International Journal of Mine Water, Vol. 3 (4), (1984) 55-62
Printed in Madrid, Spain

EXPERIENCE IN SEALING WATER BEARING STRATA DURING DEEP SHAFT SINKING

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ABSTRACT

The paper deals with major concepts of grouting through holes drilled from the surface. The results of grouting through a single borehole at the location of two 1090 m deep shafts in Donbass are presented.

INTRODUCTION

Leading companies in Great Britain, USA, South Africa, Germany and elsewhere specializing in the field of mine construction under severe geological conditions widely employ the use of grouting techniques. In most cases grouting is executed from the face of the workings by means of sophisticated and, in our opinion, expensive grouts.

From technical discussions with the specialists of a number of companies it may be stated that the use of pre-grouting through holes drilled from the surface is limited due to the clients' caution in defining the extent and costs of operations. This fact, to some extent, may be associated with the lack of reliable, sustantiated grouting design methods, quality control techniques and cheap grouts providing guaranteed sealing of water bearing rocks in a fixed time and at optimum cost.

In the practice of USSR mine construction preference is primarily given to grouting from the surface as the use of conventional cementation techniques from the face of workings has been acknowledged as inefficient due to the following reasons :

- cutting operations are delayed for long periods due to grouting and advance rates are sharply reduced;

- operations are carried out with low-production equipment in constrained conditions and the skilled labour of shaft sinkers is required;
- a large amount of manual labour is needed;
- operations are characterized by increased danger for workers during pressure injection.

Pregrouting of vertical shafts and other mine workings according to the Integrated Method used in the USSR makes it possible :

- to execute hydrosealing of the shaft during the equipping period and prior to the commencement of sinking;
- to guarantee a reduction of water inflow within prescribed regulations;
- to provide conditions for high-speed shaft sinking;
- to eliminate laborious task of hydrosealing from the face of the workings;
- to carry out hydrosealing operations using high-production grouting equipment on the surface.

This hydrosealing technique adopts a composite solution to scientific problems in the field of hydrodynamics, hydraulics and rheology of grouts, rock mechanics, design and technological developments.

The paper deals with the experience and results obtained during grouting at two 1090 m shafts of the Zasyadko Mine in Donbass.

Grouting operations at each shaft were executed to the full depth through a single hole.

GENERAL SITE CHARACTERISTIC

The projected depths of the ventilating and downcast shafts of the Zasyadko Mine are 1090 and 1080 m respectively with an excavated diameter of 6.7 m and concrete shaft lining.

The shafts were sunk into the Middle Coal Measures C_2^6 and C_2^7 and Upper Coal Measures C_3^1. These sediments consist of sandstones, siltstones, mudstones, coal layers and limestones.

The coalfield lies in a southern part of the Kalmius-Toretsk syncline on the elevated wing of the Frantsuzki overthrust fault. The coalfield is intersected by the Semenovski and Sophievski faults which lie 1 km of the shaft site.

At a depth of 168 m the shafts encounter abandoned excavations driven through a worked-out 1.2 m coal seam. The hydrogeological conditions of the site are complex. Water bearing rocks of the Coal Measures consist of fissured sandstones, sandy shales and limestones (Fig.1). Some aquifers are up to 60 and 77 m thick. The total thickness of water

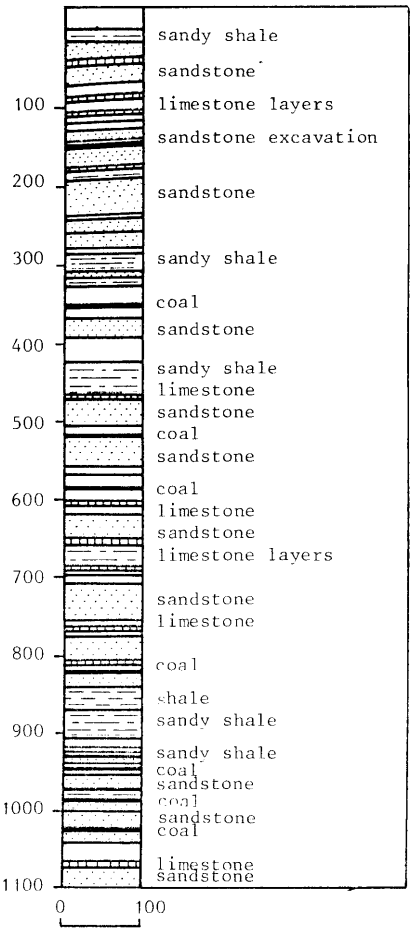

Figure 1. Geological section

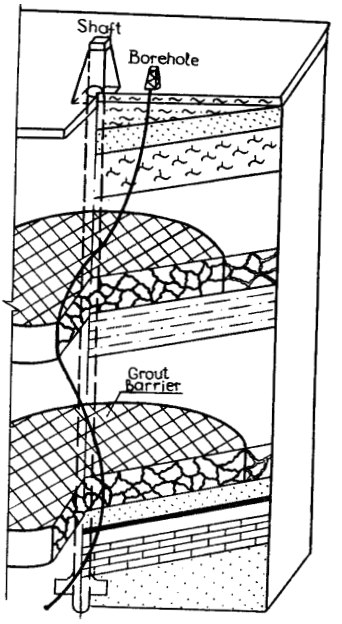

Figure 2. Grout hole directional drilling scheme

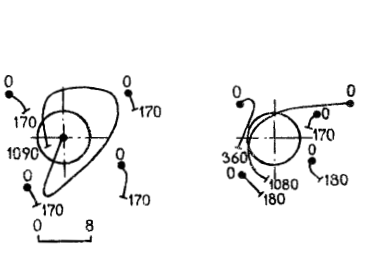

Figure 3. Layout of boreholes
a. Ventilating shaft, b. Downcast shaft

bearing strata in the shaft sections equals to 403.9 and 463.0 m. The predicted water inflows from individual aquifers are up to 17-18 m^3/hr. The total predicted water inflows in the ventilating and downcast shafts are 225.6 and 188 m^3/hr respectively.

GENERAL APPROACH

Taking into account the sinking conditions of the ventilating and downcast shafts a project was developed at the Spetstamponazhgeologia and pre-grouting was accomplished from the surface to the total depth of the shafts using a single grout hole drilled in the vicinity of the proposed shafts for the depth between 168 m and 1090 m (Fig.2).

Multi-purpose grouts (in a broad range of hydrochemistry) giving high penetrability, reliable sealing properties and long-term stability against corrosion were used for hydrosealing. These grouts consist of 89% clay slurry with a density of 1200-1230 kf/m^3, 10% cement and 1% structure-forming additives.

Taking into account the presence of abandoned workings in the upper part of shafts at a depth of 168 m which considerably complicate sinking and contributes to increased fissuring in the roof of a worked-out zone, the length from 19.7-170 m was hydrosealed using four holes spaced 10 m from the centre of the would-be shaft.

A hydrodynamic investigation programme has been carried out to provide more accurate information on hydrodynamic characteristics of aquifers employing flowmetering and pressure build-up techniques.

This investigation programme makes it possible :

- to determine the number of aquifers, their bedding depth and thickness;
- to estimate the pressure head in each aquifer, permeability, void ratio, the type of aquifer and degree of fissuring.

The instruments and tools, used during hydrodynamic investigations, were required to be of simple design and capable of operating in any liquid within a broad range of pressure and temperature parameters. They are also intended to be used for investigation techniques under any geological conditions, and ensure high reliability and long-term operation.

EXECUTION OF WORK

The main grout hole 1090 m deep at each shaft site was executed by means of turbo-drilling techniques with the minimum designed deviations from a shaft projection so that its course would travel spirally around a shaft at a distance of 3-4 m. This was accomplished by employing special technical means for directional drilling (Fig.3).

Because the strata had insufficient strength and stability to provide the necessary condition for reliable plugging the holes with packers, the main borehole was cased with 219 mm casing. The grouting of separate aquifers was carried out with jet perforation in the range of each aquifer.

The calculated volume of grout was then injected into each perforated zone. The results of perforation were estimated by repeatedly carrying out flowmetering investigations.

Major grouting parameters at the ventilating and downcast mine shafts are listed in Tables 1 and 2.

Preparation of the basic slurry was carried out employing a special set of prefabricated units. The clay-cement grout preparation and injection was accomplished by the 2SMN-20 cement-mixing units and CA-320M high-pressure pump units which provided a long, continuous injection process.

Quality control of hydrosealing was evaluated taking into account injection regimes and by pressurizing the grout barrier up to the calculated value. For this purpose the SKC-2M control station was employed which provides an automatic monitoring with a printout of the parameters characterizing the grout quality, pressure, flow rate and grout injection volume.

RESULTS

Compared to the designed grout volume of 16020 cu. m., the actual volume of injected grout was 15915 cu. m. for the ventilating shaft and 14500 cu. m. for the downcast shaft. On completion of grouting, the shafts were sunk at a steady rate of 60-100 m per month. The residual water inflow in the ventilating shaft was 3.5 m^3/hr of which 2 m^3/hr came from the 0-19.7 m length that had not been treated due to the vicinity of the earth's surface. The residual inflow in the downcast shaft was 1.3 m^3/hr.

Table 1. Parameters of grouting programme at the ventilating shaft of the Zasyadko Mine

Water bearing zones, m	Strata thickness, m	Pressure head Pa x 10^5	Water inflow prior to grouting, m^3/h	Number of injection points	Volume of grout, m^3
19- 25	4.0	0.70	14.8	4	202
25- 45	13 0	2.57	3.2	4	426
45- 86	23.0	6.60	14.7	4	1615
86- 122	20.0	8.53	16.4	4	1821
130- 145	14.0	11.38	4.7	4	1039
164- 234	26.4	13.93	18.0	1	960
240- 283	22.0	21.90	9.0	1	400
291- 322	17.8	25.36	7.0	1	130
345- 397	24.6	33.10	11.0	1	615
423- 509	28.9	44.47	4.0	1	637
531- 550	28.9	49.75	15.0	1	982
650- 676	23.4	60.38	17.0	1	260
679- 697	17.5	63.31	6.0	1	320
708- 757	20.7	68.28	11.7	1	643
764- 766	2.4	70.15	4.0	1	50
781- 834	44.0	76.96	9.0	1	400
878- 905	16.0	84.20	14.0	1	540
925- 968	14.4	90.36	10.0	1	521
981- 998	8.8	92.43	14.1	1	100
1000-1036	12.2	96.20	16.0	1	322
1068-1089	21.9	102.50	6.0	1	400
Total :	403.9		225.6		15915

Table 2. Parameters of grouting programme at the downcast shaft of the Zasyadko Mine

Water bearing zones, m	Strata thickness, m	Pressure head Pa x 10^5	Water inflow prior to grouting, m^3/h	Number of injection points	Volume of grout, m^3
10- 52	26.0	4.0	10	4	1915
57- 82	8.0	6.0	9	4	1616
140- 168	23.0	11.2	3	4	1726
174- 210	2.0	14.0	1	2	354
237- 269	24.0	21.2	4	2	595
273- 315	11.0	29.5	7	2	619
328- 362	27.0	30.3	5	2	886
394- 422	19.0	36.8	6	1	200
435- 463	14.0	40.5	3	1	317
472- 492	10.0	42.0	9	1	250
500- 522	16.0	46.0	7	1	385
530- 570	14.0	51.3	7	1	475
577- 623	5.0	56.0	2	1	243
634- 655	31.0	60.5	10	1	448
678- 713	24.0	65.2	17	1	751
715- 740	14.0	68.0	10	1	357
748- 774	26.0	71.5	6	1	520
775- 813	21.0	75.3	4	1	394
840- 858	18.0	80.2	9	1	405
867- 890	18.0	89.0	12	1	246
894- 924	15.0	86.0	11	1	223
925- 955	26.0	89.5	11	1	267
954- 998	43.0	94.0	13	1	595
1031-1094	28.0	102.0	12	1	716
Total :	463.0		188		14500