An Interdisciplinary Response to Mine Water Challenges - Sui, Sun & Wang (eds)

Application of the Advanced Curtain Grouting Technology to Drifting in Soft Rock in Water-Rich Bed

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Abstract Safe, smooth and quick drifting of roadway may be realized by application of the advanced curtain grouting for water blockage and reinforcement on the roadway at the top station of West Mining District 3 near the west ventilating shaft of Qianyingzi Coal Mine, which passes through the water-rich bed as well as such areas with complex hydrogeological and engineering and geological conditions. The surrounding rocks that are broken and easily subject to hydrolyzation and argillization to seal and reinforce the pathway for grpoundwater from the fissured sandstone roof and floor of roadway as well as the surrounding rocks.
Keywords advanced borehole, curtain grouting, reinforcement of surrounding rock, grouting pressure, soft rock, management

Overview

The control of mine water disaster is always the first priority during safe production of coal mine and the grouting technology for water blockage is one of the effective measures. Grouting for water blockage is to make the grouting material (i.e., cement, sodium silicate, chemical pulp, clay, sand, gravel, etc.) into grout and squeeze the grout to the desired location underground with high pressure equipment so that it may spread along such channels as the rock fracture and loose bed and play the role of water blockage after consolidation and hardening to reinforce the soft rock formation and block the guide channel in order to reduce or eliminate the probability of water burst and decrease or avoid the water inflow at the water bursting point. The advanced curtain grouting for water blockage and reinforcement is one of the control measures for mine water disaster that needs to be performed in advance in case the roadway of coal mine must passes through the water-rich bed with complex hydrogeological conditions and the rock formation with poor engineering geological conditions.

Issues proposed

Located at the shallow area of West Mining District in the vicinity of the outcrop of 3_2# coal seam, the top station of West Mining District 3 of Qianyingzi Coal Mine is subject to light oxidation to certain extent. The geologic position is 60-120 m beneath the 3_2# coal seam floor and F25 reverse fault (H=350 m) is found in the lower part. The whole roadway goes through K3 sandstone floor and finally gets into the roof.

The data obtained from the advanced drilling of roadway indicate that water inflow from multiple exploration holes is found with the maximum water inflow of 110 m^3/h per hole, a large quantity of water inflow from some drill holes are still discovered during examination after grouting and water seepage of different extents from the heading face, roof and floor of roadway is found with the total yield of 2-4 m^3/h. It could be concluded that the sandstone aquifers in this district have a good water yield property, especially K_3 sandstone. Besides, the surrounding rocks of roadway are dominated by mudstones with aluminum that are very soft, broken and easily subject to hydrolyzation and argillization. With great pressure on the surrounding rocks, the roadway is easily subject to floor heave and expanding sidewall, which may result in greater difficulty in the construction (especially raising, during which a

small quantity of inflow from the heading face will lead to hydrolyzation and argillization of rocks, seriously affecting the delivery, drilling, blasting, etc.) during drifting.

Advanced curtain grouting for water blockage and reinforcement is carried out in advance for the water-rich bed where the roadway passes through to block the guide channel where water burst from the sandstone aquifer may occur and reinforce the surrounding rock in order to ensure the safe drifting in the West Mining District 3.

Grouting scheme and technical process

Layout of grouting holes

Based on the lithological characteristics of the surrounding rock, occurrence characteristics of the aquifer and the grout penetrating area and in combination with the roadway layout and the requirement for smooth drifting, it is primarily determined that the segment to which the advanced curtain grouting for water blockage and reinforcement will be applied shall have a length of 90 m, with the drifting of 70 m and the reserved safe rock pillar of 20 m and each segment shall be designed with 3 groups of drill holes (fig. 1). Each group shall be composed of 6 drill holes (5 holes for the roof and two sidewalls of roadway and 1 hole for the floor). The final drill holes of the three groups shall be located 20 m outside the center of the roadway under construction, designed in a circular shape in the bottom (fig. 2) and 30 m, 60 m and 90 m in advance respectively (i.e., with a distance of 30 m between the hole bottom of two groups). Upon completion of advanced curtain grouting, two inspection holes shall be provided (to be determined according to the water yield of the grouting hole and grouting volume) for further grouting.

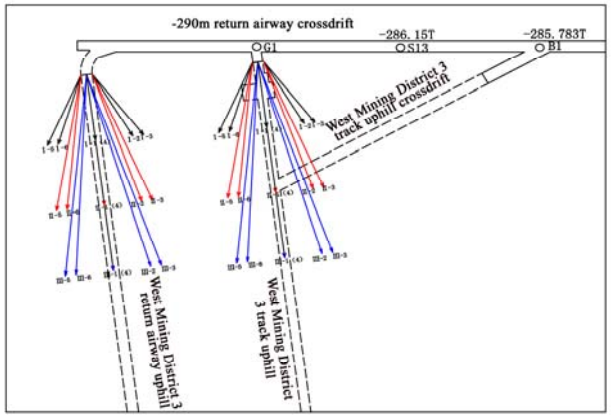

Fig. 1 *Layout plan of drill holes for advanced curtain grouting*

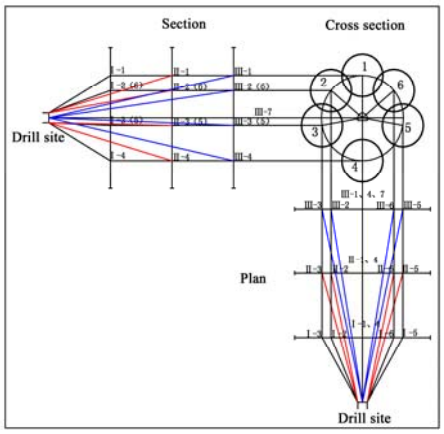

Fig. 2 *plan, section & cross section of drill holes for curtain grouting*

Requirement for grouting technology

Structure of drill hole

The drill hole for curtain grouting shall be of secondary structure, which is primarily drilled for 15.5 m with *Φ*108 mm drill, provided with *Φ*108×6 mm orifice pipe for 15.5 m and finished with *Φ*75 mm open-hole drill after being subject to grouting and passing the pressure-tight test.

Construction sequence of drill hole

The drill holes shall be constructed in the order of group 1, 2 and 3. Finally, two inspection holes shall be designed according to curtain grouting.

Grouting sequence of drill hole

Grouting shall be carried out in the order of group 1, 2 and 3 after the guide hole is grouted and checked as qualified. The holes of each group may be subject to symmetric construction and grouting.

Grout diffusion radius

Since the final drill holes are located 20 m outside the center of the roadway under construction, therefore, the surrounding rocks within 30m outside the roadway are filled and reinforced (to be considered as 10 m).

Construction design of grouting

Grouting material and grout ratio

The cement grout shall be mainly adopted for grouting of orifice pipe, with the cement-water glass grout as the supplement. PO42.5 ordinary Portland cement and 40-45Be′ sodium silicate, with M=2.5-3.0 shall be applied. The water-cement ratio of 1:1 shall be preferred for cement grout. If obvious leakage is found in this process, cement grout may be replaced with cement-water glass grout according to the actual situation on the site with cement-water glass ratio of 1:0.2-0.6 in volume.

Grouting process

Cement + water → primary mixing → secondary mixing → cement grout (or cement-sodium silicate grout) → grout pump → ground grouting pipeline (i.e., ground grouting system) → shaft grouting pipeline → roadway grouting pipeline → working face grouting pipeline → mixer → control valve → orifice pipe → entry into the rock fracture

Grouting material and grout ratio

The concentration is the key to the quality of grout. A pressure test shall be conducted every time before grouting. The concentration shall be increased based on the grouting pressure until the pressure of grout is raised.

The cement grout shall be mainly adopted for grouting of orifice pipe, with the cement-sodium silicate grout as the supplement. PO42.5 ordinary Portland cement shall be applied, with the caking cement eliminated. 40-45Be′ water glass, with M=2.5-3.0 shall be preferred.

The water-cement ratio of cement grout shall be 2:1, 1.75:1, 1.5:1, 1.25:1 and 1:1. To ensure the grouting effect and increase the grouting rate, clear water shall be pumped first during grouting, initial concentration of grout determined based on the water absorption inside the hole and grout ratio adjusted according to the pressure change and grout absorption (Generally, the grout shall be made thin, thick and thin in order). The site preparation of cement grout is shown in the table below.

Table 1 *Site preparation sheet of single liquid cement grout*

Water-cement ratio	Cement (50kg/bag)	Water (L)	Grouting quantity (m^3)
2:1	9	900	1.050
1.75:1	10	875	1.042
1.5:1	11	825	1.008
1.25:1	13	812	1.029
1:1	15	750	1.000

If there are large quantity of water inflow or obvious water bursting point and severe grout leakage from any crack within the grouting area, single liquid cement grout may be replaced

with cement-sodium silicate grout according to the actual situation on the site. Intermittent grouting may also be performed if necessary. Finally, cement-water glass grout shall be adopted for sealing of hole. The cement-sodium silicate ratio of the grout shall be 1:0.2-0.6 in volume.

Pressure of final grouting hole

Curtain grouting pressure: The hydrostatic pressure shall be 3.0MPa. Considering the specific characteristics of the project and the occurrence of rock formation, the curtain grouting pressure shall be 6.0MPa which is two times of the hydrostatic pressure based on calculation and in combination with the previous grouting experience in order to ensure the grouting effect.

Standard for completion of grouting

(1) Cement grout shall be adopted. When the grouting pressure reaches the final pressure or the grouting rate is less than 30 L/min, thinner cement grout shall be applied continuously for 20-30 min (considered as conforming) or more than 30 min (considered as optimal).

(2) Cement-sodium silicate grout shall be adopted. When the grouting pressure reaches the final pressure or the grouting rate is less than 50 L/min, thinner cement-water glass grout shall be applied continuously for 10-15 min (considered as conforming) or more than 15 min (considered as optimal).

Analysis of grouting reinforcement effect

At present, theadvanced curtain grouting for water blockage and reinforcement has been performed 4 times at the top station of west mining district 3 of near the west ventilating shaft ofQianyingzi Coal Mine, rail in the mining area and return-air rise (upper section). Comparison of roadway construction before and after curtain grouting shows that the surrounding rocks before grouting are broken and easily subject to hydrolyzation and argillization and obvious water seepage from the floor and roof of roadway and water yield from the anchor rod and anchor rope are found, resulting in greater difficulty in roadway supporting, small footage and great potential risks. After construction, severe deformations such as the expanding sidewall and floor heave are presented and shed supporting, dinting and shotcreting for the second time as well as reinforcement and supporting for the third time by grouting at the rear roadway with anchor rod and anchor rope are required, wasting a lot of human, material and financial resources and time and adversely affecting the progress of works. However, after grouting, the actual situation of roadway shows that water seepage is only locally presented and surrounding rocks are well reinforced. Besides, normal anchor-mesh-shotcreting technology could meet the safety requirement for roadway supporting, the footage is increased and safety is thus reliably ensured, proving that the advanced curtain grouting scheme is reasonable and the grouting can be properly done.

Innovations of curtain grouting design

Establishing a ground grouting station and increase the grouting rate;Raise the grouting rate and expand the grout diffusion radius;Intercept the water filling channel in the aquifer; Reinforce the surrounding rocks.

Conclusion

The grouting scheme reaches the advanced level in terms of treatment effect, time and cost, bringing great economic and social benefits, thus, it is worth being applied and promoted. Currently, this advanced curtain grouting scheme is continually applied to this coal mine and is being applied and used for reference at Hengyuan Coal Mine.