	15	2.1	3.6
1.0:1	295	7	20	1.4	2.2

With the increase of water-cement ratio, the single liquid mobility of blasting sealing material showed an increasing trend. The initial and final setting time of dual-liquid mixing gradually extended with the increase of water-cement ratio, while the 0.5h and 1h uniaxial compressive strength of blasting sealing material decreased with the increase of water-cement ratio. The lower the water-cement ratio, the higher the uniaxial compressive strength, but the fluidity will be reduced, which is not conducive to pumping. Generally, a blasting sealing material with a water-cement ratio of 0.8:1 is selected.

3. Double Bag Type Sealing Device

Based on the principle of "two blocks and one injection", the double-bag sealing device is developed. Compared with the way of polyurethane sealing and grouting in the hole, the equipment does not need to be replaced, the construction steps are simplified, and the work efficiency is improved.

3.1. Device Composition

The double-bag sealing device is composed of two bags, a grouting pipe, a regrouting pipe, a blasting valve, two check valves and a plug. The bag is a permeable cloth bag, the grouting pipe and the regrouting pipe are polyvinyl chloride pipes with the same material and diameter of 16mm. The blasting valve breaks after bearing a certain pressure, the one-way valve makes the slurry flow unidirectional, and the plug closes the inner end of the grouting pipe. As shown in Figure

2.

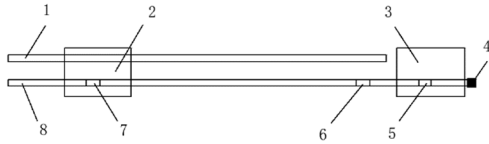


Figure 2. Structure of sealed bag

1. Antislurry pipe 2. Bag 3. Bag 4. Plug 5. Check valve 1 6. Burst valve 7. Check valve 2 8 grouting pipe

3.2. Principle of action

The structure of the pouch is shown in Figure 2. The blasting sealing material is pumped into the grouting pipe by the grouting equipment. Because there is a plug at the end of the grouting pipe, the pressure in the grouting pipe will increase continuously with the continuous injection of slurry until the check valve 1 is broken and the slurry flows into bag 1. After the bag 1 is opened and filled, the pressure of the grouting pipe will continue to increase until the check valve 2 is broken. After the bag 2 is opened and filled, the pressure of the grouting pipe continues to increase and the blasting valve is broken; Since bag 1 and bag 2 are stretched and filled, blocking both ends of the hole sealing section, with the bursting valve, the slurry flows into the hole sealing section, and the regrouting pipe is connected to the roadway. The compressed air in the hole sealing section flows into the hole sealing section along the regrouting pipe into the roadway, and the inner end of the regrouting pipe is below bag 1. When the regrouting pipe begins to discharge the slurry, it proves that the hole sealing section has been filled.

4. Sealing Process

The rapid sealing process includes the use of blasting sealing materials, double-bag sealing devices and pneumatic grouting pumps, as shown in Figure 3.

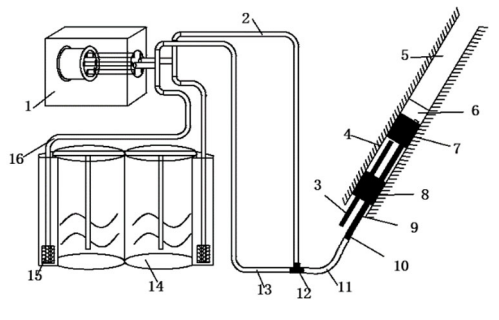


Figure 3. Sealing process diagram

1. Pneumatic grouting pump 2, 13. Grouting pipe 3. Regrouting pipe 4. Sealing section 5. Blasting section 6. Air column 7, 8. Bag 9. Grouting pipe 10. Straight 11. Mixing tube 12. Tee 14. One-piece mixing barrel 15. Suction faucet 16. Suction pipe

The sealing process implementation flow is as follows:

The bag sealing device is sent into the sealing section, and the grouting pipe and regrouting pipe are exposed to the coal wall more than 300mm to the position that is easy to operate manually;

The air pressure pipe is respectively connected with the sealing pump and the connected mixing barrel. The two suction pipes of the sealing pump are respectively put into the discharge port on the side of the mixing barrel. The two slurry

pipes are connected with the mixing pipe through the tee.

Add water into the connected mixing bucket, open the air pipe switch of the connected mixing bucket and the air pipe switch of the sealing pump, and check whether the equipment is running normally and the grouting pressure is normal. If everything is normal, finish the water and turn off the seal pump switch;

Add A material and B material with a water-cement ratio of 0.8:1 into the two barrels of the connected mixing bucket respectively, add water first and then add the material, and stir for 3 minutes until the mixing is uniform;

Turn on the switch of the sealing pump and observe the slurry discharge of the mixing pipe. When the slurry turns brown, turn off the grouting pump, connect the mixing pipe and the grouting pipe through the direct connection, turn on the grouting pump switch and start grouting.

When there is slurry flowing out of the regrouting pipe, the hole is basically full, and the regrouting pipe is blocked. When the plunger of the grouting pump returns twice and the hole is full, the grouting pump is closed, the grouting pipe is cut off and blocked, and the next hole is poured.

After the grouting of all holes is completed, the grouting pump is cleaned to finish the grouting work.

After 30min, the slurry was fully cured and reached the target strength, and the hole sealing was completed.

The rapid sealing process takes the pressure air as the power source, uses the pneumatic grouting pump instead of manual, realizes the mechanization of sealing operation, and greatly reduces the labor intensity of workers. The time required for sealing can be reduced effectively and the efficiency of sealing can be improved by using inorganic grouting material with fast setting and fast hardening instead of mortar. The strength of the new sealing material can reach 2.8MPa in 30min, which is better than the clay and reduces the possibility of punching.

5. Engineering Application and Effect Investigation

5.1. Project Overview

The 4315 coal face of Chengzhuang Coal Mine is located in one level and four plates area, with an average coal thickness of 6.3m. The working face is 4315, 4315 working face adopts the "two inlet and one inlet" type arrangement, in which 43151 lane is the main inlet lane, 43153 lane is the auxiliary inlet lane, 43152 lane is the return air lane. Lane 43131 is the return air lane of the upper working face, and Lane 43152 should be retained as the main air inlet lane of the next working face, which is called the reuse roadway. The roadway location diagram of 4315 fully mechanized caving face is shown in Figure 4. As the coal seam roof belongs to the hard roof, the support of the side wall of the coal pillar of the mining roadway and the high-strength support of the roadway roof at the end of the mining roadway can not fall in time, the hanging roof area of the working face reaches 20m², and the deformation of the reused roadway is serious. It has caused great safety hazards and seriously affected the safety production of coal mines.

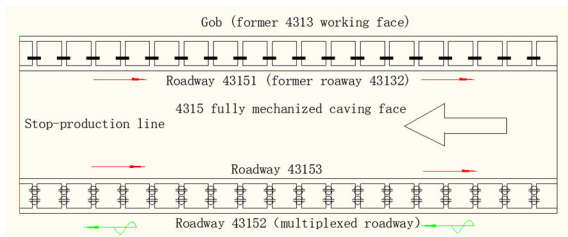


Figure 4. Roadway location diagram of 4315 fully mechanized caving face

5.2. Setting Drilling Parameters

In order to solve the problems of large hanging roof area at the end of 4315 working face in Chengzhuang Mine, late caving of gob and strong ore pressure in reused roadway, the technology of deep hole pre-cracking blasting is adopted to deal with the problems.

5.2.1. Drilling position

Theoretically, the smaller the distance between the drilling position and the coal wall, the better. Considering the construction space of the roof drilling rig, the roof support situation, and the layout of roadway equipment, the distance between the blasting drilling hole and the coal pillar side is determined to be 700mm.

5.2.2. Diameter and spacing of drilling holes

According to the actual situation of the coal mine site, the 60mm diameter drill is selected. On site, permissible emulsified explosive of tertiary coal mine was used for blasting, and the preliminary design of hole spacing was 2m according to experience.

5.2.3. Drilling Angle

Lane 43153 is a belt lane. According to field investigation and analysis, drilling rig operation is limited by space. In the roadway profile, the Angle between drilling hole and vertical direction is designed to be 0° , while in the roadway center profile, the Angle between drilling hole and horizontal direction is designed to be 75° .

5.2.4. Drilling depth

The basic roof thickness can be calculated using the following formula:

$$m_z = \frac{h - S_a}{K_a - 1} \quad (1)$$

Where: m_z - basic top thickness, m;

h -mining height, 6.3m;

S_a - Settlement value of rock beam contact with dirt, General value 0.15~0.25, This time the value is 0.2;

K_a -caving rock breakage coefficient is generally 1.2~1.5; 1.3 for mudstone.

By substituting into the formula, $m_z=21.03$ m, the drilling Angle is set to 15° , and the drilling depth is 22.5m. The blasting hole depth is designed to be 22.5m. The length of the sealing hole shall not be less than 1/3 of the length of the gun hole, and the length of the blasting section shall be 14m and the length of the sealing section shall be 8.5m.

5.3. Sealing effect

The field test shows that the blasting hole depth is 22.5m and the sealing hole length is 8.5m. Using the rapid sealing technology, the single hole operation time is about 14min, while the traditional mud sealing method has a single hole sealing time of about 60min, which greatly improves the sealing efficiency. Blasting hole sealing material has the

characteristics of fast solidification and fast hardening, and the uniaxial compressive strength can reach 2.8Mpa within 30 minutes after the completion of the hole sealing, which can meet the requirements of the hole sealing. The sealing material is used with the sealing pump and the double bag sealing device. The equipment replaces the manual, realizes the mechanization of the sealing operation, and greatly reduces the labor intensity of the workers. There is no punching phenomenon during the field using the rapid sealing process, and the punching rate is much less than 4-8% of the shot mud sealing method, which solves the problem of poor sealing effect and low efficiency of deep hole pre-splitting blasting.

6. Conclusions

(1) The blasting sealing material has been developed. The material loses flow in 4min after water mixing with a water-cement ratio of 0.8:1, and can be hardened in 12min. The uniaxial compressive strength reaches 2.8MPa in 30min. Meet the construction requirements of fast solidification and fast hardening.

(2) Based on the principle of "two plugging and one injection", the double bag sealing device is designed, which is simple to operate, optimizes the sealing construction steps, and improves the work efficiency.

(3) The field test shows that the blasting sealing material combined with the sealing process of the double bag sealing device and the pneumatic grouting pump only takes 14min to complete the 8.5m sealing operation, which realizes the mechanization of the sealing operation. There was no punching phenomenon during the field test.

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