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The Application of Floor Grouting Consolidation in Zhengzhou Mining Area

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Abstract Zhengzhou mining area mainly mines the Shanxi Formation coal seam Ⅱ$_1$, which is being threatened with Taiyuan Formation thin limestones water and Ordovician limestone water. In this mining area, the hydraulic pressure of Ordovician aquifer has reached 3~4 MPa and its recharge is rich. For the safety of mining the technique of floor grouting consolidation has been widely used. This article takes one working face as an example to elaborate on the application of the technique. The results show that the technique is an effective solution to floor confined water which have a high pressure and hard to drainage.
Keywords floor grouting consolidation, confined water, Ordovician limestone aquifer

Introduction

The floor grouting consolidation has been used to assurance safety in working face production by reducing the threat of floor confined water since the eighth decades of last century in china (Qiang Wu 2013). This method can be used to strengthen the original soft rock, enhance the floor's ability of anti-penetration and anti-pressures, as a result, this method can effectively reduce the probability of water inrush from floor confined water. In recent years, with the mining depth increasing, the bottom bearing pressure increases, especially to the Shanxi Formation coal seam Ⅱ$_1$, the threat of Ordovican limestone water is growing more heavier. In this case, the floor grouting consolidation has been widely used in FeiChang/FengFeng/JiaoZuo mining areas (Guangde Zhang 2002).

Mining area survey

In this mining area, the main regional tectonics are high-angle normal faults, the next are folds, and gravity gliding structures are developed locally (Tiechui Zhao 2006). There is a large area of limestone outcrop to make-up water in this mining area, so it has a rich recharge of the bottom aquifer; and there is a disproportionate number of water conducting channels because of the well-developed fault structures (Zhirong Wang 2003). There are four aquifers of coal bottom mainly: the $L_{7\text{-}8}$ / $L_{5\text{-}6}$/ $L_{1\text{-}4}$ aquifers of Taiyuan formation, the O_2 aquifer. The threat of $L_{1\text{-}4}$ and O_2 are considered greater in the four aquifers, and they are always considered as one because of the short distance between them, the closely hydraulic connection of them, and the synchronization of their gauge heights' change. The distance between O_2 and coal is about 60~80 m, the thickness of O_2 is about 70 m, and the gauge height is about +80~ +100, as the mining depth of most mine achieves -300, the hydraulic pressure of mining has reached 3~4 MPpa, the water inrush coefficient T is getting higher than 0.06 MPa/m, and the threat is increasing more seriously.

The floor grouting consolidation

Grouting process

Because of the greater mobility of the working face, the combination process is applied. The grouting bore holes are constructed under the well, and the ground grouting station, grouting pump use the feeding hole/the grouting pipe/the grouting hole to grout the bottom limestone aquifers (as shown by the fig. 1).

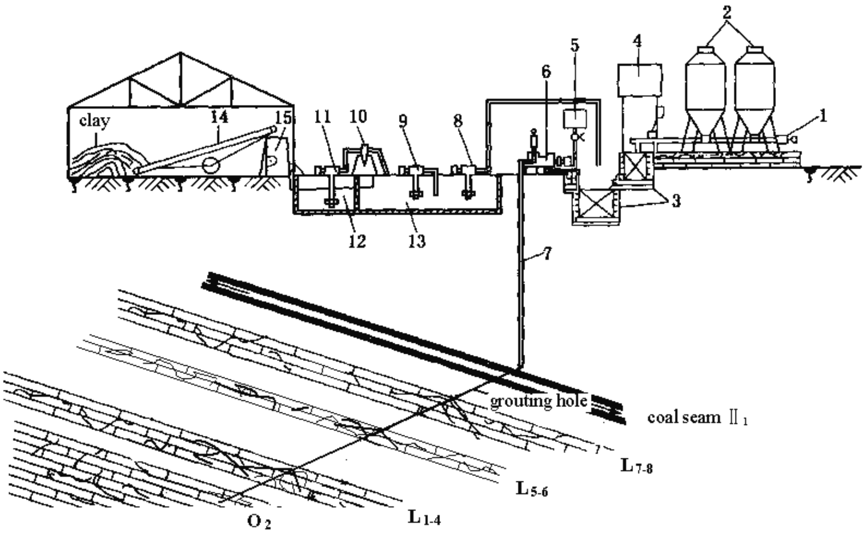

Fig. 1 *The diagram of the floor consolidation grouting system*
1-screw conbeyor; 2-bulk cement tank;3-mixer;4-overhead water-tank;5-additive tank;6-grouting pump;7-grouting pipe;8-slurry pump;9-circulating pump;10-cyclone;11-vortex pump;12-pulp pool;13-seminal plasma pool;14-belt converyor;15-pulping machine

Grouting material and the mix proportion

Cement, clay, fly ash, additive and water etc are often chosen as grouting materials. And the water-cement ratio should be controlled to the range of 08:1~2:1; relative density of the clay cement slurry and clay slurry should be controlled to the range of 1.12~1.18.

Suitable areas of grouting

This technique is suitable for the mining area where the hydraulic head is hard/ uneconomical to drainage, in Zhengzhou mining area, the technique should be used in the following areas:

(1) The area where there is fractured floor or low resistivity zone of geophysical exploration, and the water inrush coefficient is higher than 0.04 MPa/m.

(2) The area where the the water inrush coefficient is higher than 0.07 MPa/m.

The standard of grouting end

(1) Grouting quantity

To one grouting hole, when its grouting cement and clay is more than twice of its water yield(m^3/h), the effect of it can be considered good .

(2) The eventual grouting pressure

The grouting pressure should meet the design requirements, which is always about 2~3 times of the water pressures, the remaining amount of grouting should be less than 40 L/min, and the time should be longer than 30 min.

Effect test and supplementary measures

(1) Check holes

The effect can be estimated by the core and the water yield of checking holes, the checking holes should be designed in the area where the fault structure is well developed, the coverage of grouting holes is not good, the water yield of hole is more than $20m^3/h$, or the grouting effect is considered not good by analysis, when the water yield of holes is less than 20m^3/h, it is considered to achieve the goal.

(2) The method of geophysical exploration, when there is no or less low resistivity zone of geophysical exploration, the effect is considered good.

Application

Working face 32071 of Pei Gou coal mine is designed at the lowest place of the 32 mining area of this coal mine. At its north is working face 32051 worked out area. At the south is the fushanzhai subsidiary fault. The mining elevation is -359~-271 m, the height of $L_{1\text{-}3}$ water level is +80 m, the water inrush coefficient T is higher than 0.07 MPa/m. There are a number of buried fault structures, 32051 combined working face have happened water inrush whose maximum water inrush occurred up to 3000 m^3/h, the reason is that the hidden structure was revealed. The fushanzhai subsidiary fault is water conductive fault, and its fall head is 80m, what makes the lower wall's Ordovican aquifer recharge the upper wall's limestone aquifers of Taiyuan Formation, increasing the floor aquifers' recharge and the difficulty to control floor water.

Engineering design

The working face inclination length was designed 148 m. In order to achieve a comprehensive coverage of the entire working face, the drilling fields were designed in the top tunnel and the bottom tunnel at the same time.

(1)The design of drilling field

The distance between two drilling fields' is 60 m, there were 9 in the top tunnel, 9 in the bottom tunnel drilling fields were designed, because the -300 track roadway through part of the face below, there was one drilling field was design in it.

(2)The holes' end position

Because it existed possibility of water inrush both of $L_{1\text{-}3}$ and Ordovican aquifers', so most holes' end position were designed in these aquifers.

The actual construction

(1)The basic holes construction

According to the construction site conditions, the design was adjusted, 10 drilling fields in the top tunnel, 11 in the bottom tunnel, 1 in the middle tunnel were finished. Because of the construction conditions, there were 2 top tunnel drilling fields were finished in track roadway, and 2 drilling fields were added in the bottom tunnel. To the end, 140 holes have been finished. Among them, the number of holes whose water yield was more than 20 m^3/h was 49, accounted for 35% of the total. Among these 49 holes, the number of holes whose grouting quantity was more than twice of the water yield was 42, made up 85.8% of it.

(2)The first time test

After 3 weeks of the basic holes construction has been finished, the test of geophysical exploration was made, and 14 low resistivity zones have been drawn. According to the situation of the basic holes construction and geophysical exploration test, test holes have been added to the area where own great water yield possibly. And 52 holes have been finished this time; at last, there were 17 holes whose water yield was more than 20m^3/h , among these 17 holes, the number of holes whose grouting quantity was more than twice of the water yield made up 88.2% of it.

(3)The final test

In the end, the second time test holes were constructed to test the first test holes whose water yield was high, grouting effect was not good, and the eventual grouting pressure was not high; at last, the number of second time test holes was 18, the number of holes whose water yield was more than 20 m^3/h was 2, accounted for 11.1% of the total, and these two holes' grouting quantity were all more than twice of the water yield, which showed that it reached the goal after the first test.

Results

Finally, the project has completed a total of 23 drilling fields , 210 boreholes, 25527.2 m drilling footage, grouting volume 27826.7 t, clay 934 m^3，The number of the holes whose water yield was more than 20 m^3/h was 64, the number of the holes whose grouting volume was more than 900t was 8(As shown in Table 1), in these 8 holes, B5-2 had the most grouting volume, 2745 t cement, 569 m^3 clay。

Table 1 *The statistical table of boreholes whose grouting volume was more than 500 t*

Number	The water yield （m^3/h）	Cement grouting volume （t）	Clay (m^3)	The final grouting pressure （MPa）
B5-2	80	2745	569	10.2
A7-1	20	2757	--	8
B1-T1	40	1565	--	8
D3-T4	50	1256	89	10
B2-8	50	913	--	10
B1-1	35	900.5	276	8.5
T6-4	50	550	--	9
T6-T1	20	537	--	9.2

In the process of face actual mining, the occurrence of water inrush didn't happen. The water inflow of working face was 60 m^3/h, 55 m^3/h was the water from roof, and the surplus 5 m^3/h was from the $L_{7\text{-}8}$ limestone. That was much fewer than the previously expected working face water inflow. And the project reached the goal.

Conclusion

This article takes an example to elaborate on the applications of the floor grouting technique in Zhengzhou mining area. The results have proved that this technique has tangible effect of transforming the aquifuge thickness and strength, and reducing the probability of water inrush. And it also has proved that the testing methods are effective, although their efficiency should be improved. In the future, how to improve the grouting quality and reduce the holes' quantity will be the research emphasis, when this problem is solved, this technology will have a more broad application prospects.

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