EXPERIENCE WITH BACKFILLING UNDERGROUND VOIDS AND SHAFTS DURING MINE CLOSURE

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ABSTRACT

This paper presents case histories of backfilling underground voids, inclined and vertical shafts for mines and pits intended for closure in Ukraine, the USA and the Czech Republic.

In order to protect aquifers from the migration of acid mine water and prevent the ground surface from subsidence. the underground voids and shafts are filled with a non-shrink bentonite-cement grout formulated using processing tailings. The grout was injected into the mine workings through boreholes drilled from the ground surface.

1. INTRODUCTION

According to a Government Program to close uneconomic mines in Ukraine, 105 coal mines in the Donbas coal basin (Donbas) should be closed.

Donbas - has been subjected 200 years of intensive mining of coal within a relatively small area of 15 thousands square kilometers. During this time 21 billions tons of material, including 15 billions tons of coal, was extracted. As a result the Ukrainian steppes was left with 12 cubic kilometers of subsurface voids, which soon filled with collapsing rock. This also caused a 1,5 to 2 meter (on average) subsidence of the ground surface over an area of 8000 square kilometer.

The subsidence caused overlying confining strata to break, thereby substantially increasing the per-meability of the distorted layers and strata and the infiltration of surface water into underground saturated horizons. This, in turn, caused the filling with water of the mining openings at depths of 800 to 1400 m .

Surface and subsurface water with a salt content of 0,5 to 1g/l thus percolated into the voids of closed mines, from where they flowed into operating mines and had to be pumped out to surface. On their way to depths of 800 to 1400 m, percolating surface and subsurface water dissolved soluble substances and were subjected to processes generating acid mine water. Consequently the salt content of the acid mine water pumped from underground reached concentrations of 20 to 30 g/l and more all of which was released into local rivers and other surface water bodies.

Currently several conventional and unconventional methods are been used to protect the aquifers from pollution by acid mine water and mining wastes, and to prevent subsidence of ground surfaces during excavation and the operation of mines and pits.

A short description of these methods is presented below.

2. METHODS FOR PROTECTING AQUIFERS FROM POLLUTION

Conventional methods for protecting aquifers from pollution includes treatment of acid mine water and effluent by:

□ mechanical and hydro mechanical methods: gravity sedimentation in settling basins; filtration;

□ chemical methods: coagulation; flocculation - for precipitation of finely dispersed and colloidal material;

□ physico-chemical methods: distillation; ion exchange; ultra filtration; reverse osmosis - for removal of inorganic t substances;

□ regenerational methods: extraction; absorption. flotation;

□ reagentive methods - reduction-oxidation;

□ destructive methods - biological and electrochemical oxidation; chlorination - for treating water with organic substances.

Unconventional methods carried out by the Ukrainian company Donbas Special Grouting Co. Ltd. (DSG) are includes:

□ isolation (bentonite-cement grouting) of acid mine water flows to prevent their migration into surface and subsurface water basins;

□ protection of aquifers from mining wastes pollution by isolating disposed wastes with sealing bentonite-cement grout covers having the required depth, shape and size.

3. METHODS TO PREVENT, GROUND SURFACE, SUBSIDENCE

Conventional methods to prevent, ground surface, subsidence, includes backfilling of underground voids, at mine closure, with unreactive rock and other inexpensive granular materials.

Unconventional methods, implemented by DSG, includes:

□ protection of ground surface from subsidence by backfilling of underground, karsts and voids with unshrinking grouts formulated using processing tailings;

□ protection of soil from gully erosion and salinization to preserve farming areas.

Several industrial applications are presented below in the form of case histories, related to the protection of aquifers from acid mine water and mining wastes pollution, and experience with the backfilling of underground voids and shafts at mine closure using the High Bentonite-Based Grouting Technology of DSG.

4. BACKFILLING OF UNDERGROUND VOIDS AND SHAFTS IN AN ABANDONED COAL MINE

About 20 years ago near the city of Karlovy Vary in Western Czechia, which is situated close to the abandoned “Maria Mayerova” Coal Mine, cold underground water with a temperature of 3ºC, started to flow in the direction of the medicinal thermal springs of Karlovy Vary. In order to prevent the temperature of the medicinal springs from decreasing, it was decided to backfill all underground openings of the mine at a depth of 270 m, as well as two abandoned vertical shafts 4m diameter each, by using the Ukrainian clay-cement grouting technology.

Following this decision the grouting operations and backfilling of the abandoned “Maria Mayerova” Coal Mine was carried out in three stages.

The First Stage - was the elimination of a sudden inrush of cold water into underground voids from a large fault zone, by sealing of this fault, with the use of 300 m deep vertical directional boreholes, drilled from the ground surface. Fig.1 shows how a water isolation curtain was created in the fault zone and how, adjacent underground voids was backfilled by the injection of clay-cement grout through vertical grouting boreholes.

The Second Stage - was the backfilling all underground voids between vertical shafts №1 and №2 by injecting a non-shrink clay-cement grout through vertical boreholes, (See, Fig.1).

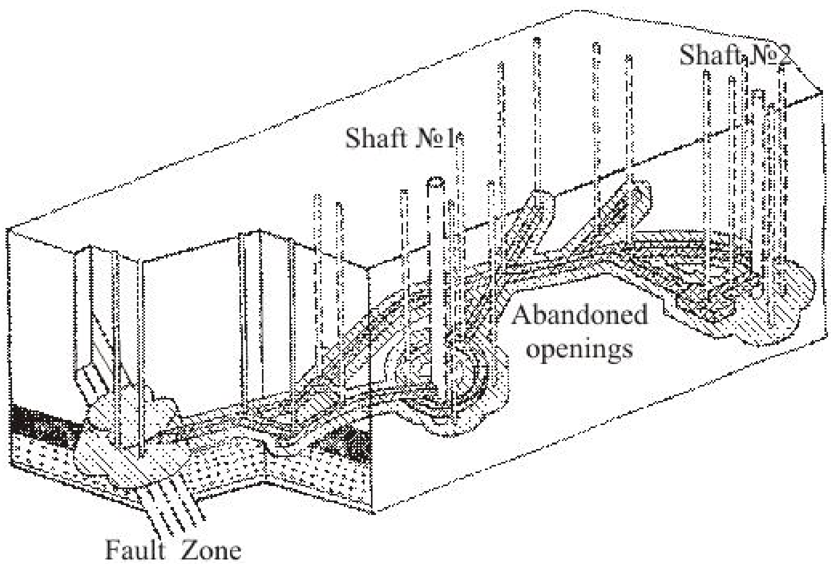

Fig.1 Schematic presentation of vertical directional grouting boreholes for backfilling underground voids and shafts of the “Maria Mayerova” Mine in Czechia

The Third Stage was the backfilling of shafts №1 and №2, and grouting of adjacent fractured rock through vertical directional boreholes, drilled from the surface around these shafts, (See Fig.1).

Principal grouting data for backfilling the underground voids and two vertical shafts of “Maria Mayerova” Coal Mine are presented in Table 1.

Table 1: Actual data of grouting operations at the abandoned "Maria Mayerova" Coal Mine

Grouting stage No.	Number of grouting holes	Depth of grouting holes, m	Volume of grout injected through each hole, m^3	Total volume of grout, m^3	Final injection pressure, bar
I	2	300	450-500	890	60-70
II	11	300	410-440	4670	10-15
III	6	300	430-450	2640	45-60
Total:	19			8200	

All drilling and grouting work for backfilling at the abandoned "Maria Mayerova" Coal Mine with non-shrink clay-cement grout was carried out during a period of 4.5 months by enterprise Geoindustria - Praha with assistance of Ukrainian experts. As a result the sudden inflow of cold water from this mine to the medicinal thermal water sources of the Karlovy Vary Health Spa was prevented..

5. PREVENTION OF SUBSIDENCE BY BACKFILLING OF CLOSED INCLINED SHAFTS

It is envisioned that the closing of each mine should include the filling of its inclined shafts in order to protect the adjacent ground surface from subsidence. The case history of backfilling and grouting the abandoned inclined shaft of the closed S.Tulenina Coal mine, near the sity Krasnodon in Ukraine, is presented below. The plan was carried out in two stages.

The First Stage was the construction of a reinforced concrete barrier of the required dimensions, thickness and shape within the inclined shaft at a calculated distance from its entrance, (See Fig.2). Nezt, the voids in the vicinity of the inclined shaft was back filled to the surface with waste rock.

The Second Stage was to drill a number of vertical boreholes from surface into the closed inclined shaft and inject through them a pre-calculated volume of bentonite-cement grout in order to grout the waste rock and to prevent migration of acid mine water from the closed mine and to protect the ground surface from subsidence, (See Fig.2).

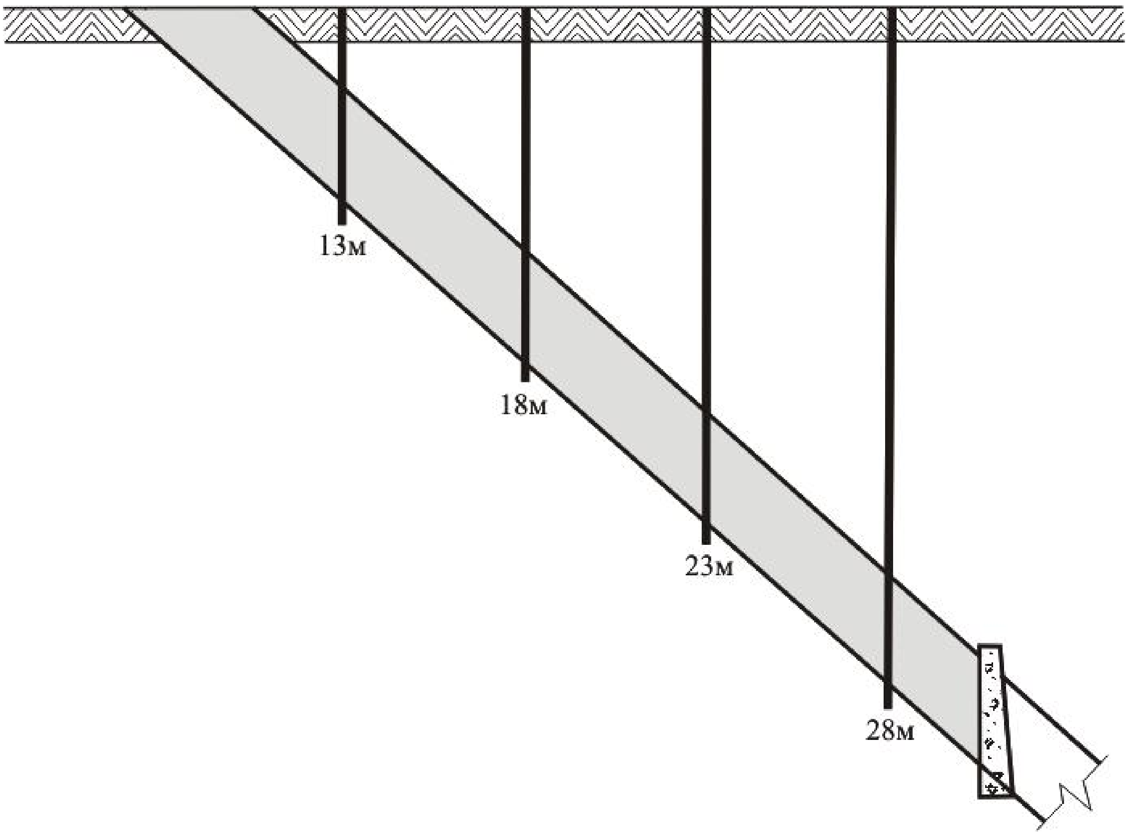

Fig.2 Arrangement of vertical grouting holes for grouting the backfill in the inclined shaft of S.Tulenina Coal Mine in Ukraine

Drilling and grouting data for the inclined shaft of the S. Tulenina Coal Mine in Ukraine is shown in Table 2.

Table 2. Drilling and grouting parameters for the inclined shaft of S.Tulenina Coal Mine

Grouting hole No.	Depth of grouting hole, m	Volume of grout injected into hole, m^3	Final injection pressure, bar	Duration of work, day
1	28	90	5-10	2-3
2	23	70	20-25	2-3
3	18	50	35-40	2
4	13	30	50-55	2
Total:		240		8-10

The above mentioned grouting activities prevented subsidence of the ground surface over the abandoned inclined shaft, and flooding of area, adjacent to the entrance to the shaft.

6. PROTECTION OF AQUIFERS FROM ACID MINE WATER CONTAMINATION

The objective of the first Ukrainian bentonite-based grouting demonstration project in the United States, funded jointly by DOE and EPA, was to reduce the inflow of shallow groundwater and surface water through the Mike Horse fault system and into the abandoned underground workings of the closed zinc-lead Mike Horse Mine near Lincoln, Montana. Acid rock drainage from the portal of the mine was reduced as result of grouting. The pH of the discharge was 5,5. The owners of the Mike Horse Mine (ASARCO and ARCO) have permitted Ukrainian bentonite-based grouting demonstration at the site under the Mine Waste Treatment Pilot Program.

To accomplish this purpose, bentonite-based grout was injected into the underlying bedrock and alluvium through two rows of inclined holes drilled from the surface, (see Fig.3).

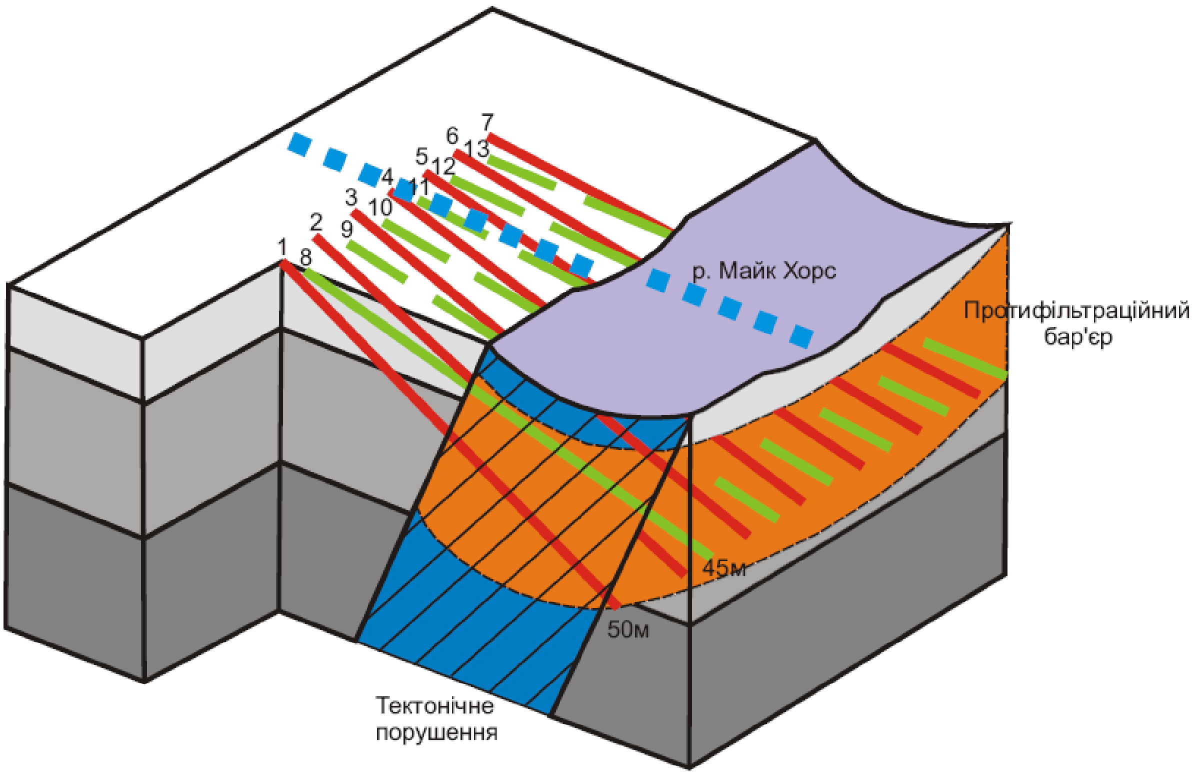

Fig.3. Schematic showing creation of the isolation curtain under Mike Horse Creek to prevent migration of acid mine water from Mike Horse Mine

First investigation angle holes were drilled, and packer tests were performed to determine pregrout conditions prior to commencement of actual work.

The angle of first row of grout holes was 35 degrees, and the angle of the remaining holes was 45 degrees. The length of the holes varied from 45 to 50 meters. The diameter of surface casing was 108mm, and the diameter of boreholes was 93mm. The grout was injected through a packer in order to control pressures and in stages to control grout dispersion.

During thirty working days, excluding packer testing, mobilization and demobilization, a total of 1195 cubic meters of bentonite-based grout was injected in the lower half of the grout holes. The average placement rate was 40 cubic meters per day and was done primarily during a single-shift operation. Immediate ramifications were observed when the water level rose in monitoring wells from 63 meters to 6 meters. The effects of grouting on stream flow, water levels in monitoring wells, and portal discharge are being monitored continuously.

The parameters for drilling and creating an isolation curtain above abandoned lead-zinc Mike Horse Mine are presented in Table 3.

Table 3. Principal drilling and grouting data for water sealing of abandoned lead-zinc Mike Horse Mine

Number of row of grouting holes	Angle of drilling grouting holes, degree	Quantity of grouting holes	Length of grouting holes, m	Volume of grout injected into holes, m^3	Total volume of grout, m^3	Final injection pressure, bar
I	35	9	50	85-95	810	25-30
II	45	4	45	90-100	385	35-40
Total:					1195	

The Mike Horse Mine site, located approximately 15 miles east of the town of Lincoln, Montana, USA, is in the inactive Heddlestone Mining District and has been recognized as a contributor to the pollution problems associated with the upper Blackfoot River ecosystem which includes Mike Horse Creek.

The Mike Horse Creek was major drainage feature in the project area. Historic data indicate that acid rock drainage and heavy metal-laden sediment from the portal discharge are being released into Mike Horse Creek. The upper reach of Mike Horse Creek loses now into the subsurface strata in the area where the stream crosses the Mike Horse vein/fault system. The mine workings generally follow the vein/fault system, which was a lead-zinc producing ore body. This area was for demonstration of the Ukrainian bentonite-based grouting technology. Grouting in the vein/fault system inhibited groundwater from entering the mine workings, was encountered a high hydraulic counductivity of fault zone and practically eliminated the acid rock drainage from the 300 foot-level portal of Mike Horse Mine.

7. BACKFILLING OF CHAMBERS AT A POTASH MINE

During operation of the Stebnik Potash Mine No2 in Western Ukraine brine suddenly started to rush into two chambers of the mine. The inrush of brine at the 140-meters level at a rate of 2000 cubic meters per day caused intensified karstification and surface subsidence with the formation of 15 meters diameter sink holes. A further increase in inflow rate and karst formation threatened the existence of the mine.

To stop the inflow of ground water and stop further subsidence, several series of vertical grouting holes were drilled to a depth of 140 meters and used to inject the designed quantity of about 76 000 cubic meters of special grout, (See Fig.4).

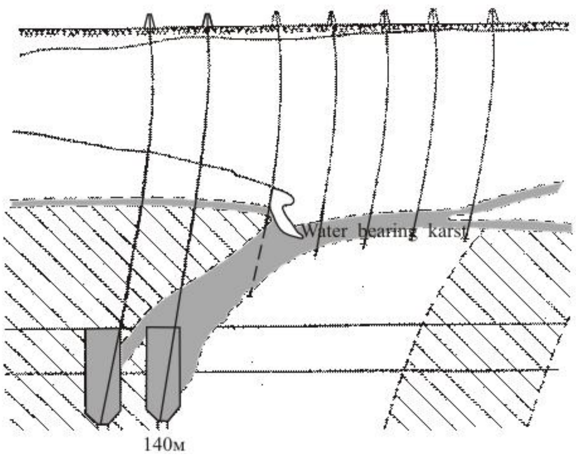

Fig.4. Backfilling of operation chambers at Stebnick Potash Mine No2 in Ukraine

Special grouts and process patterns to meet the conditions of high mineralization and magnesium aggressiveness of ground water were used during the backfilling o0f operation chambers at Stebnick Potash Mine No2, in order to prevent further subsidence of the ground surface, and potential forced closure of the mine.

As a result of the action taken, the situation was normalized, mining operations were resumed and ground subsidence stopped completely.

8. CONCLUSION

Application of the unconventional Bentonite-Based Grouting Technology of Donbas Special Grouting Co. Ltd. has been shown in the above and other applications to provide environmental protection in mining operations, including:

□ protection of aquifers from acid mine water and mining wastes pollution;

□ protection of underground waters and rivers from seepage of radioactive wastes contamination;

□ protection of ground surface from subsidence in areas with abandoned underground works;

□ protection of ground surface from deformation below foundations of civil and industrial sites;

□ protection of soil from contamination near tailing ponds and slime tanks;

□ protection of ground surface from subsidence in areas of mining extraction of mineral

resources;

□ protection of ground surfaces from subsidence in areas overlying inclined shafts.

9. REFERENCES

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