Ground Advanced Grouting Technique in Xuandong No.2 Mine

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ABSTRACT

Xuandong No.2 Mine is located in northern-west of Beijing 150km away. It has two shafts, the main shaft and the auxiliary shaft, the former depth is 829m and the later is 849m. The No.2 Mine is in the Xuandong valley, in this area underground water is very abundant, water inflow predicted was about 500~600m3/h for every shaft. So it is the best way to take the use of ground advanced grouting in the period of management and preparation for shafts construction, the grouting depth is 839m for the main shaft and 859m for the auxiliary shaft.

FLOW LOGGING

It is important to obtain the accurate data of water-bearing strata in shafts area. Applying the MDS-1 flow logging instrument in the surveying hole for shafts is very suitable for this purpose. The principle of flow logging is : the drilled hole passes through many water-bearing strata which have different rock nature, thickness, and the opening of fracture. When pump or pump-in in the whole drilled hole, each aquifer has different ability to give or absorb water, this causes different speed of flow in different horizontal level of the hole in aquifers and the same speed of flow in the non-water-bearing strata section. The flow logging instrument in the drilled hole when pump or pump-in could survey the speed in any horizontal level when it is lifted up or down in the hole. After the flow logging data was analyzed by a computer, we could get the data of the aquifer: location, thickness and the coefficient permeability. In Xuandong No.1 surveying hole for shafts we used the MDS-1 flow logging instrument, the logging depths from 85m to 860m and the flow logging result indicated that there are eleven water-bearing strata in the whole grouting length, the main aquifers are located between 100m and 539m in depth. The detailed data is showed in Table1.

Table 1: Flow logging result and the grouting stage length designed

Catalogue	Items \ Aquifer No	1	2	3	4	5	6	7	8	9	10	11
Aquifer	depth (m-m)	95.0 ~105	194.9 ~202.1	305~ 309	346~ 349.7	407.8 ~413	385~ 389	533~ 539.7	628.8 ~632	672.3~ 667.8	726.4~ 734.4	838.4~ 841.8
	thickness (m)	10.1	7.2	4.0	3.7	5.2	4.0	6.4	3.2	5.5	8.0	3.4
	properties	G	G	G	G	G	A	G	A	G	G	G
Stage grouting	Grouting depth (m-m)	85.0 ~170	170 ~246	246~ 332	332~ 390	390~ 478	478~570		570~ 645	645~ 707	707~ 766	766~ 859 839(M)
	stage(m)	85	76	86	58	88	79		75	62	59	93 73(M)
	stage No.	1	2	3	4	5	6		7	8	9	10

Note: G-giving water, A-absorbing water, M-main shaft

GROUTING PARAMETERS

The strata from top to bottom in the whole length are weathered layer, basalt, sand stone, gabbro, mudstone and the coal measures. According to the flow logging results, the grouting stages were designed between 80m~100m and every grouting stage responding to one or two water-bearing strata, see Table 1.

The Number of Grouting Holes and Construction Sequence

There are six grouting holes located evenly around the shaft center, the diameter of the grouting holes circle was 9.8m for the main shaft and 10.5m for the auxiliary shaft. Six grouting holes are divided into two groups and construction respectively. No.1 grouting hole is located at the upper reaches of the underground water flow and No.2 to No.6 are named in clockwise. No.1 and No. 6 are the core drilling holes. No.1, No.3, No.5 grouting holes are first group and drilled at first, grouting downward. No.2, No.4, No.6 grouting holes are second group, grouting upward. No.6 grouting hole is the final inspecting borehole and the grouting hole. The locations of grouting holes are showed in figure1.

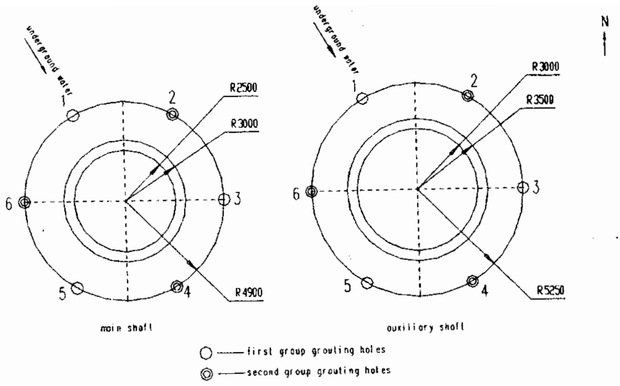

Figure 1. The locations of grouting holes

Quantity of Grouting

The designed quantity of grouting is calculated by the following equation:

$$Q=\Sigma A\pi R^2 Hi\eta i\beta$$

Where: A-Clay-cement grouting consumption coefficient, A=1.3;
R-Effective diffusion radius of clay-cement grout, taken shaft center as center of circle, designed R=11.5m for the main shaft and 12m for auxiliary in m;
H-Length of grouting stage in m;
η-Rock crack rate;
η-Grouting filling coefficient, designed β=0.95;
n-The number of grouting stages;
Q-Quantity of grouting clay-cement slurry in m^3;
The quantity of grouting slurry and the rock crack rate are showed in table2.

Table2: The quantity of grouting slurry and the rock crack rate

Shaft	Quantity of grouting slurry (m^3)		Rock crack rate (%)	
	Designed	Real	Designed	Real
Main Shaft	9667	10170	2.50	2.63
Auxiliary shaft	10805	11280	2.5	2.61

The pressure and rated flow of grouting

The grouting pumps are YSB-300/200 and NS-300, they are special designed for grouting, the rated flow is 2001/min to 8001/min and the grouting pressure is 2.2~3.0H_o.

Grouting boreholes drilling

JDT-5 Gyroscopic inclinometer is used to measure and monitor the borehole deviation, which provides a measured result at every 10m interval. Using the Navi-Drill to correct the deviation and at the end of every grouting holes, the deviation rate is less than 0.6%. The deviation rate of the six grouting holes are showed in Table 3.

Table 3: The deviation rate of the six grouting holes

Shaft	Fixed pipe section (%)		Grouting section (the end of boreholes) (%)	
	Designed	Real	Designed	Real
Main shaft	0.3	0.13~0.28	0.6	0.31~0.50
Auxiliary shaft	0.3	0.06~0.22	0.6	0.28~0.46

GROUTING MATERIAL

The main grouting material is clay-cement which has advantage of good ability of pumping, good solid stability, high plastic strength, low bleeding rate, non-separation property in water, good grouting property and high water-proof efficiency. Clay was collected from the Mine Industry Square of the Mine, using the clay mixer machines to make clay slurry.

The mixture ratio of grout is : clay slurry: 75%~90%; cement: 10%~20%; additive: 0%~5%.

The slurry properties of clay-cement material is :

specific gravity: clay slurry: 1.18~1.28

clay-cement slurry: 1.25~1.35

relative viscosity: clay slurry >16s

clay-cement slurry: 16s-drip

plastic strength: $P_m = K \frac{G}{h^2}$

where k-instrument coefficient;
G-weight of test conical in g;
h-depth of conical sinking into test body in cm;
P_m-plastic strenght in kPa;

In some grouting stages, using fly-ash instead of part of cement, and this reduced the cost of grouting material about 20%. It was proved very efficient after the shaft was completely constructed.

The plastic strength of clay-fly-ash-cement is shown in table 4.

Table 4 : The plastic strength of clay-fly-ash-cement

Specific gravity (g/cm³)	Content of fly-ash-cement (g/l)	Additive (%)	Plastic strength (x10²Pa)							
			4h	5h	8h	10h	12h	24h	48h	72h
1.15	200	2.5	19.6	23.8	47.6	68.7	73.8	117.4	164.0	245.0
1.18	200	2.5	20.5	37.5	61.2	77.5	88.2	164.0	245.0	551.0
1.21	200	2.5	68.6	77.5	88.2	137.8	164.0	352.0	793.7	2204.0
1.24	200	2.5	137.0	164.0	245.0	310.0	470.0	551.0	3175.0	3175.0
1.26	200	2.5	146.3	174.0	268.0	310.0	510.0	680.5	4961.0	4961.0

GROUTING QUALITY CHECKING

There are two methods to check the grouting quality : pump and pump-in test. We usually use the pump test within the depth of 600m, pump is effective and beyond the depth of 600m, pump-in is convenient. In Xuandong No.2 Mine grouting project we only used the pump-in method. Every grouting stage had the pump-in test before first grouting. Water absorption rate is calculated to determine the connection state of cracks and assesses grouting effects. The absorption rate of first group holes is not the same as the second group, there is a reducing tendency between them. We set up a criterion to check the grouting quality by absorbing rate in pump-in test, the criterion was coming from a lot of data in grouting practice. The equation of water absorption rate is as follows :

$$\omega = \frac{Q}{P.L}$$

where ω-water absorption rate of pressurized water in 1/min.m.m;
Q-pressurized water inflow in l/min;
P-upper level static pressure of pressurized section in m;
L-length of compression strata in m;

If we found the absorption rate didn't match the criterion, we would pay attention of this part and until it came up to the standard.

The predicted water inflow of shafts after grouting is calculated from the absorption rate of the final No. 6 grouting hole.

$$K=0.527\,\omega \log a.L / r$$

$$Q=1.366K(2H-M)M/\log(R+r_{\#})/r_{\#}$$

$$R=10s\sqrt{K}$$

Where k-coefficient permeability in m/d;
L-length of compression strata in m;
a-Length coefficient;
Q-predicted water inflow of shaft in m^3/d;
R-influencing radius of water pressure in m;
M-the thickness of water-bearing strata in m;
H-lower level static water pressure in m;
$r_{\#}$-the radius of shaft in m;
r-the radius of grouting hole in m.

The result of predicted water inflow of shafts tallies with the actual water inflow , see table 5.

Table 5: The result of predicted water inflow of shafts and the real water inflow

Shaft	Predicted water inflow (m^3/h)	Real water inflow (m^3/h)
Main shaft	0.98	0.86
Auxiliary shaft	1.13	0.93

CONCLUSION

1. Water flow logging technique makes the grouting design more reasonable and more efficient.
2. Applying the fly-ash instead of some cement is successful. It has the big signification for the fly-ash applying in a big scale in grouting project.
3. Applying pump-in test to check the grouting quality is convenient, low cost and reliable.

Reference

Qiang WU and Jun ZHENG, "Variations of flow logging curve responding to the ones of well diameter
and the method to process", Hydrogeology and Engineering geology,Vol.22,No.2, March 1995,pp17~20.

Jun ZHENG ,"The relations between absorption rate and the quality of grouting",Mine Construction
Technology,Vol.78,No.4, Aug.1996,pp20~23.

Jun ZHENG, "The application of flow logging in ground advanced grouting",Coal Science and
Technology,Vol.24,No.9, Oct.1996, pp12~14.