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GROUTING OF LARGE KARSTIC CAVERNS IN DOBROGEA COALFIELD, BULGARIA

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ABSTRACT

The paper describes the results of an experimental grouting programme carried out by the Spetstamponazhgeologia association at the Dobrogea coalfield in Bulgaria. The anticipated water inflow into a shaft at this deposit totals 8 m^3/s at a pressure of 12 MPa, from a cavity size equal or exceeding 3 metres. Grouting operations made it possible to cut down water inflow by a factor of more than one thousand. The success of this investigation has enabled the author to design an experimental shaft sinking project through the valange formation at Dobrogea mine.

INTRODUCTION

The Dobrogea coalfield in Bulgaria is characterized by extremely severe hydrogeological conditions caused by heavy karstification, large strata thickness and bedding depth of water bearing horizons, also by considerable water inflows. The most serious complication is associated with the Valange formation that stratifies in the range of 650 to 1350 metres and is represented by a thick layer of heavily karstified limestones and dolomites with cavity size often exceeding 3 metres. The total anticipated water inflow into a shaft from this formation was about 8 m^3/s at a strata pressure of 12 MPa and a flow rate of subsurface water of 5×10^{-3} m/s. Worldwide mine construction experience has no previous examples of shaft sinking under such water abundance.

In order to solve water inflow problems, a contract was signed in accordance with which the spetstamponazhgeologia association executed hydrodynamical investigations, supplied necessary instrumentations and provided technical assistance for controlling ground water inflows. On the basis of the data obtained an experimental grouting project was devised and implemented for the Valange formation. The main objectives of the experimental grouting were as follows :-

- Determine the possibility of sealing protective barriers within most appropriate geological formations
- Verify by large scale field experimentation the validity of design assumptions and grouting scheme for karstified formation; and
- Prove by field trials the quality of the grout and the methods of evaluating the effectiveness of the grouting.

To secure quality and reliability of the investigation programme was the prime objective taking into account that efficient design and carrying out of grouting, under such severe conditions, are only possible having reliable and exhaustive hydrogeological information.

For attaining the planned task a new technological scheme of hydrodynamic investigations was used employing the DAU-1 packers and DAU-3M flowmeters. The tests were carried out at intervals during the course of drilling approximately in 50 metres (Fig.1). Each interval was tested under several drawdown rates while pumping and injecting.

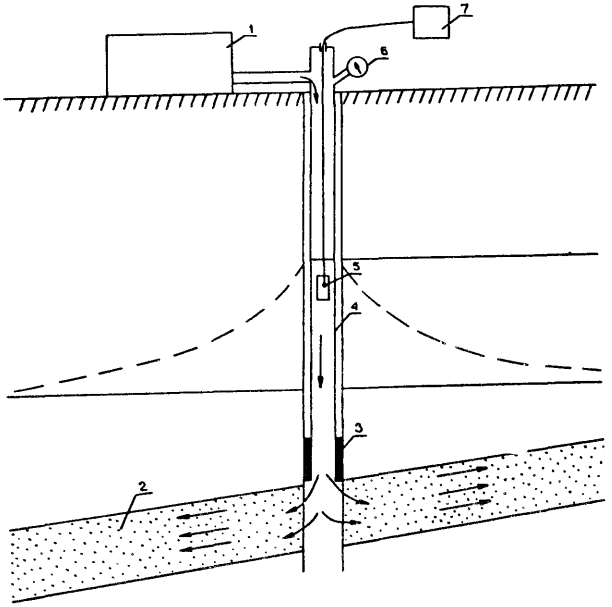

Figure 1. Technological scheme of hydrodynamic investigations with a packer
1. Pump, 2. Aquifer, 3. Packer, 4. Boring tubes,
5. Electrical level meter, 6. Pressure gauge,
7. Readout unit.

Due to the usage of the special investigation methods, it became possible, for the first time in the Dobrogea coalfield, to test water bearing strata in intervals without borehole casing and to obtain comprehensive hydrogeological information: subsurface water pressure head, filtration and permeability factors, karstic voidage, location, number, spacing and size of karstic voids, and also fissures and voids ratio in the total formation voidage.

Results of the study on filtration parameters and karstification character are listed in Table 1.

Table 1

Interval, m	Permeability, 10^{-12}, m^2	Strata pressure, MPa	Predicted in-flow m^3/s	Total voidage, %	Maximum karst size, m
689 - 733	0.042	6.12	0.0069	13.7	0.040
733 - 783	2.880	6.60	0.6583	6.3	1.200
789 - 833	4.820	7.12	0.9528	21.7	1.400
840 - 883	5.180	7.62	1.0278	26.1	0.550
884 - 933	6.380	8.13	1.6889	16.4	2.700
933 - 983	4.400	8.63	1.2278	8.4	0.550
983 - 1033	0.498	9.13	0.1972	6.9	0.200
1033 - 1083	1.360	9.63	0.4083	12.2	0.200
1083 - 1133	2.950	10.13	0.7889	13.8	0.830
1133 - 1183	0.299	10.62	0.0861	13.4	0.360
1183 - 1233	0.082	11.12	0.0194	12.7	0.070
1233 - 1283	0.014	11.61	0.0056	7.3	0.008
1283 - 1335	0.010	12.05	0.0042	2.0	0.004

INJECTION TECHNOLOGY

The main difficulty in sealing large voids consists in the necessity to provide an identical grouting process both for large water-transmissive channels and for smaller fissures and voids. In relatively small channels the grout movement must have the character of a continuous flow whereas for large karstic voids, the process of grouting must have a more constructive character (analogous to 'laying the voids' technique) that could facilitate eliminating the unproductive spreading of the grout. Consequently, for sealing water-transmissive channels of various sizes, one must have such a grout as would incorporate two phases as minimum. Each phase is characterized by intensively diverse rheological and structural-mechanical parameters.

Theoretical and experimental studies resulted in the development of a special technique which allows, (depending on the technological parameters) the provision of either a structural regime of the flow of the viscous-plastic grout maintaining the unbroken nucleus of the flow, or a regime when no structure formation takes place and no maintaining of the unbroken nucleus of the flow occurs.

Thus, the same grout is used for injection. However, it penetrates first the water bearing strata having high strength properties and fills large caverns and voids, and then, it attains lower strength properties for grouting small fissures.

Thanks to the particular features of the developed technique, the grout penetrates both large and small water permeable fissures and karstic voids reliably sealing them.

GROUTS

A special grout formulation developed at the Spetstamponazhgeologia association in regard to the conditions of the Dobrogea deposit, was used for treating the Valange formation. The basic components of the grout are clay slurry and structure-forming additives. The usage of clay from local deposits is foreseen for the grout preparation. These grouts are characterized by high penetrability, are not washed out by subsurface water, do not produce sediment and remain pumpable while flowing through the pipes and fissures, but gain strength rapidly when at rest. Blasting operations in sinking or driving only make them more compact. The above positive properties ensure reliability of the sealing barriers during the total mine production period.

MAJOR RESULTS OF GROUTING

For execution of grouting the permeable strata intervals in the range of 886 to 903 metres and 903 to 923 metres were selected. The total predicted inflow from these intervals was 1.7 m^3/s, and the size of caverns amounted to 2.7 metres. The major data of the executed grouting operations are listed in Table 2.

Table 2

Parameters	Unit	Injection 886-903	Zones, m 903-923
Predicted water inflow	m^3/s	0.2	1.5
Total voidage	%	16.4	16.4
Strata pressure	MPa	7.63	7.80
Maximum karst size	m	0.2	2.7
Packer depth	m	886	903
Total grout volume	m^3	7827	14133
Initial injection pressure	MPa	0 4	0 4
Final injection pressure	MPa	17 19	16 22
Residual water inflow	m^3/s	0.00014	0.00019

As it may be seen in Table 2, the inflow from the Valange formation has been reduced after grouting more than one thousand times.

On the basis of the results obtained the Spetstamponazhgeologia association has developed a project of pregrouting the Valange formation while sinking exploratory-experimental shafts of the Dobrogea Mine. The project foresees drilling seven grout holes 1350 m deep at each shaft site. The holes are spaced at a distance of 6-12 m from the center of a shaft and their allowable deviation, up to the project, must not exceed 3 m in the bottom. The project

guarantees water inflow reduction into a future shaft of not less than one thousand times. Accomplishing grouting programmes on each shaft site would take about 3.5 years.

Thus, the Integrated Grouting Method developed at the Spetstamponazh-geologia association ensures high efficiency and reliability also in extreme, severe conditions of sinking.