MINING WATERS TREATMENT AT PIN LIN PROJECT IN TAIWAN

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ABSTRACT

The paper deals a complex approach to the solution of the present-day problems of underground waters treatment by application of Bentonite-based grouting technology during shaftsinking and tunneling at Pin Lin Project in Taiwan. Original methods for providing reliable watersealing of fractured rock and consolidation grouting of fault zones from the ground surface and from tunnels are presented. These methods ensure efficiency of safe and fast shaft sinking and tunneling. Case histories of preliminary mining waters treatment are presented.

Key words: shafts, tunnels, waterbearing fault zones, ground treatment

INTRODUCTION

The Taipei – Ilan Expressway in Taiwan is about 31km in length, including 65% of tunnels works (5tunnels). The Pin Lin Tunnel with length 12.9 km is the critical path engineering project controlling the date of completion of the Taipei – Ilan Expressway construction project.

Pin Lin Tunnel are includes two main tunnels, pilot tunnel and three twin-ventilation shafts. When the main tunnel is bored using a tunnel boring machine, the outside diameter of the round each cross section is 11.8m. The pilot tunnel located between and runs parallel to the main tunnel throughout its length, 4.8m in diameter. Provided for purporses of geological exploration, pretreatment for adverse ground conditions, and for use as an auxiliary tunnel during and after construction of the main tunnel.

Ventilation shafts. Two vertical shafts each at strategic locations for fresh air and exhaust respectively. Shafts are set 50m apart. The depth of shafts N1 is 513m.The depth of shaft No3 is 438m respectively.

Pin Lin Tunnel comes through the Rock formations on the Northern dip of Central Range of Taiwan in active seismic zone. The tectonic and hydrologic conditions along alignment of the tunnel and shafts are very complicated.

For watersealing and consolidation grouting in complicated hydrological and seismic conditions of Pin Lin tunnel the conventional cement and chemical grouting was accepted. As result during excavation of pilot and main tunnels there were collapsed and during sinking of shaft N3 sudden inrushes of water inflow into the face of shaft.

For providing safe and fast shaftsinking and tunnel excavation through waterbearing fractured and fault zones authors proposed to use Bentonite-based grouting technology at Pin Lin Project.

Below are presented methodology and some results of application Bentonite-based grouting technology at Pin lin Project.

METHODOLOGY

Bentonite-based grouting technology facilitates new and improved shaft and tunnel construction and operation especially with respect to the following:

- preliminary water sealing operations around shaft performed through directional grouting holes drilled from the ground surface;
- preliminary water suppression operation implemented from the face of tunnel or side niches during driving tunnels;
- significant increases in the rate of shaftsinking and driving underground workings;
- better estimation of deadlines and schedules and of construction costs;
- minimization of power consumption and labor use in grouting operations;
- minimization or elimination the rate of production of shaft or tunnel drainage.

The key elements in the Bentonite-based grouting technology revolve around new grouting philosophy and approach, on integrated design procedure and new bentonite-based grout compositions. The general principals of the Bentonite-based grouting technology is the following:

1. the technology is based on scientifically-founded theory and calculations throughout the entire grouting process including:

a. the rheology of the bentonite-based grout:
b. the geometry of the isolation curtain around the shaft or tunnel;
c. taking into account anisotropy of permeability;
d. specification of the number and design of injection boreholes;
e. the injection pressure modes;
f. the evaluation of the effectiveness of the completed grout curtains.

2. Quantitative information is obtained on the character of the fracturing and on the transmissive properties of the rock. These hydrodynamic characteristics are obtained from direct measurements and hydrogeologic investigations in the first exploratory-grouting borehole.

To implement the technique of hydrodynamic testing should be by STG's flowmeters which are acknowledged to be the best instruments of this type and which allow to determine:

- the number of water-bearing zones;
- thickness of each water-bearing strata;
- depth of occurrence of each water-producing horizon;
- type of an aquifer;
- size and degree of blockage of fissures and joints;
- voidage of water-bearing zones;
- permeability;
- hydrostatic pressure.

3. the grouting is implemented with calculated volume of highly effective, visco-plastic bentonite-based grout. Currently the bentonite-based grout composition runs approximately 85 - 90 percent bentonite slurry, 10 -14 percent cement and 1 percent additives. The bentonite-based grout formulation and its application are customized for each project and the entire process is integrated, based on the nature of the problem, the objective of the application, and the detailed site specific information on geology, geochemistry and hydrogeology of the host ground.
Important feature is that bentonite-based grout remains plastic and unpermeable throughout its history.

4. The production layouts for implementing ground treatment operations stipulate the use modern grouting equipment and instruments.

5. Deep directional grouting holes with final diameter 76mm to use for preliminary watersealing of waterbearing rock around future shaft.

6. Long horizontal boreholes with final diameter 76mm-59mm to use for preliminary ground treatment of saturated rock around tunnel.

7. the results of watersealing are evaluated objectively prior to the beginning of shaftsinking or underground excavation operations using special quality control methods.

DISCUSSION OF RESULTS

1.First application of the Bentonite-Based Grouting Technology in Taiwan had been realized in 1997 for watersealing of 150 liters per second inflow from the face of Pin Lin Pilot Tunnel. In the February 1996 the face of Pin Lin Pilot Tunnel had passed the fragmental zone consists from large quantity of waterbearing faults. As a result the geologic fault with 150 liters per second water inflow have trapped Robbins TBM inside Station 39k+079 of Pilot Tunnel. For one year several worldwide famous contractors from different countries tryed to suppress the water inflow from Pilot Tunnel. They used cement and chemical grouting, but failed to reduce such water inflow. In 1997 the Client of Pin Lin Tunnel accepted the application of Bentonite-based grouting work plan proposed by authors for water sealing of inflows from mentioned above fault zone in Pin Lin Pilot Tunnel. Bentonite-based grouting work proposal planned to eliminate water inflow in Pilot Tunnel from geological fault in 3 Stages.
First Stage it is elimination of 40-50 l/sec water inflow from By- Pass C through two grouting holes with length 30 and 50 meters respectively and diameter76mm.

Second Stage it is elimination of 15-20 l/sec water inflow around cutter head of TBM Robbins through one grouting hole with length 20 meters.
Third Stage it is elimination of 50-60 l/sec water inflow from By-Pass A through two grouting holes with length 25 meters each.
The calculated volume of bentonite-based grout for First and Second Stages was 600 cubic meters. Actually, 592 cubic meters of bentonite-based grout was pumped into above enumerated three boreholes. The practical result of implementation of First and Second Stages are summarized in Table1.

Table1. Details of the First and Second Stages of Bentonite-Cement Grouting at Station 39k+079 of Pin Lin Pilot tunnel

Stage number	Number of grout holes	Grout hole length (meters)	Angle (degrees)	Azimuth (degrees)	Standpipe length (meters)	Grout volume (cubic meters)	Final Injection pressure (bars)
1-st	1	50	+10	-75	4.5	121	40-50
	2	30	+20	-55	4.5	276	50-60
2-nd	3	18	+5	-25	9	225	60-70
Total		98				592	

After injection of calculated volume of bentonite-cement grout in holes from 1 through 3 water inflows from By-Pass C and above of TBM cutter head decreased to zero and from BY-Pass A reduced to 40 liters per second. Third stage of watersealing not realized. It was done to provide water depression of the site of excavation of West Bound Tunnel.

All above enumerated drilling and grouting work at this zone of Pilot Tunnel were performed by RET-SER Engineering Agency in accordance with authors calculations.
After the detour tunnel was driven through the grouted zone, large fractures filled with bentonite-based grout were penetrated, measured, and sampled. The was no residual inflow of groundwater into Detour Tunnel after driving through the grouted by Bentonite-Based grouting technology zone.

2. Shaftsinking of Pin Lin Intake Shaft No3 began in 1996. For watersealing in complicated hydrogeological and seismic conditions the conventional cement and sodium silicate grout was accepted. As a result during sinking of Intake Shaft No3 to depth 157 meters after cement grouting was several sudden inrushes of high pressure underground water inflows from the face of this shaft.

For providing safe and fast sinking of Intake Shaft No3 to final depth 438 meters authors proposed to carry out preliminary ground treatment of all waterbearing stratums in interval 157m – 438m trough 4 grouting holes with depth 281 meters each drilled from the ground surface using bentonite-based grout instead of cement and sodium silicate grout.

In order to realize this proposal in interval from ± 0 to 157m (face) of Intake Shaft No3 installed and fixed 4 guide pipes with outside diameter 114mm each for providing drilling of 4grouting holes in interval 157m – 438m. The pregrouting of the Intake Shaft No3 will be performed in 17 target zones as presented in Table 2.

According with above presented work plan pregrouting of waterbearing stratums from 157m to 438m of Pin Lin Intake Shaft No3 should be executed during 10 months , including time for mobilization of drilling and grouting equipment on jobsite of this shaft. All drilling and grouting work at Pin Lin Intake Shaft No3 will carry out Ukrainian Spetstamponazhgeologia Agency (STG) and Taiwanian Company Diffisoil Geotechnical Engineering Inc. (DGE).

Table2. Work Plan for Pregrouting of Waterbearing Stratums from 157m to 438m of Pin Lin Intake Shaft No3 through grouting holes drilled from the ground surface.

No	Waterbearing stratums or grouting intervals, m	Calculated dimension of grouting curtain around shaft, m	Quantity of grouting holes	Quantity of checking holes	Total depth of drilling, m	Volume of grout injected trough each hole, m^3	Total volume of grout, m^3	Final injection pressure, bar
1	157-172	8	3	1	60	45	180	55
2	172-199	9	3	1	108	100	400	60
3	200-215	10	3	1	60	70	280	65
4	215-238	11	3	1	92	80	320	70
5	238-254	12	3	1	64	70	280	75
6	254-272	13	3	1	72	75	300	80
7	272-286	14	3	1	56	65	260	85
8	286-289	15	3	1	52	65	260	90
9	289-316	16	3	1	68	65	260	95
10	316-332	17	3	1	64	65	260	100
11	332-348	18	3	1	64	65	260	105
12	348-363	19	3	1	60	70	280	110
13	363-378	20	3	1	60	70	280	115
14	378-395	21	3	1	68	75	300	120
15	395-406	22	3	1	44	70	280	125
16	406-417	23	3	1	44	75	300	130
17	417-438	23	3	1	84	125	500	140
Total					1120		5000	

Later DGE and STG will carry out preliminary ground treatment at Pin Lin Exhaust Shaft No1 and Intake Shaft No1 with depth 513m through directional grouting holes drilled from the ground surface.

CONCLUSION

It is necessary to admit that while developing the Pin Lin Project design, plans and specifications not all the geological and seismic terms were taking into account. As a result the application of conventional cement and chemical grouting did not provide the planning rate of excavation of Pin Lin Pilot Tunnel and his Shaft No3.

From the other side successful experience of application Bentonite-based grouting technology for treatment of fault zone in Pin Lin Pilot Tunnel proved that for reliable watersealing of fractured, fragmental and fault zones it is more effective for Pin Lin Project to us Bentonite-based grouting technology.

In Pilot Tunnel zone of bentonite-based watersealing RET-SER Engineering Agency excavated detour tunnel behind the site where have trapped TBM. After avoiding difficult fragmental section, the detoured tunnel will be merged back to the original Pilot Tunnel. Water inflow in bentonite-based grouted zone during excavation of detour tunnel was absent. All fractures with aperture from 0.2mm to 5-10cm with bentonite-cement grout was sealed.

BIBLIOGRAPHIC REFERENCE

1. Kipko E.J., Spychak Y.N. (1998). Water sealing of fault zones at Pin Lin Pilot tunnels in Taiwan. IMWA Symposium, Johannersburg, pp, 141-148
2. Tseng D.J. (1999) A Case Study on Treatment against High – pressure Groundwater Ingression of a Rock Tunnel Construcsion. Chinese Taipei Tunneling Association, Taipei, pp. 11-19.