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Technical aspects of liquidation of the shafts "Głowacki" in Rybnik, "Jas VI" and "Jas II" in Jastrzębie Zdrój, Poland

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Abstract:

Mining plants liquidating the unnecessary objects, especially shafts, encounter difficulties related mainly to the selection of appropriate technology. In this material, we present solutions for two more difficult cases. The first consists in liquidating the shaft without making dams and maintaining the water permeability of the backfilling (Głowacki shaft), while the second one is the liquidation of the shaft, leaving the ladder compartment, pipelines and with the so-called artificial bottom which is in the shaft (Jas II shaft).

Keywords: shaft liquidation, backfilling column, backfill material

1. Introduction

The SRK branch in Jastrzębie Zdrój was established on October 1, 2016 as KWK "Jas-Mos". Its task, in the first place, was to liquidate, among others, the "Jas II" and "Jas "VI" shafts and then the "Jas I" and "Jas IV" shafts. On December 2, 2016, the activity of the branch was expanded to include part of the area of KWK Rydułtowy I and since then the branch has been operating in a two-branch structure with the Ruch "Jas-Mos" and the Ruch "Rydułtowy 1" branches. Tasks realized in the Rydułtowy I included: liquidation of some redundant and unsuitable for development buildings and liquidation of the entire underground infrastructure, including the liquidation of two shafts, i.e. the "Leon III" shaft in Rydułtowy and the "Głowacki" shaft in Rybnik. The restructuring process of Ruch "Rydułtowy I" was finally completed on December 31, 2021. In the following year, on 1 January, the Jastrzębie III mine was added to the SRK Branch in Jastrzębie Zdrój, which since then formed the Ruch "Jastrzębie III" of the Branch "Jas-Mos-Jastrzębie III" KWK mine and this organizational and legal status has existed to this day (1.05 2023).

2. Methods

This article discusses technical issues related to liquidation of the "Głowacki" shaft in Ruch "Rydułtowy I" and the "Jas II" and partly "Jas VI" shafts.

2.1. Liquidation of the “Głowacki” shaft

The SRK branch in Jastrzębie Zdrój, together with the creation of the Ruch "Rydułtowy I", received for liquidation two shafts together with their underground and surface infrastructure – the "Leon III" shaft in Rydułtowy and the "Głowacki" shaft in Rybnik - Niewiadom. The "Leon III" shaft was liquidated at first, the liquidation technology was similar to the technological process [1, 2] of the "Jas VI" shaft discussed later in the article. The decision to proceed with the immediate liquidation of the "Głowacki" shaft was made after an analysis of the technical condition of the shaft steelworks. The "Głowacki" shaft originally was used as a ventilation shaft, and after the fan station was liquidated and reinforced, it served mainly as an intake shaft, which was a way for water to run off from each water reservoir. This water was further captured in underground workings by the main drainage system of PGG S.A. KWK "ROW" Ruch Rydułtowy mine. To ensure the safety of the present and future coal mining, an extremely important issue was to maintain stable water ratios, i.e. underground water runoff routes and their intakes. It was of great importance to design the liquidation of the shaft in such a way as not to disturb and maintain the current migration of water in the rock mass in the vicinity of the shaft [3, 4]. It should also be noted that the nearby "Kościuszko" shaft, which was liquidated earlier, was also supposed to be a water runoff route, but already at the stage of its liquidation, the filling was sealed and from that time all water was discharged only through the "Głowacki" shaft. The amount of water flowing into the workings of KWK "ROW" Ruch Rydułtowy mine was also variable and depended on weather conditions. Regardless of the underground conditions, there were limitations on the surface related to the fact that the shaft was located in the Historic Mine Ignacy, and the shaft building itself was included in the register of immovable monuments of the Silesian Voivodeship since 2005. The "Głowacki" The shaft has a shaft landing and a steel, single-bolt hoisting tower built in 1901, reinforced in 1947, with a rivet-welded structure made of cylindrical profiles. Details of the liquidation project and technological arrangements were discussed on an ongoing basis with representatives of the Consultative Team appointed by the President of the city of Rybnik. In 2019, Mines Restructuring Company SA (SRK) commenced implementation of the project with the acronym TEXMIN. The TEXMIN (The Impact of Climate Change on Closed and Abandoned Mines) project, co-financed by the Research Fund for Coal and Steel, was implemented by an international consortium of the following partners: the Silesian University of Technology and SRK from Poland, the University of Exeter from Great Britain, the CERT Research Center from Greece, the Brown Coal Research Institute from the Czech Republic, Subterra Ingenieria from Spain and DMT from Germany with the Central Mining Institute (GIG) as the project coordinator. As part of the TEXMIN project, a team of scientists from the Central Mining

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Institute and the SRK S.A. Working Group. The Department of KWK "Jas-Mos-Rydułtowy I" Ruch Rydułtowy I, under the leadership of the Chief Mining Engineer, developed a project for liquidation of the "Głowacki" shaft, taking into account the change in weather conditions as well as defined the requirements for the backfill regarding its water permeability.

Main technical parameters and geological-and-engineering conditions:

- shaft depth 625 m,
- cross-section of the shaft was uneven, from barrel (0.0 m - 115 m) through rectangular (115 m - 200 m) to circular (200 m - 625 m), and the cross-section area ranged from 14.4 m^2 to 18.3 m^2,
- type of the shaft lining is not uniform along the length of the shaft pipe. The section from the ground to the depth of 400 m was made in a brick wall casing. The remaining section was made in a masonry casing made of bentonites. The shaft documentation does not contain any information on the strength parameters of the lining material and the brand of the mortar used to make it.

Table 1. Shaft inlets and insulation dams in "Głowacki" shaft [5]

Depth [m]	Inlet	Type of a dam
0.00	Shaft outset	--
10.50	Ventilation telescope I	Wall dam. Telescope liquidated
33.00	Ventilation telescope II	Wall dam. Telescope liquidated
150.00	Level 150	Wall insulation dam
200.00	Level 200	Wall insulation dam
240.00	Level 240	Wall insulation dam
300.00	Level 300	Wall insulation dam
350.00	Level 350	Wall insulation dam
393.00	Pipe telescope	Wall insulation dam
400.00	Level 400	Wall insulation dam
455.00	Level 455	Wall insulation dam
584.00	Inlet to the seam 620/1-2	Wall insulation dam
594.34	Level 600	Wall insulation dam

The liquidated inlets to each level in the "Głowacki" shaft were closed with insulating wall dams. Due to the lack of access to the above-mentioned dams at each shaft level, it was impossible to determine their dimensions, thickness and technical condition of the wall based on the on-site inspection. In this situation, the location of the dams listed in Table 1 above and their dimensions were adopted on the basis of the available archival documentation.

Hydro-geological conditions

Amount of water inflow to the "Głowacki" shaft in 2009÷2016 ranged from **0.95÷-1.67 m^3/min**. Since 2018, the water inflow to the shaft has stabilized at the level of approximately 1.10 m^3/min, and the rate of water flowing directly into the shaft from the levels of 150 m, 200 m, 240 m, 300 m and 400 m and leaking from the shaft lining flows down the shaft cross-section (at the level of 600 m, is observed as a torrential rain in the entire cross-section of the shaft.

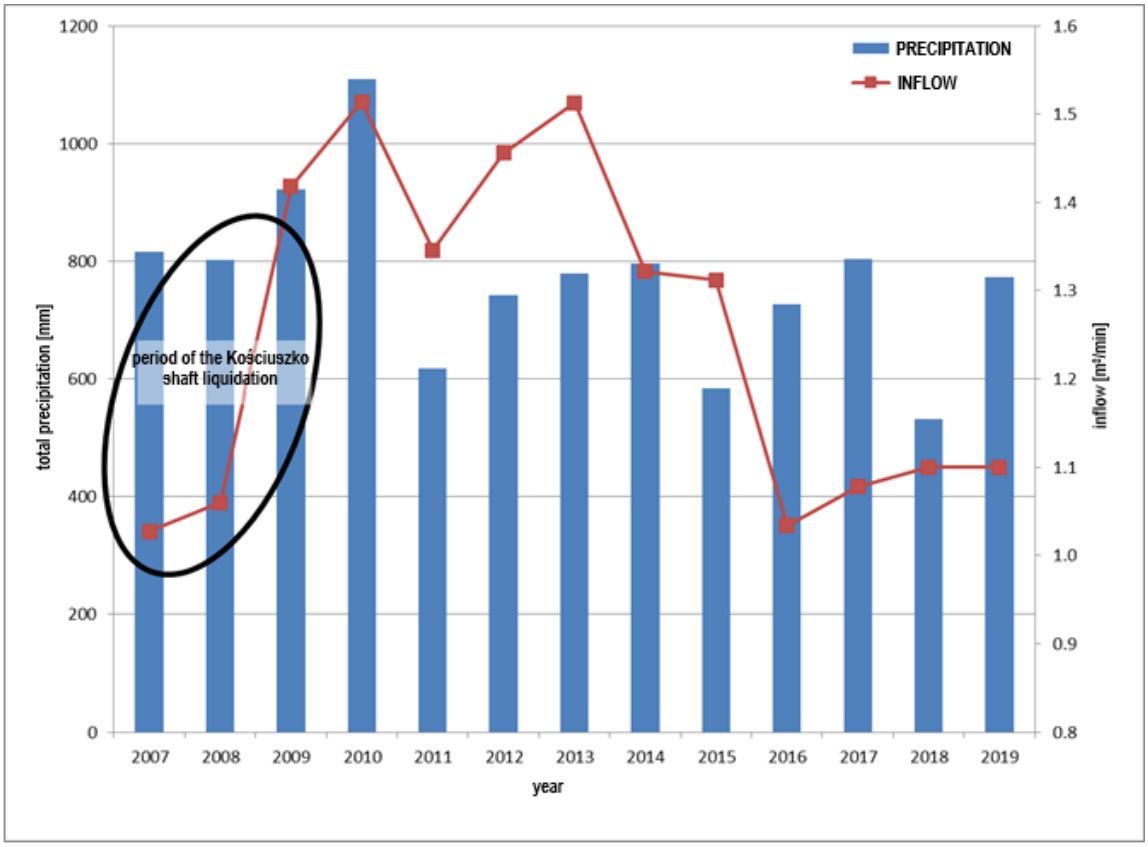

Fig. 1. Variability of the natural inflow of mine water to the "Głowacki" shaft in relation to the variability of the amount of precipitation in the period 2007÷2019 [5]

Comparison of amount of water inflow and the sums of annual precipitation shows that there is no direct relationship between these values. Lack of impact of the amount of precipitation in the years 2016÷2019 is clearly visible, where the amount of precipitation ranges from 531.4 to 804.1 mm (nearly 30%), and the water inflow to the "Głowacki" shaft varies from 1.034 m^3/min to 1,100 m^3/min i.e. approx. 6% (Fig. 1).

In a result of the analysis of mining, geological and surface conditions, but also based on the results of testing and the experience gained from the previously liquidated shafts, the following method of decommissioning the "Głowacki" shaft was decided:

Assumption for the liquidation of "Głowacki" shaft:

- No preparatory work will be carried out in the "Głowacki" shaft in terms of closing the shaft inlets and changes in the shaft's equipment due to the lack of technical possibilities.
- - During liquidation, water flowing to the "Głowacki" shaft will seep through the shaft backfilling to the workings at pos. 600 and further it will flow by gravity to the main drainage system of KWK ROW Ruch "Rydułtowy" mine.
- - If it is not possible to discharge the water inflow through the backfilling in the "Głowacki" shaft, the water at level. 400 will flow through the workings on the level 400, further through the gobs of seam 615/1 to "Blind Shaft III",
- Due to the small cross-section of the shaft and a very large water inflow, very high filtration property for the backfilling material is required. It is assumed that in practice most of the water flowing into the "Głowacki" shaft will seep through the shaft backfilling while the remaining water will flow through the working and gobs to level 400 to " Blind Shaft III".

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In the Central Mining Institute, a metallurgical aggregate intended for the liquidation of a mine shaft, fractions of 31.5÷63.0 mm, was tested in a laboratory. Fig. 2 shows grain degradation of metallurgical aggregate before and after discharge into the shaft.

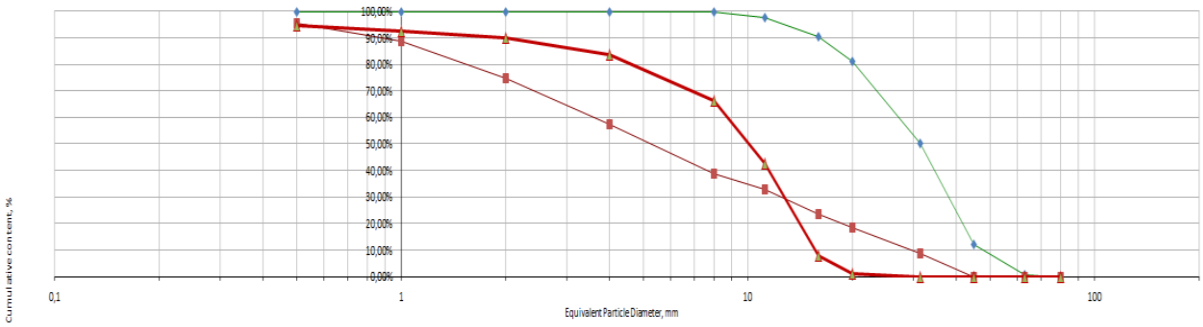

Fig. 2. Grain degradation of metallurgical aggregate 31.5÷63.0 mm before and after discharge into the shaft (green line the material before, red the material after discharge) [5]

The metallurgical aggregate of the following parameters was planned liquidation of the "Głowacki" shaft (Fig. 3÷6):

- grains from 31.5 to 63 mm,
- volume density above 2.0 T/m^3,
- filtration coefficient after discharge to the shaft 1.18*10^{-3} m/s.,
- compressing strength above 100 MPa,
- water-repellent material (Skuty A factor),
- does not adversely affect the chemical composition of mine wate.
- work related to filling the shaft pipe will be carried out from the surface.
- the backfill material will be delivered from the outside by self-dumping vehicles to the storage site and fed from there by a tire loader to a mobile screening machine. From the boom of the mobile screening machine, the charging material will be placed in the shaft through the charging funnel.

The calculated total backfilling volume was 13072 m^3. Implementing the liquidation process based on the presented assumptions, all work of the shaft liquidation was carried out over 3 months. Use of a mobile screening machine before feeding the filling material into the shaft was one of the most important elements, apart from the selection of the right aggregate for backfilling. Based on the experience gained during the liquidation, it was found that despite the fact that the aggregate delivered to the storage yard was of the correct grain size distribution, during the manufacturer's transport from the storage yard to the mobile screen as well as operation of the screen itself, a quite significant amount of bottom product is generated, about 5%. Thanks to the use of appropriate aggregate for liquidation and the use of a mobile screen in the technological process for additional cleaning of the of the backfill material from the bottom product, the shafts were liquidated and water runoff routes were maintained.

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Fig. 3. Building of the „Głowacki"shaft landing

Fig. 4. Land development during liquidation

Fig. 5. Position of the screening machine for backfilling

Fig. 6. Discharging chute for liquidation

2.2. Liquidation of "Jas II" and "Jas VI" shafts

The "Jas II" shaft is one of the main shafts, located in the central part of the former mining plant, is a vertical excavation with a depth of 1063 m and a diameter of Ø7.2 m, originally intended for mining, later it served only as an inhalation shaft. "Jas II" shaft was a two-compartment shaft, equipped with a mine shaft hoist with a skip. The run-of-mine was transported in the northern section from a depth of 714 m and the southern section from a depth of 914.5 m. At a depth of 753.6 m, an artificial bottom of the shaft was made, located under the bottom product tank of the northern compartment, with a total height of 10.5 m and a 6-meter shock-absorbing layer.

A reinforced concrete shaft tower with four-rope hoisting machines was built over the shaft. Mining was continued until January 31, 2017, and in 2020 the skip vessels were liquidated. The "Jas II" shaft has a ladder compartment (on the western side between the -400 m and -800 m levels), the following pipelines: fire protection, compressed air, main drainage, supplying technological media, capturing dripping water as well as power cables, shaft signalling and telecommunication cables.

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In order to properly fill the shaft pipe of the "Jas II" shaft, the preparation of the backfilling column (Fig. 7) was preceded by disassembling work in the shaft. The scope of these work was as follows:

- shaft gates, platforms, shaft chair covers, protective canopies over inlets at levels -400 m, -600 m and -800 m were disassembled,
- the bottom product tank and the artificial bottom were perforated,
- conveyances, hoisting and balancing ropes were dismantled.

Due to the economic aspect, the main reinforcement girders, guides, pipelines and cabling were neglected during the disassembly of the existing shaft equipment.

The assumptions for liquidation of the "Jas II" shaft determined the technological process, which it was decided in two main stages. In the first stage, the shaft was liquidated by filling it with a self-spreading mineral and cement binder from the sump to the level of 400 m, i.e. in the section where the artificial bottom, ladder compartment, pipelines, etc. were created. At present, the liquidation of the first stage has already been completed. In the second stage, the shaft will be liquidated from the level of 400 m to the shaft core. The technological process will be similar to the one used in the earlier liquidation of the "Jas VI" shaft, with the use of solidified filling mixtures, with near-coal stone aggregate [6].

Basically, in accordance with the project for liquidation of the "Jas II" shaft developed at the Central Mining Institute, the inlets at levels -400 m, -600 m and -800 m were secured by making insulating and resistance plugs. The traffic jams at the levels -400 m and -600 m were located in the working near the shafts. They will consist of two insulating dams spaced at least 6 m apart and a mineral binder with a strength of $R_c^{28} \geq 15$ MPa filling the space between them. The plug securing the level -800 m consists of dams built in the shaft workings and a mineral binder with a strength of $Rc28 \geq 15$ MPa filling the shaft from its bottom to the level of -1043 m. of different thickness. Due to the properties of the backfill material and the complete filling of the workings, it was assumed that the dams in the shaft inlets at a given level of the liquidated shaft are to carry the load from the shaft backfill during the material solidification. Thickness of the dams built from the side of the shaft inlets was determined as for single-resistance pyramidal mine water dams.

The use of backfill materials for the liquidation of the shaft with parameters and properties listed in Tables 2 and 3 allows assuming that the reconstruction of the original water conditions in the area of the "Jas-Mos" deposit is not expected. Intake for water inflow to the "Jas II" shaft is planned only in the first stage of forming the backfilling column at the level of -800 m. It is assumed that after the material is set, the backfilling column will not have filtration properties.

Stages I and II were completed after the horizontal workings had been secured with dams and insulating plugs by filling them with binder. The binders were **hydraulic, fine-grained, produced on the basis of high-quality cements**. **The binder in bulk** was transported in closed transport, in airtight road tankers, it was delivered directly from the manufacturer, and after being mixed with water, it was fed through pipelines to each level of the liquidation process [7] (Fig. 8)

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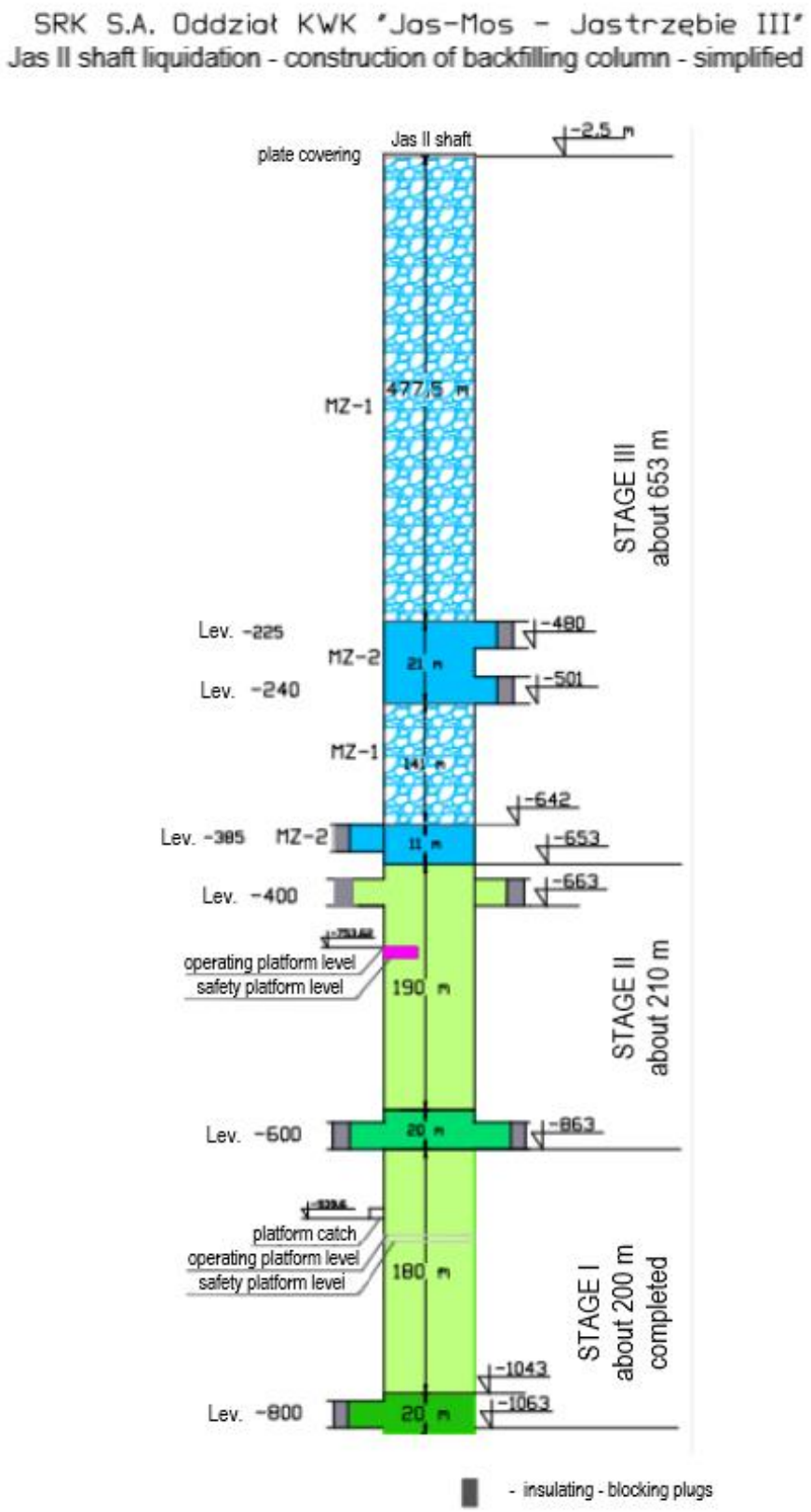

Fig. 7. Schematic diagram of backfilling column for "Jas II" shaft

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Table 2. Requirements for the materials used in liquidation of "Jas II" shaft in stages I and II [8]

MZ-3	Fine-grained, self-levelling, hydraulic mineral-cement binder Compressing strength after 28 daysRc28 > 1,5 MPa Flowability acc. to PN-G-11011:1998 > 130 mm Consistency ready-to-be pumped Output > 0,85 m³/Mg
MZ-4	Fine-grained, self-levelling, hydraulic mineral-cement binder Compressing strength after 1 day Rc1 > 1,5 MPa Compressing strength after 28 daysRc28 > 15 MPa Flowability acc. to PN-G-11011:1998 > 130 mm Consistency ready-to-be pumped Output ≥ 1,20 m³/Mg

Fig. 8. Feeding the hydraulic binder with the use of a mixer

Stage III of the shaft liquidation is planned from June 1, 2023. This stage will use 1.0 MPa and 4.5 MPa mixtures. Production of mixtures from post-mining aggregate with grain size below 63 mm and a hydraulic binder will take place on site, i.e. in the area of the shaft landing. Mixtures will be produced using a mixing device. Aggregate from near-coal shale will be delivered from unburnt heaps or directly from the production from processing plants by trucks, while the hydraulic binder will be delivered by tankers unloaded to the silo of the mixing device. Due to the fact that the liquidation of "Jas VI" shaft was completed in April 2023, was carried out using the same technology, the photos in Fig. 9÷12 show characteristic shots of liquidation of this shaft.

Table 3. Project requirements for materials used for the stage III [8]

MZ-1	Solidified filling mix with near-coal stone aggregate Continuously grained mixture for fraction 0-63 mm Compressing strength after 1 day Rc1 > 0,5 MPa Compressing strength after 28 days Rc28 > 1,0 MPa Soakability acc. PN-G-11011:1998 < 20% Compressibility acc. PN-G-11010:1993 (after 28 days of seasoning and pressure 15 MPa) < 10%
MZ-2	Solidified filling mix with near-coal stone aggregate Continuously grained mixture for fraction 0-63 mm Compressing strength after 1 day Rc1 > 0,8 MPa Compressing strength after 28 days Rc28 > 4,5 MPa Soakability acc. PN-G-11011:1998 < 15% Compressibility acc. PN-G-11010:1993 (after 28 days of seasoning and pressure 15 MPa) < 5%

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Fig. 9. Installation from the feeding side

Fig. 10. Installation of discharging to “Jas VI” shaft

Fig. 11. The mixer controlling panel

Fig. 12. Installation during filling

3. Conclusions

1) Liquidation of the “Leon III” shaft in the “Rydułtowy I” and “Jas VI” shaft in the Ruch “Jas-Mos”, using mixtures of mine stone aggregate and hydraulic binders produced at the liquidation site, gives great certainty as to the quality of the material used due to ongoing monitoring of the liquidation process.
2) The use of mixtures based on mine stone aggregate and hydraulic binder seals the shaft filling very well, what was confirmed by appearance of water above the filling during breaks in liquidation. At the same time, the water collected above the filling was used to bind the supplied backfill material.
3) The shafts liquidated so far with the use of mixtures of mine stone and hydraulic aggregates show very high stability, so far no losses of the backfill material have been found both in the shafts discussed in the article and in the "Chrobry II" shaft of the "Anna" mine, liquidated in 2013.
4) The applied method of liquidation of the "Głowacki" shaft, with the use of post-metallurgical aggregate with strength of Rc 100 MPa and granulation of 31÷63 mm, as well as the use of a mobile screening machine directly in the shaft landing, ensures high certainty of stable water conditions of the liquidated shafts.
5) The materials used in liquidation of mine workings are the materials processed from waste of other technological processes. The use of this type of materials in place of the often used natural

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aggregates, such as dolomite, granite or basalt, is a pro-ecological activity that supports the sustainable development.

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