Study and application of joint layout of underground coal bunker and gangue bin in Guotun coal mine

Zheng Zhong Ming1, Zhao Ren Bao1*, Wang Long Jiang1

1 Guotun Coal Mine, Linyi Mining Group Co. Ltd, Heze, Shandong, 27400, China;
*Corresponding author’s e-mail: 826633069@qq.com

Abstract: In order to solve the problem of corrosion of roadway metal support materials in high temperature and humid environment, the combination of theory and material experiment, design and development of new anti-rust and tensile cement slurry and spraying technology, develop new anti-rust and tensile cement slurry, design by ourselves The multi-purpose slurry spraying machine and the new type of spray gun have been successfully applied in the concentrated air inlet of the south wing of the second mining area of our mine, and have achieved good anti-rust effect, effectively eliminating the hidden danger caused by the corrosion of the metal mesh, effectively proves that the technology is in technology and Economically feasible.

1. Introduction
In actual production of coal mines, the prepared roadways are mostly coal roadways and semi-coal rock roadways[1]. If they are all constructed using the traditional spray method, the tunneling speed will be seriously restricted, causing great pressure on the continuity of the mine. In addition, the cost of guniting materials is relatively high, and deformation of the roof of the coal roadway and the semi-coal rock roadway is relatively large with easy-to-crack pulping skins, leading to large workload in roadway repair. For roadways with a long service life in an environment with a high temperature and humidity, the metal supporting materials such as the metal mesh and anchors are seriously corroded, resulting in a decrease in the support strength and large safety risks to the roadway roof[2-4]. Therefore, in order to ensure the continuity of the mine and the roof safety, a roadway anti-corrosion guniting technique that can be applied rapidly will bring huge benefits to safe and efficient mine production.

2. Preparation of anti-rust and anti-seepage concrete slurry
This paper proposes add certain polymers to change the physical properties and chemical properties of cement slurry, thus obtaining the concrete slurry which can prevent the metal supporting materials from rusting based on the theoretical research on anti-rust and guniting. The slurry is is evenly sprayed on the surface of the metal supporting material to prevent rusting.

2.1 Selection of material to modify the cement slurry
The modified cement slurry prepared must feature sag resistance, high fluidity, high strength, and water resistance. To this end, based on the physical and chemical properties of the additives, the main components of the cement slurry should be silicate 52.5 cement, fly ash, gypsum powder, rust inhibitor, defoamer, redispersible latex powder, polyvinyl alcohol (PVA), and water retention agent.
2.2 Analysis of the influence of additives on the physical and mechanical properties of the slurry

This test mainly studies the influence of the additives of polymer rubber powder, water retention agent, fly ash, and gypsum powder on the performance of sag resistance, water retention, water repellency, gas content, shrinkage rate, flexural strength, compressive strength, and bond tensile strength of the cement slurry in order to find out the modification mechanism of the cement slurry.

The fly ash is externally blended with the dosage of 40%-45% based on its fluidity. The amount of water is controlled based on the fluidity. The gypsum powder and the redispersible rubber powder are adjusted according to the viscosity and strength of the slurry, and the water retaining agent and the polyvinyl alcohol are adjusted according to the sag resistance. The antifoaming agent and the rust preventive agent are added after completing matching the cement slurry, and the amount is determined based on its influence on the defoaming and antirust property of the slurry.[5]

During the experiment, the added PVA can significantly improve the performance of the slurry, while the polyvinyl alcohol does not chemically react with the cement particles. The affinity of the rubber powder, especially during its dispersion and the increase of the slurry consistency can enhance the slurry cohesion and its workability. The performance of the slurry improves with the increase of the PVA rubber powder. This test mainly focuses on the influence of the change of the PVA rubber powder on the sag resistance and flowability, gas content, water retention rate, flexural strength, and compressive strength of the slurry.

The reason why dilute and thick PVA rubber powder delivers opposite outcomes is that the low-concentration PVA powder solution will condensate in the presence of sulfate ion (SO42-) and precipitate out of the solution, releasing more water, resulting in a decrease in the water demand of the slurry and a decrease in the consistency. When the concentration of the PVA rubber powder is increased, the condensation effect disappears, and the organic-inorganic composite film formed by the PVA rubber powder and hydrates causes an increase in water demand and the consistency, leading to an increase in unhydrated cement minerals, thus destroying the microstructure of the slurry changing its physical properties[6].

Studies have shown that the redispersible powder (EVA) can significantly improve the tensile strength and flexural strength of the modified cement concrete, but not the compressive strength. The results of the study on the mechanical properties of the EVA modified mortar show that EVA has little effect on the compressive strength of the mortar when the cement content is within a certain range. In order to make the slurry feature better sag resistance and mimetic stability, this test adds an appropriate amount of EVA to the slurry for analyzing the influence of its content on on the slurry performance, sag resistance, gas content, water retention rate, flexural strength, and compressive strength of the slurry.

3. Based on the analysis of the influence of the different EVA content on the physical properties of the slurry, it can be known that:

1) EVA can improve the workability of dry-mixed mortar. In order to meet the requirements of strength and flexibility of various kinds of dry-mixed mortars, the suitable amount of added EVA shall be 3.0%-4%, otherwise, it will have only a little influence on or even hinder the performance of the mortar;

2) EVA in the dry-mixed mortar can help to bleed air. When the amount is less than 3%, it significantly promotes the air bleeding effect when the mortar is stirred. A large number of tiny bubbles significantly reduce the flexural and compressive strength of the mortar. When the amount is more than 3%, the excessively high rubber powder concentration will reduce the air bleeding effect[7];

3) The higher the amount of EVA is, the more continuous the polymer film on the surface of the mortar hydration product is, and the better the adhesion, water resistance and crack resistance of the mortar will be;

4) EVA has an inductive effect on the air, so that the cement mortar has the air bleeding effect. It can help the components of the agglomeration to flow separately when the mortar is stirred, thereby improving the workability of the mortar. It can also form a polymer film on the surface of the cement
mortar hydration product, which becomes a part of the pore wall, thus improving the cohesion and the resistance to stress and strain damage of the mortar.

Since the water retaining agent is water soluble, a polymer film can be formed on the surface of the dry powder mortar when hydrating. The tensile strength of the film is more than ten times that of the ordinary dry powder mortar, so that the dry powder mortar has excellent compressibility and bonding properties, thus slowing the evaporation and infiltration of water. This experiment focuses on the effect of HPMC on slurry performance, gas content, water retention, flexural strength, compressive strength, and bonding tensile strength[8].

It can be seen from the above experiments that an appropriate amount of PVA added into the cement slurry can help to form an organic-inorganic composite film matrix during hydration. A dense spatial network micro-structure is formed by the integration of the cement hydration products and the organic-inorganic composite film matrix, which can improve the mechanical strength of the cement slurry. When there is too little PVA added, the presence of calcium sulfate will cause condensation, resulting in a decrease in the standard consistency of the cement. When there is too much PVA added, the composite film encapsulation effect will be triggered, which will prolong the time of cement setting and increase the consistency, thus affecting the cement hydration process. The experiment shows that the optimum amount of PVA added is P/B = 4.5%.

EVA and other additives such as methyl cellulose ether (HPMC) are used for rheology improvement. They can improve mortar fluidity, reduce bleeding and sedimentation so as to ensure the long-term adhesion of the cement slurry. They can significantly also improve the wear resistance and the cohesive force so as to improve the deformability of the cement slurry. In addition, they are able to reduce the elastic modulus and improve the crack resistance, and significantly improve the flexibility and workability of the cement mixed material. The test shows that EVA can obviously improve the tensile strength and flexural strength of the modified cement concrete material, but hardly improve the compressive strength (there is even a certain degree of reduction of compressive strength).

The major component of the water-retaining agent is the cellulose ether, which can improve the water-retaining property, shrinkage, and strength of the slurry. This test adopts the nonionic cellulose hydroxypropyl methyl cellulose ether. The hydroxypropyl methyl cellulose ether can prolong the setting time of dry powder mortar, reduce the density of dry powder mortar mixture and the strength of hardened body, and significantly improve the water-retaining property of mortar. As the amount of cellulose ether increases, the flexural strength of the mortar increases while the compressive strength decreases. This is because the increase of the gas content leads to larger porosity of the dry powder mortar, thus making the internal structure of the hardened body loose. Therefore, the cellulose ether should be used reasonably when formulating the slurry, so as to solve the contradiction between the working performance and the mechanical properties of the mortar.

Experiment shows that the optimal ratio of the dry slurry is determined by the total weight of the polymeric material. The polyvinyl alcohol (PVA) added is set to be 4%-5%; EVA YJ606 3.5%-4.2%; first grade fly ash (F) 43%-47%; gypsum powder 13.0%-17.0%; defoamer (AF) 0.3%-0.45%; water retention agent (HPMC) 0.35%-0.45%; rust inhibitor (VCI) 0.7%-0.9%; the water-cement ratio during the preparation of the slurry 0.65-0.7.

4. Research on atomized guniting equipment
The main working area of the guniting machine is the double-acting pneumatic hydraulic booster pump, whose reversing mechanism is a special-type pilot-operated fully-air-controlled gas distribution reversing device. At present, the guniting machine is mainly divided into air guniting machine and high-pressure airless guniting machine. Both of them have electric devices with no explosion-proof function, thus not suitable for underground use. Therefore, it is important to devise a pneumatic guniting device that is easy to carry in cement slurry construction.

4.1 Wet mixer
The waste wind coal drill is used as a power component, which is fixed above the self-made cement
slurry mixing tank and connected with the stirring shaft in the barrel. Two helical blades are installed in the middle and the lower part of the stirring shaft, and each blade is made using the metal plate that forms a certain angle with the bottom of the barrel. A pneumatic pump is fixed at the upper edge of the mixing barrel with the liquid suction pipe reaching the bottom of the mixing tank so as to directly suck the uniformly mixed cement slurry into the pressure tank. In this way, the integration of mixing and guniting operation can be realized. A sewage outlet is set under the mixing tank as an outlet for cleaning and letting out the sewage.

4.2 Pressure tank
The pressure tank is made of air supply tank. Two openings are placed above the tank to weld the φ10 mm straight through as the air inlet and the cement slurry outlet. A galvanized steel pipe is welded to the bottom of the tank. The φ108 flange opening in the tank is used as the inlet, while a small hole with a diameter of φ20 mm is reserved under the tank as the discharging hole. To ensure the safety of the pressure tank, a pressure relief valve is installed on the tank body with the unloading pressure of 0.8 Mpa.

4.3 Spray gun
The spray gun consists of the atomizing piece, the fixed casing, the gun body, the mixed flow plug, the fixed casing, the deflector, the sealing ring, the air inlet pipe, and the inlet pipe. The atomizing spray gun has a simple structure, making it easy to disassemble, clean, and maintain. So, it can effectively solve the problem of atomized guniting of the underground anti-rust and anti-sludge cement slurry. In addition, the structure can adapt to the cement slurry of various concentrations using atomized pieces with different pore diameters. Therefore, it can deliver good atomization effect, and reduce the waste of the slurry and the maintenance cost of the parts caused by the frequent blockage of the nozzle, thus bringing high economic benefits.

5. Economic benefit analysis
The new anti-rust and anti-stretch cement slurry and guniting technology is simple in operation and low in cost. They can save a lot of traditional spray materials and labor costs, and reduce the amount of roadway repairing work, saving more than 4.4 million yuan per year. Using the new anti-rust and anti-stretch cement slurry to spray the roadway can effectively solve the problems of the corrosion of metal supporting materials in hot and humid mines, the reduction of supporting strength, and high frequency of roadway maintenance, thus ensuring the safe production and tunneling efficiency, and delivering significant economic benefits.

The new anti-rust and anti-stretch cement slurry and guniting technology can save a lot of cost compared with the traditional guniting method. It has been successfully applied in the concentrated wind inlet of the south wing of the second mining area, and has achieved good anti-rust effect. It effectively eliminates the hidden risks caused by metal grid rust, proving its technical and economic feasibility. The roadway for construction is 600 m, thus an additional 52582.5 yuan is needed for the use of anti-rust and anti-stretch cement slurry guniting technology (cement and polymer materials of 45,420 yuan, accessories of 412.5 of yuan, and staff salary of 6,750 yuan). According to the current roadway use, the maintenance cycle can be postponed to more than 12 months after adopting the technology, with the annual labor cost going down by 450,000 yuan. Statistics show that the length of the roadway to be sprayed is 8000 m per year, of which 2000 meters of roadways need guniting. The unit price of spray material per meter is 58.3 yuan, so the total cost for the 8000 m roadway is 466400 yuan. The spray accessory is changed every 1000 m, and the annual cost is 3,300 yuan. After adopting rust-proof cement guniting, the labor cost of roadway maintenance can be reduced by 450,000 yuan. The rust-proof cement slurry guniting technology used in the 2000 m roadway can reduce the unit price of the extended meter (labor fee) by 1,600 yuan/m, thus saving 3.2 million yuan. The remaining 6000 m roadway is sprayed with rust-proof cement slurry, which can be completed by 3 workers, who can gunite 48 m per day. Based on the working unit price
of 300 yuan, it requires a total labor cost of 112,500 yuan. The unit price of traditional spray per meter is 692 yuan, thus costing 1384,000 yuan to spray the 2000 m roadway every year. Calculation shows:

450,000 yuan (roadway maintenance costs saved) +3200000 yuan (labor costs saved) +1384000 yuan (traditional spray material costs) -466400 (new spray material costs) -112500 (new spray labor costs) -30000 (components cost) = 4451800 yuan.

6. Conclusion

The new anti-rust and anti-stretch cement slurry and guniting technology follows the basic principles of Safety, Science and Efficiency. It can effectively solve the problems of the corrosion of metal supporting materials in hot and humid mines, the reduction of supporting strength, and high frequency of roadway maintenance, thus laying a foundation for the safety of roadway roof, rapid tunneling construction, the continuity of the mine, and its sustainable development under complicated geological conditions. The new technology can be widely applied in the rust prevention of underground metal supporting material in coal mines, especially in those with a high temperature and humidity.

References
[1] Zhong GZ. (2016) Development trend and key technology of coal roadway rapid tunneling system [J]. Coal science and technology, 44(1):55-60
[2] Zhao XS. (2008) Current status and development trend of efficient mining technology in coal mines [J]. China coal society, 35(4):5-14.
[3] Tian L. (2013) Application research of rapid tunneling technology of coal roadway [J]. Modernization of coal mine, (06):87-89.
[4] Liu YD, Lin J, Yang JW et al. (2017) Rapid tunneling and support technology based on integration of excavation and anchor for extra-thick top coal roadway [J]. Coal science and technology, 45(10):60-65.
[5] Nie XF, Yan GF, Song YG et al. (2013) Rapid tunneling technology of large section coal roadway [J]. Coal science and technology, (s2):141-142.
[6] Zhang GC, He FL. (2016) Asymmetric failure and control measures of large cross-section entry roof with strong mining disturbance and fully-mechanized caving mining[J], Chinese Journal of Rock Mechanics and Engineering, 35(4) : 806-818.
[7] He FL, Zhang GC. (2016) Deformation and failure mechanism and control technology of large section coal roadway subjected to severe mining dynamic load[J]. Journal of Mining & Safety Engineering, 33(3):423-430.
[8] Li XH, Liang S, Yao QL, et al. (2011) Analysis on fissure-evolving law and roof-falling mechanism in roadway with mudstone roof[J]. Journal of China Coal Society, (6):903-908.
[9] Yan H, He FL, Duan QT. (2012) Failure characteristic of coal roadway with water spraying and gushing in fragmentation roof and its control countermeasures[J]. Chinese Journal of Rock Mechanics and Engineering, 31(3): 524-533.