UNDERGROUND TREATMENT OF FLOODED FULLY MECHANIZED MINING FACE

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ABSTRACT

In the event of underground fully mechanized mining face (FMMF) flooding in China, the normal rectifying actions are: (1) drill from surface down to the affected area, (2) pour river sand down the hole to cover and protect the FMMF support, (3) fill the hole with rubble and cement paste to seal inflow points, and (4) after successful sealing, clean up the river sand to expose the support equipment for dismantling and repairing. This tried and tested technique is simple, but consumes large amounts of material, is time consuming and expensive. This paper introduces an underground drilling and injection method which is applicable in the case of FMMF flooding events and overcomes all the disadvantages of the traditional approach. Using this method, through careful planning and construction, we successfully rehabilitated a major flooding event within three months. .

China Shanxi Jiexiu Yitang Coalmine is located in the middle of Shanxi province. It is a large modern state-owned mine with over 1.2 million metric tons output a year. During the coal mining process, its underground No. 100302 FMMF intercepted an oval shaped collapse column of 40 by 26 meters. Intercepting the collapse column gave rise to the inflow of water from the deeper lying Ordovician limestone formation. Heavy water inflow from the coal floor of around 200 to 300 cubic meters per hour, submerged the working face with 94 FMMF supports, one shearer, and two scraper conveyors. This resulted in a direct loss of 5 million dollars.

In view of the large inflow of water, we first constructed two water plugs on the upper and lower sides of the gate road. These plugs isolated the working face from the rest of the mine and turned the dynamic water inflow into a static situation. Next we excavated an access tunnel through the body of solid coal to establish a drilling base from which we drilled towards underneath the inflow points on the working face seam floor and injected grout. To prevent cement from spreading up to the working face and burying supports, we chose cement-water glass double liquid quenching slurry for the injection process. The initial setting time was controlled to between 30 and40 seconds. By grouting at fixed amounts and pressures and repeatedly alternating injecting and cleaning holes , we achieved the goal of sealing flow channels.

During 54 days of intense work (November 22nd, 2008 – January 14th, 2009), we drilled 29 holes and used 434 tons of cement, 160 tons of water class, and 39.6 tons of fly ash. Drainage of the flooded area started on January 14th, 2009. The water level subsided quickly. The residual water inflow was less than 30 cubic meters per hour after removing sands on the working face. All supports were still in good condition while no grout entered the working face. The grouting project to stop the inflow of water was judged to be completely successful.

1. PROJECT BACKGROUND

China Shanxi Jiexiu Yitang Coalmine is located in the middle of Shanxi province. It is a large modern state-owned mine with over 1.2 million metric tons output a year. No.100302 fully mechanized mining face (FMMF) is the major working face, which measures 2.4 x 142.5m in mining height and length and is extracting the No.10 coal seam. It consists of 94 light FMMF supports, one shearer, and two scraper conveyers.

This mining face is lower than the +540 meters static water level of the underlying Ordovician limestone aquifer.. It is classified as an under pressure mining area. The inflow of water from the roof is always present. However, the maximum water inflow from this source is around $100m^3/h$. Two faults were intercepted during the mining process on September 16th, 2008. The fault throws were 2m and 0.5m respectively and exhibited clear fault features. Between these two faults were graben structures. On September 28th an oval shaped collapse column of 40 by 26 meters was revealed on the mining face. Water flow carrying sediment and broken rock from the roof made the roof unstable. However, the major problem started at 11 pm on October 27th when water burst out of the floorand by 5 am on October 28th part of the mining surface was submerged. This stream of water increased with time and quickly reached 200-300 m^3/h. The mining face was completely inundated within days due to insufficient pumping capacity.

Tests on the water sample indicated that the inflow originated from the deeper lying Ordovician limestone aquifers from which water flowed upwards through the collapse column. Ordovician limestone aquifer contain much water. It was accepted that with time, the inflow channel would become smoother, and that the inflow volume would increase. In circumstances such as these it is impossible to contain the water inflow by increasing the pumping capacity.

2. CONTROL PLANS SELECTION

To solve the flooding problem and save the equipment, we considered three alternative plans.

Plan A: Surface Drilling and Grouting

This plan required to construct two water plugs in the two gate roads connecting to the No. 100302 working face in order to stop the discharging and turn the dynamic water flow into a static situation. Next to drill from surface down to the working face and inject river sand, crushed rock, and cement slurry to seal the water conduits in order to stop the water inflow. River sand and crushed rock can also help to protect equipment by insulating them from contact with cement slurry.

Although this method is expensive and takes a long time to complete, it is effective in stopping water inflow. If carried out in the appropriate way, this method may save most of the equipment.

Plan B: Freezing the Working Face

This plan also required to drill holes from surface to the working face. Next, freezing facilities would need to be established on surface and the freezing liquid circulated through the holes to below surface in order to freeze the water confined in the working face and stop inflow. After stopping the inflow, blast and excavate through the ice to retrieve all equipment.

This method requires much work and complicated equipment. In addition, the low temperature may damage rubber hoses, emulsion, and valves of FMMF supports.

Plan C: Drill Inside the Mine and Control Grouting

Silmilar to plan A, the first step is to construct two water plugs in order to stop the inflow of water and convert the dynamic water flow into a static situation.However, different to plan A, plan C requires the excavation of a special purpose access tunnel through the solid coal to a point close to the point of water inflow.. From this point holes would be drilled towards the water inflow points and a grout cement-water glass double liquid slurry would be injected into the inflow points and surrounding areas. To achieve the dual goals of sealing the water conduits and preventing slurry from reaching the working face at the same time, we planned to repeatedly alternate the cleaning of holes and injection of slurry.

This method was accessed to take less timeand show faster results than the alternatives. Since it is impossible to observe what is being done, the whole project relies heavily on engineers' experience and skills to precisely control the operation

Comparison of plans

After careful technical and economic comparison between the three plans, we selected plan C, which beat the other two with respect to both feasibility and cost.

3. DETERMINATION OF GROUTING PARAMETERS

Selecting Slurry

During grouting, it was necessary to control the spread of slurry and it was deemed best to keep all slurry in the collapse column under the working face floor. Therefore, we chose cement-water glass double liquid quenching slurry for the injection process. The initial s time was controlled to between 30 and40 seconds.

Grouting Materials

The selected cement was P.O. 42.5 ordinary silicate fresh cement. The water-cement ratio was 1:1. Water glass used had a modulus of M=2.8-3.1 and density of 30-35º Be'. The cement slurry to water glass ratio in volume was 1:0.5. In order to increase the ratio of solid materials in the slurry, we added fly ash to the water glass slurry.

Grouting Distance

The grouting distance ranged from 5 to 10 meters. Whenever water inflow from the drilled holes was over 2m3/h, no matter what the grouting distance was, we stopped drilling and started grouting.

Terminal Grouting Pressure

The terminal grouting pressure was set at 4mpa.

Maximum Grouting Quantity

In every single grouting hole, no matter what the water outflow from the hole was, the maximum grouting quantity for each injection was 200 bags (10 tons) of cement. Grouting stopped immediately after injecting 200 bags of cement no matter whether the pressure increased or not. After the slurry solidified, we re-flushed the holes and re-injected slurry.

Ending Injection

When grouting pressure reached 4mps, and water flow remained stable for 20 minutes at 20-30L/minute, , injection was stopped.

Grouting Equipment

The selected equipment included KQJ90HT pneumatic DTH explosion-proof drills for drilling Φ80mm holes, 2TGZ-210/60 double-liquid speed-controllable explosion-proof injection pumps for grouting, cylinders of varying diameters for mixing two types of slurry in a volume ratio of 1:0.5, and ordinary explosion-proof vertical 200L cement slurry blenders for blending.

4. CONSTRUCTION

Construction of Water Plugs

Two six meters long walls were constructed at the selected places along the two gate roads. Each plug was built with two rock outer walls, the middle of which was filled with broken rocks and cement slurry.

Drilling Site Construction

Within the solid coal body of coal seam No. 10 a 3x2m tunnel was excavated as the drilling area, where air pressure pipes, water pipes, and power lines were available. Figures 1 and 2 show the layout of the tunnel and drilling site.

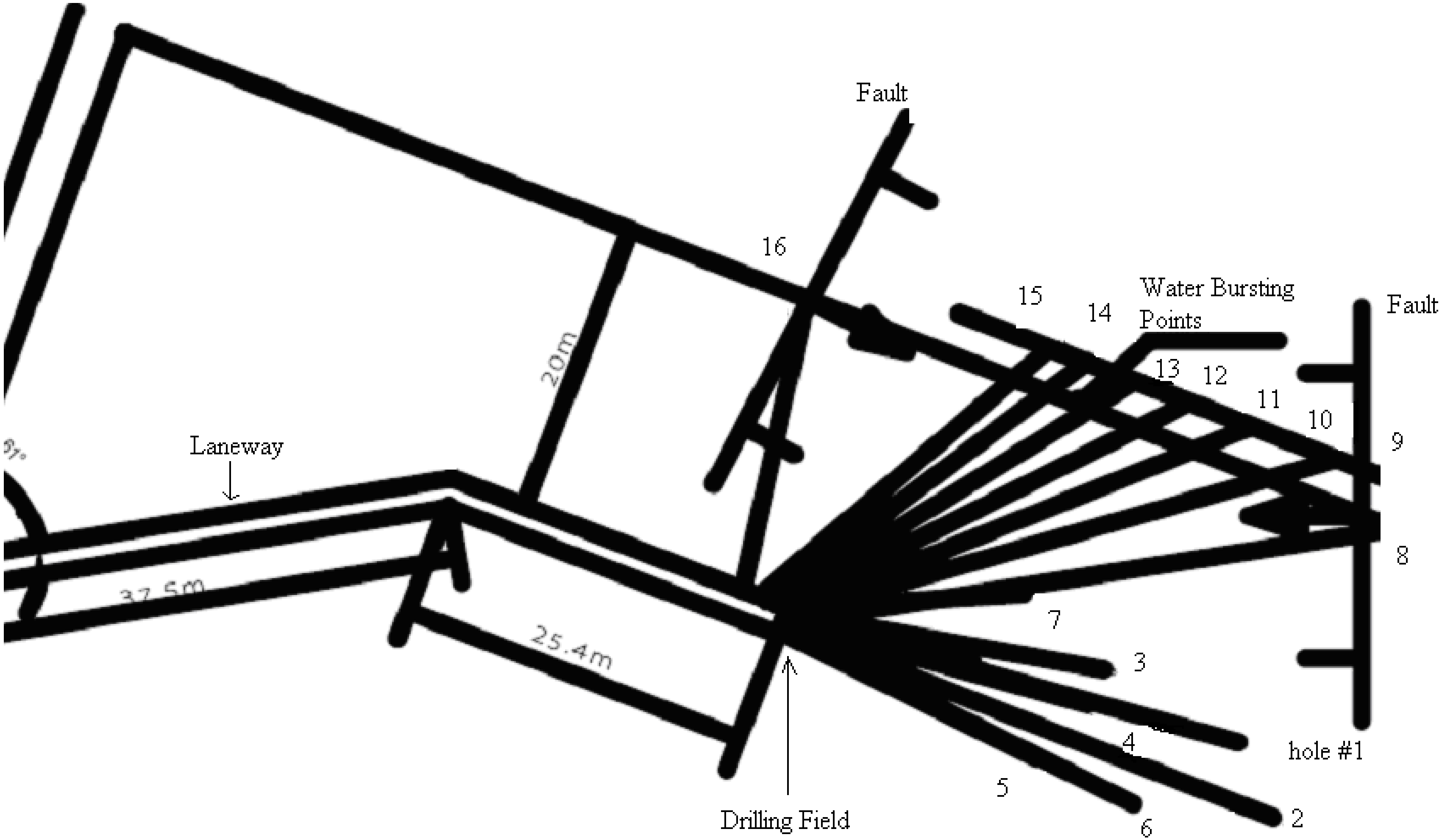

Figure 1. Floor Plan of No. 1 to 16 Grouting Holes

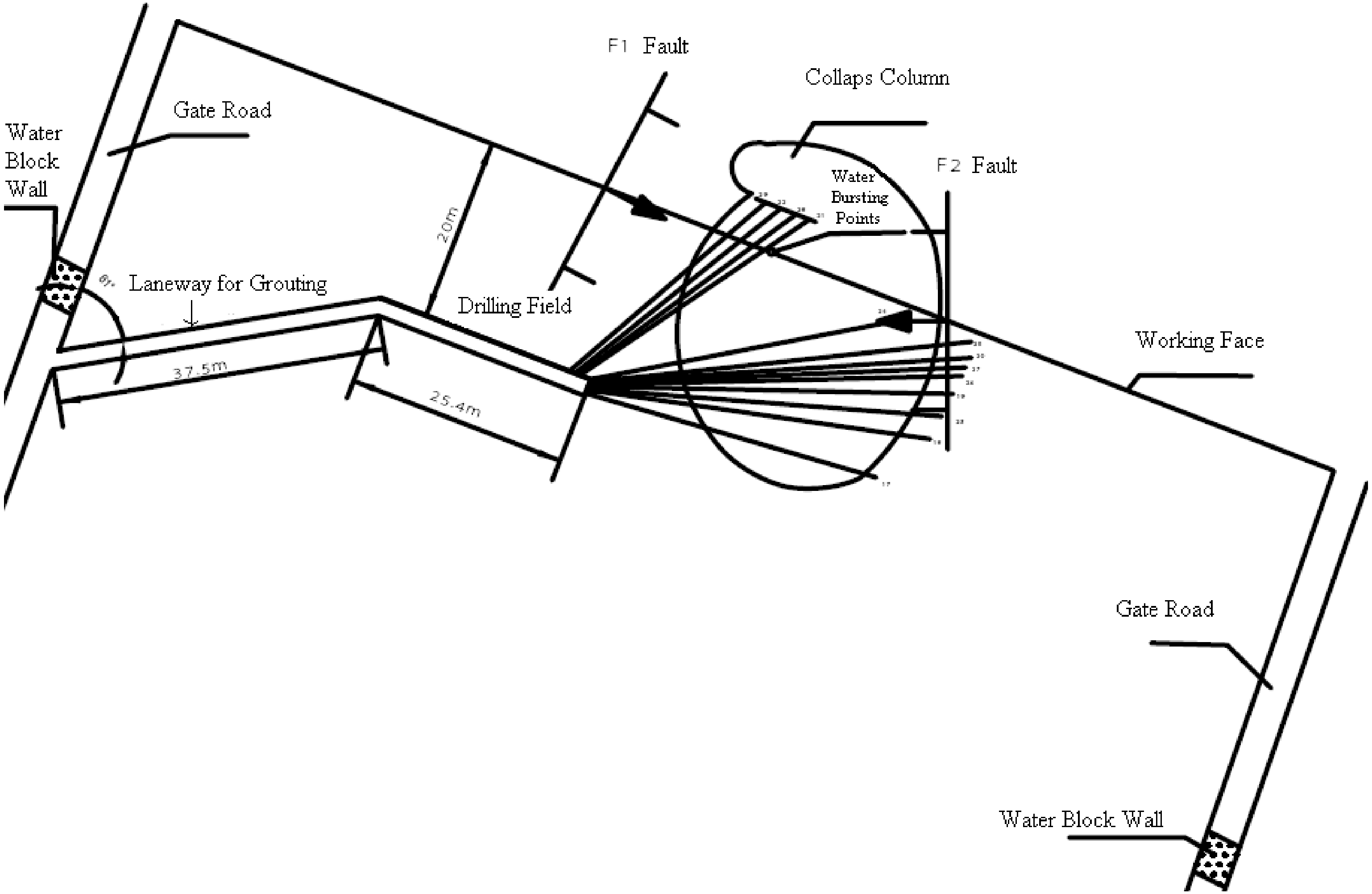

Figure 2. Floor Plan of No. 17-29 Grouting Holes

Drilling and Grouting

TABLE 1. Grouting Holes Parameters

Hole #	Hole Depth (m)	Depression Angle	Carrying Angle	Max Water Inflow (m^3/h)	Flush Times	Cement Quantity (in bags)	
1	33	0°	7°(L)	20	5	978	
2	37	0°	0°	60	7	825	
3	30	40°	10°	60	8	1198	
4	29	40°	7°	80	8	1310	
5	27	40°	5°	25	5	300	
6	28	10°	5°	7	5	218	
7	27	60°	9°	30	6	244	
8	25	50°	25°	20	6	380	
9	33	25°	30°	30	5	262	169
10	42.5	30°	37°	6	6	259	82
11	34.5	33°	43°	40	6	405	338
12	41	36°	48°	5	3	96	105
13	41	38°	53°	30	4	253	228
14	40	40°	58°	3	5	126	51
15	37	41°	62°	3	4	178	30
16	32	51°	99°	1	3	124	72
17	37	19°	5°	0.5	3	110	68
18	41	18°	13°	0.8	3	126	60
19	39	17°	20°	40	3	160	56
20	44	17°	25°	0.5	3	109	26
21	38	32°	55°	5	3	85	31
22	36	32°	59°	6	7	405	161
23	42	16°	16°	1	3	50	10
24	42	16°	22°	1	4	138	19
25	42	16°	27°	2	4	120	27
26	42	30°	32°	0.2	5	118	37
27	40	16°	24°	2	3	49	14
28	36	35°	58°	3	3	22	0
29	36	35°	62°	1	3	32	0

Figures 1 and 2 also depict the positions of the 29 drill holes. Table 1 reports their construction parameters, including orientation, depression angle, and hole depth, etc. The whole project consisted of drilling and flushing 133 times in total, excavated 2,747 meters in depth, and used 434 ton of cement, 160 ton of water glass, and 39.6 ton fly ash.

5. CONCLUSIONS

The construction started on November 22nd, 2008 and was completed on January 14th, 2009. The whole project took 54 days to carry out. Discharge of the flooded water commenced on January 15th. By midnight on January 20th, the water level was lowered to +519.6m (the static water level of the Ordovician limestone aquifer +540m). The accumulated water in the working face was quickly pumped out. After cleaning up mud and sand, the residual water inflow was less than $30m^3/h$. The majority of it being seepage coming from extracted areas. The original inflow points were completely sealed. A field investigation at the working face revealed some small solidified slurry remnants scattered around the lowest parts on the bed of the working face. No slurry was found elsewhere. All 94 FMME supports were recovered and found to be in good condition.

This grouting control method not only stopped water inflow into the working place, but also prevented slurry from spreading to the working face and helped to keep all supports, a shearer, and conveyors intact. The task was successfully completed and the goal with the project was fully achieved.