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GROUNDWATER CONTROL IN A SHAFT BORING OPERATION

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ABSTRACT

Application of sinking machines during construction of mine shafts is an innovative technology that allows to increase the average sinking rates by 2-3 times and combine all major labour-consuming operations entailed in rock blasting, mucking and shaft lining into a continuum shaft boring operation. Whilst analysing the experience gained in this method, one has to indicate that the increase in water inflow in the shaft sum up to 30-50 m^3 and results in sharp decrease of productivity of sinking. One of the technical solutions that tackles this problem is to apply effective techniques of ground water control. The paper deals with various aspects of grout treatment method practised during shaft sinking in Donets Coal Basin, Ukraine and presents a case history.

INTRODUCTION

Construction of mine shafts in the Donets Coal Basin, Ukraine is associated, in terms of hydrogeological environment, with carboniferous strata that contain subvertical zones of extensive rock fracturing and breakage. Intersection of such local zones is accompanied by high water inflows into mine excavations which slow down development rates and require the application of specialist methods of inflow prevention.

Grouting of local fracture zones exposed by a shaft excavation under high hydrostatic pressure head and flow rates entail the formation of thick grout curtains. The conventional approach of cover drilling has many inadequacies, these include unpredictability, loss of development production time, but most importantly the shallow depth of grout injection holes precludes the use of high pressure and, as a result often only achieves a redistribution of water zones.

The inflow prevention in such environment becomes low-effective since the process of grout treatment transmutes to partial filling of water-bearing fractures and flow paths located around a mine shaft (Zabora, 1988).

These problems may be avoided if the pattem and depth of grout holes is designed taking account the stress concentration radii around the mine shaft and the rheological and mechanical parameters of the injected grout. The water-bearing zones detected during shaft sinking are intersected by inclined long boreholes drilled from the upper deck of sinking stage or shaft sinking machine. They are designed to expose the problematic zone at the designed distance from a shaft excavation. Drilling and injection sequence is decided on the basis of the uniformity or otherwise of the fracture porosity and permeability. The volumes of grout must be sufficient to both create the curtain thickness determined to be necessary and to achieve interlocking between the grout placed from each hole. The latter is a function not only of the formation parameters but also of the rheological properties of the grout and the pressures which can be applied without causing disintegration of permanent lining or undesired hydrofracturing of the rock mass.

On the completion of drilling hydraulic testing of the boreholes is conducted to assess the boundaries and thickness of water-bearing zones, fracture apertures and rock permeability parameters. Grouting is carried out applying stabilised clay grouts. The stabilised clay grouts consist of finely dispersive heterogenous systems that include clay minerals, binding agents, structure forming reagents and a mixing liquid. An important advantage of these mixes is the low content of binding agents which usually does not exceed 10-15%, and their neutrality to the geologic environment.

CASE HISTORY

The ventilating shaft of Kholodnaya Balka coal mine, in Ukraine, was sunk by the SKIV shaft sinking machine. The final depth of the shaft is 830m with finished diameter of 7m. The shaft lining is 400mm thick unreinforced concrete.

Three major water-bearing layers were traversed in the course of sinking which were associated with subvertical zones of extensive fracturing. The aperture of water-bearing fissures varied between 1-2 cm and the total inflow amounted to 48 m^3/h when the shaft reached 378m depth. This necessitated the plant stoppage to carry out a program on eliminating the ground water seepage.

The program design comprised five rounds of 105 mm diameter holes which were drilled from the upper deck of the shaft sinking flatform. The water bearing zones were designed to be intersected at a distance R of 11-12 m from the shaft lining. This was dictated by the spacing patterns of ground water flow paths, configuration of future grout covers, grout injection regimes and lining material strength.

During drilling of grout injection holes, water was inter-encountered in all boreholes and flowmeter tests were conducted on the completion of boreholes. Grout injectlon was performed through downhole packers set in proximity to the upper boundary of a water-bearing section. Details of the grouting program are given in Table 1.

The shaft section in the interval of 274-308 m traversed the water-bearing zone of large thickness encountered in sandstone. Grout treatment was performed in two stages (Fig 1).

Table 1. Grouting program for ventilating shaft in Kholodnaya Balka Mine, Donets Coal Basin, Ukraine.

Treated Shaft Section, m	Original Inflow, (m^3/h)	Number of Grouting Holes	Hole Depth, (m)	Quantity of Grouting inj. (m^3)	Residual Seepage after Treatment (m^3/h)
127-130	16	4	25-30	60	3.2
274-308	18	4	19-35	268	2.0
343-380	13	4	18-53	356	1.0

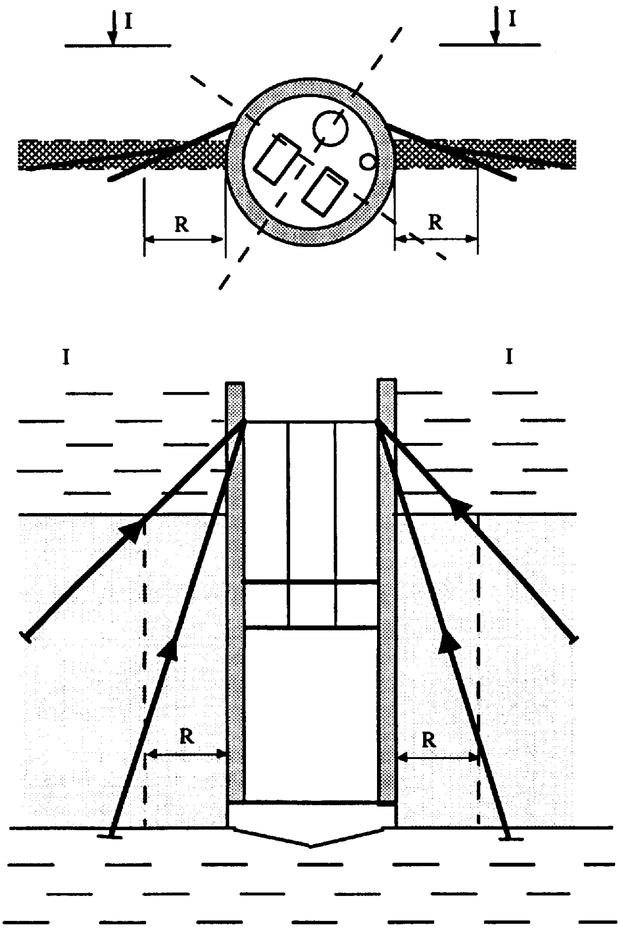

Figure 1. Process pattern for residual seepage control within 274 - 308 m shaft section, Kholodneya Balka Coal Mine, Ukraine

First stage - drilling of two inclined holes 25 m and 27 m deep. Borehole yield received on the completion of drilling amounted to 2.5 and 2.7 m^3 respectively. The quantity of injected grout totalled 125 m^3. The injection of grout into hole N_2 was executed by portions equal to 12-15 m^3 due to the fact that grout inrushes had occurred during its treatment. 4-6 hours were being given between each portion for the injected grout to stabilize and cure.

Second stage - drilling of two inclined holes 35 m deep and injection of 143 m^3 grout.

The water-bearing zone in the 343-380 shaft section was traversed partially by the shaft excavation in the interval of 343-367 m. The lower boundary of this zone was at a depth of 384 m which had been prompted by observing water percolations both from the shaft walls and bottom. Grout treatment in this zone was again subdivided into two stages (Fig 2).

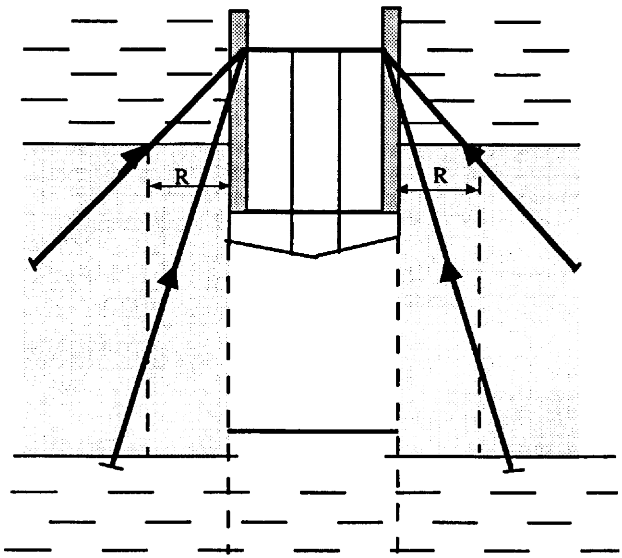

Figure 2. Process pattern for ground water control within 343 - 380 m shaft section, Kholodneya Balka Coal Mine, Ukraine

First stage - treatment of the exposed section through two 18 m deep holes. Borehole yields were 1.5 m^3/h and 1.7 m^3/h respectively, quantity of injected grout - 314 m^3.

Second stage - drilling of two 53 m long holes and injection of 142 m^3 of grout.

Total duration of the program on eliminating the ground water seepage in the shaft totalled 98 eight-hour shifts.

CONCLUSIONS

Grouting scheme that utilises long directional boreholes drilled in mine shafts sunk by shaft sinking machines or classical drill-and-blast method was successfully applied at seven projects in the Donets Coal Basin, Ukraine.

Intersection of problematic water-bearing zones at the designed distance from a shaft excavation provides for use of pressures sufficiently high both to enable placement of reliable grout covers and preclude any possible disintegration of permanent shaft lining.

REFERENCES

Zabora V V (1988), Exclusion of Residual Water Manifestations in Mine Workings. Proceedings 3rd International Mine Water Congress. Melbourne, Australia, pp. 601-615.