NEW DEVELOPMENTS IN THE FIELD OF GROUTING USING INTEGRATED METHOD

E. Ja. Kipko, Prof., D Sc Min. Eng.

STG Specialized Association
7a Petrovski St., Antratsit
Voroshilovgrad Region, USSR

ABSTRACT

The paper presents the results of developing and usage of new process schemes for advanced grouting in driving major mine workings and shaft stations. These schemes are based on a comprehensive approach to the problem of water shut-off. In all cases the schemes foresee executing the preparation and injection into water bearing rock of inexpensive and effective clay-cement grout employing advanced grouting equipment located on the ground surface, and to use reliable technology and original technical means.

The paper deals also with the information on forming the filtration-proof curtains in karstified and fissured rock during construction and operation of mines in various deposits, and tailings ponds of concentration plants.

INTRODUCTION

The deposits which are being mined at present are often overlaid by a thick strata of water bearing rock. Putting into operation new mines requires carrying out large volume of work on constructing vertical, horizontal and inclined mine workings, the length of which only in one mine may reach tens of kilometres. The scheduled time of putting the mines into operation depends on the rates of driving and sinking major workings. One of the main factors reducing the rates of operations is water content in rock. Pregrouting during driving and sinking major workings is, as a rule, the basic way to increase the efficiency of mine construction.

The process of driving and sinking major mine workings foresees in most cases the development and execution of procedures on prevention and elimination of water inflows into the workings employing the use of special techniques successful accomplishment of which influences time and economic factors of mine construction.

Conventional water-shut-off techniques, such as precementation from the working's face or freezing which had been widely used earlier, proved to be in many cases low-effective and too expensive. Moreover, the execution of these techniques required much time that increased excessively the period of mine construction.

Taking into account these disadvantages, and sometimes no possibility to use cementation technique in encountering large water bearing fissures, there have been developed at the STG association new process schemes for pregrouting water bearing strata during driving lengthy horizontal and shaft station workings.

BASIC PRINCIPLES OF DEVELOPMENTS

New process schemes advantageously differ from the previously used ones in that they enable forming a reliable sealing curtain around the excavation via only one-two underground boreholes, ensure guaranteed water inflow shut-off, and increase driving rates. Besides, labour consumption is reduced and safe working conditions are improoved since the volume of drilling is cut down, grout preparation and injection are conducted from the ground surface, grouting and driving operations are brought into coincidence, and there is no need in carrying out special operations in the workings face.

All parameters of sealing curtain formation around a horizontal opening (from its size to the number of grout holes and injection regimes) are calculated in the course of design activities.

To obtain accurate initial data needed for carrying out calculations, there has been designed the DAU-3M-G flowmeter based on the well-known DAU-3M model. There has been also the methodology and process scheme for executing the flowmetering tests in horizontal and inclined underground holes in the diameter range from 44 to 76 mm. The flowmetring tests provide the information on fissure spacing, their opening, and hydrodynamic characteristics of water bearing strata.

Execution of the designed programme is carried out by grout injection into strictly specified zones which are sealed with the DAU-1 packer.

The preparation and injection of grout during drivage are performed by high-production machinery located on the ground surface. The grout is injected into the aquifer via a high-pressure pipeline laid down the shaft, or down a special borehole drilled from the surface, and further depending on the designated purpose of grouting programme, via boreholes which are drilled from underground workings, drill chambers, shaft-station cutting chambers, or drill chambers in overlaying mining levels.

Grouting through boreholes drilled from side-wall chambers makes it possible to carry out drivage without stoppages since grouting and driving, in such a case, are brought into coincidence.

As for shaft stations construction, the developed process schemes enable pregrouting of water-bearing rock within the total designed area prior to the beginning of drivage. For this purpose a drill chamber is excavated at the junction of a shaft with shaft station. A fan-shaped pattern of horizontal grout holes is then drilled to intersect the entire water bearing strata encountered by the designed workings, or a fan-shaped pattern of inclined grout holes in case grouting of the shaft station is expedient to be carried out ting of the shaft station is expedient to be carried out from the upper or already finished mine workings.

The application of the above mentioned process scheme makes it possible to execute grouting operations in the excavation zone of shaft stations and other complex junctions prior to their drivage, and to considerably increase the rates of driving since there is no need to stop drivage faces for drilling and grouting operations. Besides, it helps to gain time saving for the construction of major workings and the mine itself.

The quality of grouting operations is controlled by testing the strength and stability of the formed sealing curtain by subjecting it to a hydrostatic test at the calculated value. Such technique makes it possible to estimate the reliability and efficiency of executed operations, guarantee their quality, and to detect and eliminate potential defects prior to the commencement of drivage[1].

INTRODUCTION OF DEVELOPMENTS

Directional drilling technique for long underground holes high effective application of the developed methods and technological schemes of pregrouting during major mine workings drivage. The application of the Integrated Grouting Method is illustrated by some mine construction projects at the Donetsk and Moscow-Region Coal Basins in driving workings of diverse designation.

The 960-m-level haulage and conveyer crosscuts in Nagolchanskaya 1-2 Mine within the area of 110 m were drived through a 43-m thick sandstone encountered in the roof of coal seam $_8$. The strata water pressure exceeded 2.5 MPa. The estimated water inflow into the crosscuts amounted to 0.10 m^3/s (350 m^3/hr), and more. The presence of water in sandstone was fixed during shaft sinking when a sudden irruption with a discharge of 0.072 m^3/s (260 m^3/hr) occured at the level of 933.6 m. It was during drilling a 76 mm dia. pilot hole which encountered a large crack in the range of 931.4-974.4 m [2].

Fissuring development analysis indicated that there are two systems of fissures in sandstone: the main system with a dip angle of 82-86° and strike azimuth of 5-10° including separate fissures with an opening from several millimetres up to 1 m, and more, and the auxiliary system with the same dip angles and close-to-normal strike including fissures with an opening of up to 1 mm.

To cut down time for crosscut drivage in the 960-m level, it was offered to employ pregrouting technique in the zone of sandstone aquifer prior to driving operations.

In accordance with the project grouting in aquiferous strata encountered by each crosscut should be carried out through two 110-m-long horizontal boreholes with a diameter of 76 mm drilled along the working's axis, Fig.1.

When the hole intersected the water bearing fissured zone, drilling was stopped and the drill string was removed. Following it, a hydrodynamic investigation programme was carried out using the DAU-3M-G flowmeter designed for horizontal underground holes. On the basis of hydrodynamic investigation data the project volumes of grout were defined more accurately taking into account the quantity of hydrostatic pressure in the aquifer, opening and length of fissures, strata thickness, and distance between the holes. Monitoring the borehole profile was continously carried out in the course of drilling by inclinometers.

On encountering each water bearing fissured zone, the DAU-1 type packer was anchored in the horizontal hole, the injection pipeline was connected to,,and clay-cement grout was injected employing the squeeze pattern scheme. The injection pipeline had been laid from the surface via the main shaft and along the shaft station workings up to the crosscut's face. The preparation and injection of grout was performed on the ground surface by the 2SMN-20 mixing units and CA-320M cementation units capable to provide high production.

In the course of operations it was defined that the bounda-

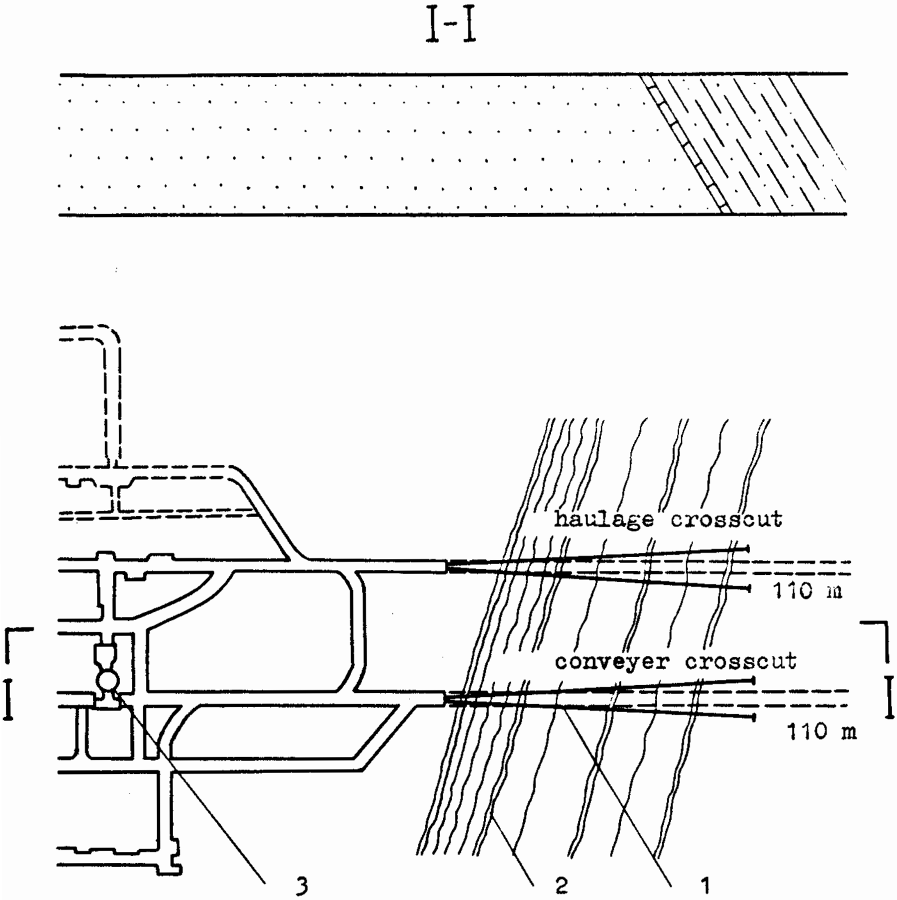

Fig.1. Advanced grouting scheme for water bearing strata in driving the 960-m level crosscuts of Nagolchanskaya mine

1 - grout holes
2 - water bearing fissures
3 - main shaft

ry of faulted zone in the conveyer crosscut was in the range of 0-95 m, and in the haulage crosscut it was in the range of 0-105 m. The intersection of fissured zones by pilot holes resulted in water makes from 0.004 to 0.023 m^3/s (from 15 to 83 m^3/hr) which is from 0.019 t0 0.106 m^3/s (23-382 m^3/hr) recalculating on the total crosscut section. Major parameters of grouting operations are enlisted in Table 1.

Quality control of the formed grout curtain was carried out by subjecting the treated zone to a hydrostatic test at a specified pressure. The pressure value was calculated with regard to proposed dimensions of a mine working, fissure opening, structural-mechanical properties of clay-cement grout, and hydrostatic strata pressure in the treated zone. When the pressure test was over, the hole was redrilled up to the next fissured zone.

Most complex conditions were encountered in the range of 16-37 m in the conveyer crosscut and in the range of 22-45 m in the haulage crosscut. Intensive fissuring of strata, abundant inflows and the task to grout large fissures within the whole sandstone thickness required, as it could be seen in Table 1, large volumes of grout.

Side by side with grouting the Integrated Grouting Method has gained ground also in the field of unstable rock consolidation. During drivage of shaft station workings in the 67-m level in Belkovskaya Mine of the Moscow-Region Coal Basin, there was a sudden irruption from the roof of a rock mass with a bulk up of 250-300 cu. m accompanied by water inflow up to 0.016 m^3/s (60 m^3/hr), Fig.2.

To eliminate the complications in the face, there had been constructed a concrete plug accomodating two standpipes running along the working's axis. During drilling the grout holes encountered a void zone in the range of 4-6 m. It was grouted from the surface via a freezing column by 40 cu. m of grout.

Additionally, there had been drilled a vertical hole from the ground surface spaced 12 m from the shaft axis. The bo-

Table 1

Grouting zone	Hole depth, m	Water inflows, m^3/s (m^3/hr)		Injection zone, m	Grout volume, m^3	Maximum final pressure, MPa
		From holes	Recalculated on headings' section			
Conveyer crosscut	16	0.008 (30)	0.038 (138)	10-6	198	9
	37	0.004 (15)	0.019 (69)	32-37	52	7.5
	56	0.005 (18)	0.023 (83)	53-56	143	8
	89	0.004 (15)	0.019 (69)	79-89	39	8.5
Haulage crosscut	22	0.023 (83)	0.106 (382)	16-22	329	9.5
	45	0.004 (15)	0.019 (69)	38-45	61	8
	78	0.005 (17)	0.023 (83)	72-78	87	8
	104	0.007 (27)	0.034 (125)	90-104	108	8,5

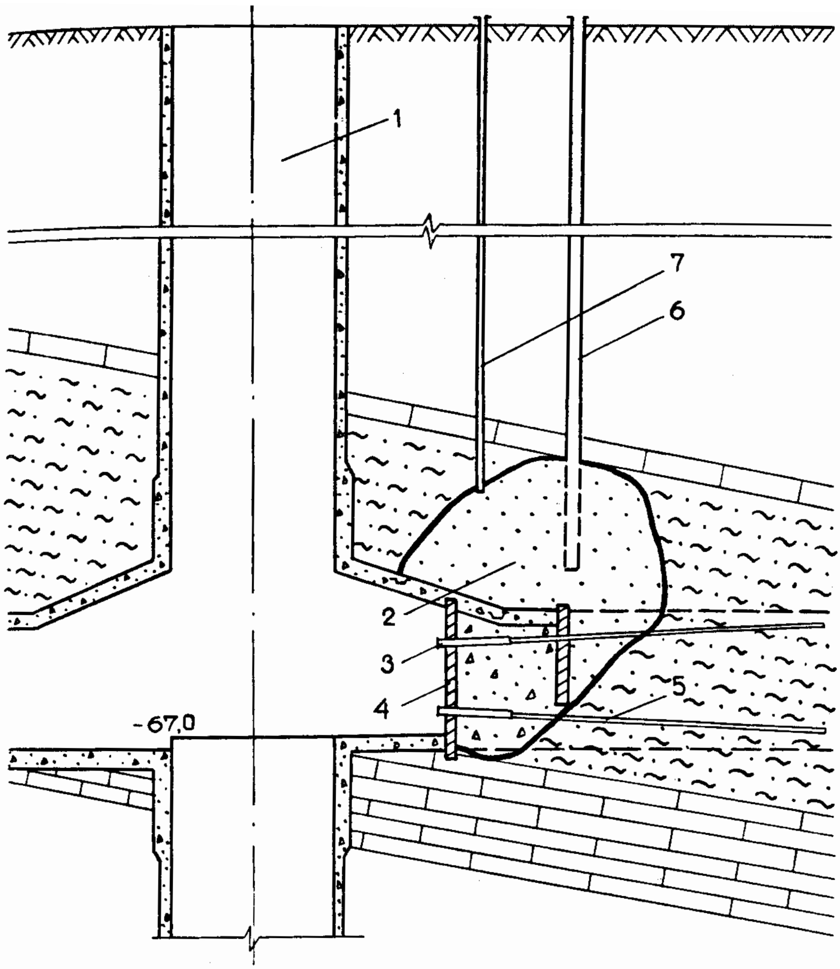

Fig. 2. Diagram of consolidation in unstable aquiferous rock

1 - shaft; 2 - irruption zone;
3 - collar pipe; 4 - stopping;
5 - grout hole; 6 - borehole;
7 - freezing column

rehole encountered the void zone in the range of 56-58 m, and was treated with 96 cu. m of grout. As a result, the grout raised up to 42 m, and grout injection was stopped.

Following it, there were drilled four 18-m-long holes through the concrete plug. The holes accomodated 89 mm dia. standpipes and were cased with perforated pipes up to the bottom. Grout injection was carried out via the standpipes or perforated casings into each hole separately. The grout volume totalled 77.5 cu. m.

On completion of grouting, the shaft junction was finished without any complications.

High hydrosealing properties of clay-cement grouts which are used in the Integrated Grouting Method revealed a new field for their application. These grouts were employed during grouting operations in the construction of tailings ponds for several concentration plants at various mineral deposits.

When the construction of a receiving pond for clear water was over and it was put into operation at Sukhodolskaya concentration plant, there was detected water loss with a discharge of 0.83 m^3/s (300 m^3/hr) through the pond's floor. Grouting operations were carried out in accordance with STG design by creating 0.15-0.20 m thick layer. The clay-cement grout volume for these operations totalled 540 cu. m. Water filtration through the pond's floor was stopped, and no loss is observed at present.

At the same concentration plant there had been sealed a vertical karstic cavern in the dam body. It was formed as a result of subsidence in the left wing of the dam.

Grouting was executed via five inclined holes from 10 to 40 m deep. When the holes intersected the karstic zone at the designed depth, it was treated with 600 cu. m of clay-cement grout. The sealing properties of the dam were recovered.

RESULTS

During drivage of the 960-m-level crosscuts of Nagolchaska-ya mine in the grouting zone, there were encountered and fixed large grouted fissures with an opening of 100-400 mm. The total residual inflow into the crosscuts after their drivage amounted to 0.0012 m^3/s (4.5 m^3/hr) versus the estimated inflows of 0.1 m^3/s (360 m^3/hr).

In Nagolchanskaya 1-2 mine pregrouting was also carried out from the surface in the shaft station workings of the 690 m, 960 m and 760 m levels via boreholes drilled from the shaft station chambers and overlaying workigs which enabled cutting down the time of construction in the range from 10 to 24 months .

SUMMARY

There are a lot of other examples to illustrate high efficiency of the new process schemes for advanced grouting and rock consolidation basing on the Integrated Grouting Method. New process schemes enable the formation of sealing curtains in large cracks and karstic zones, manifest much more potentialities versus cementation technique schemes, and can successfully replace expensive freezing technique operations in driving under severe geological conditions.

Besides, they are characterized by the usage of inexpensive and effective clay-cement grouts, employment of special technical means and grouting quality control methods; by an original grouting technique which foresees the preparation and injection of grout on the earth surface; by maximum bringing into coincidence grouting and driving operations, and by the guaranteed water shut-off providing an increase in the rates of multi-purpose driving.

REFERENCES

1. 'Tekhnicheskoe predlozhenie po primeneniyu kompleksnogo metoda tamponazha obvodnennyh gornyh porod pri sooruzhenii shakhtnyh stvolov i drugih kapitalnyh gornyh vyrabotok' (Technical offer on usage of the Integrated Method for grouting water bearing fissured rock during shaft sinking and driving other major workings), Moscow, TsNIEIugol, 1980, p.56.

2. Velikiy, I.G., Tsapenko, A.T., Kipko, E.Ja., Polozov, Ju.A., Lagunov, V.A., 'Primenenie glinotsementnogo rastvora dlya likvidatsii katostrophicheskih proryvov vody pri prokhodke shakhtnyh stvolov' (Usage of clay-cement grout for elimination of catastrophic irruptions during shaft sinking), Shakhtnoje stroitelstvo, Vol.2, 1974, p.4-6.

3. Kipko, E.Ja., Polozov, Ju.A., Lagunov, V.A., Spichak, Ju.N., 'Novyi metod predvaritelnogo tamponazha obvodnennyh porod okolostvolnyh dvorov shakht' (New method of advanced grouting in water bearing rock of shaft stations), Shakhtnoje stroitelstvo, Vol.4, 1978, p.20-23.