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The mining of igneous rocks – mining technology exemplified by the "ZALAS" Porphyry Mine

The geological structure and rock resources of the region of Krakow are very diverse. This results from its location at the junction of three structural units as well as from the variety of geological processes that have taken place during their geological history. Devonian to Quaternary formations are visible on the surface, while the rocks found in boreholes are even older.
Igneous rocks in the region of Małopolska (Lesser Poland) are concentrated in a relatively small area. The following rocks have been mined in the past: red porphyry in Miękinia, melaphyre in Regulice, porphyry in Orla. Currently active mines – quarries, which are engaged in continuous exploitation, include the "Zalas" Porphyry Mine in Zalas and the "Niedźwiedzia Góra" Diabase Mine in Tenczynek.

Key words: *igneous rocks, quarry, opencast mines, deposit exploitation system, blasting works*

1. INTRODUCTION

The area where igneous rocks occur in the region of Krzeszowice is relatively small. It should be mentioned that within a radius of several kilometres, there used to be four quarries where rocks of volcanic origin were mined.

Melaphyre was mined in Regulice, whereas porphyry was found in Miękinia.

Currently, igneous rocks are extracted and processed in two mines – quarries belonging to Porphyre and Diabase Mines in Krzeszowice: the "Niedźwiedza Góra" Mine, with a mining tradition of 120 years, and the "Zalas" Porphyry Mine, which has been operating for 50 years.

The "Zalas" Porphyry Mine (Fig. 1) is engaged in the extraction and mechanical processing of porphyry rocks of volcanic origin [1].

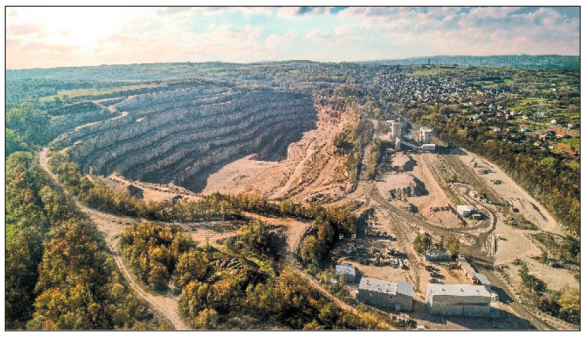

Fig. 1. "Zalas" Porphyry Mine

Porphyry is a very hard, difficult to process volcanic rock. The word "porphyry" comes from the Latin word meaning "purple", which was a noble colour for the Romans. Despite the processing difficulties, porphyry was the most prestigious stone in the Roman Empire, used for making columns, vases, altars, busts and other objects.

It is a rock with very good physical properties, characterized by high strength and frost resistance, as well as high resistance to polishing. Owing to its properties, porphyry is a valued material in the construction of roads and highways. It is usually found in the layers most exposed to abrasion, i.e. in asphalt. In addition, porphyry is widely used as a ballast for both tram and railway tracks. Due to its low water absorption, it is valued as a hydrotechnical stone in water melioration facilities [2].

2. HISTORICAL OVERVIEW

The porphyry quarry in Zalas was exploited in primitive ways by the local population.

The obtained material was used to harden roads as well as for the foundations of cottages and farm buildings.

In the interwar period, crushed stone, stone slabs and cobblestone were produced in this place for the construction of local roads and streets.

In 1972, the finishing works of the new plant were intensified (Fig. 2). At the same time, the staff were trained and the start-up of a new processing plant began.

Fig. 2. Beginning of exploitation

In 1974, the planned annual production capacity of one million tons was exceeded (Fig. 3).

Over the years, the machines for both stone processing and preparatory processes have been modified. Modern technical solutions were applied with the use of both domestic and foreign equipment [1].

In the initial phase of the mine's operation, production was based on the following machines and devices: DCJ jaw crushers, MAKRUM 40.17 jaw crushers, and SYMONS 5.5 cone crushers.

Fig. 3. Millionth ton – 1974

The mined rock was loaded by means of E-302, E-303 single-bucket rope-electric front shovels.

Technological transport is mostly based on Belarusian Biełaz 7523 rigid dump trucks.

The blastholes were drilled with HS-6 drilling rigs driven by WEK-103 mine compressors.

The blasting works were carried out and supervised by the plant's own blasting staff.

Loading of finished materials and auxiliary works were performed by HSW Ł-34 loaders.

3. CHARACTERISTICS OF THE MINE

The "Zalas" Porphyry Mine is a hillslope-deep-seated mining excavation. The overburden at the overburden levels and the deposit at levels I +328, II +308, III +292, IV +273, V +260, VI +240 and VII +220 are mined in a hillslope manner.

The overburden is removed and transported to the landfill in order to uncover the mineral deposit. Both the removal of the overburden and the exploitation of the proper mineral are carried out in parallel to each other on one or several levels.

Mining on several levels enables pre-emptive extraction, ensuring continuous, uninterrupted production.

Individual levels are designed to ensure safe operation of the mining and transport machines located on them. The height of the levels is limited by the reach of the mining/loading machines. The width of the levels must provide sufficient manoeuvring space for excavators or front loaders and haul trucks [3, 4].

Figure 4 shows the characteristic elements of the construction of the slope of an open-pit mine.

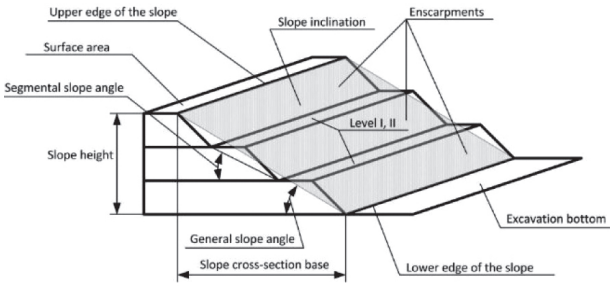

Fig. 4. Elements of the construction of an open-pit mine slope

4. DEPOSIT EXPLOITATION SYSTEM

The deposit exploitation system determines the way the mineral is extracted from the deposit. It includes all elements of the technological process and auxiliary works. In rock materials mines, exploitation systems based on the use of explosive materials (EM) for rock excavation are usually used.

The mining cycle applied in nearly all mines extracting hard-to-mine rocks is based on four basic cycles:

- blasthole drilling,
- blasting,
- loading the blasted rock by means of an excavator or a loader,
- transport to a processing plant or to a mobile crusher.

5. BLASTING WORKS

The rock extracted in volcanic origin rock mines is hard and difficult to mine mechanically. If there are no contraindications, the only solution enabling large-scale extraction and production is drilling and blasting (blasting works) (Fig. 5).

Fig. 5. Blasting works [5]

The type of blasting works depends on a number of factors, such as: blasthole drilling methods, mining and geological conditions, type of final product, available technical facilities.

6. BLASTHOLE DRILLING

Blasting works in the "Zalas" Porphyry Mine are supervised by the manager of the blasting technology department.

He/she plans blasting sites, calculates the required parameters, plans a grid of drills and controls their correct execution.

The duties of the head of the blasting technology department also include supervision of the performance of blasting works by a specialized external entity.

Blastholes are drilled with Furukawa DCR22 (Fig. 6) and HCR 1450 Japanese rigs.

Fig. 6. Furukawa rig in the process of drilling

7. BLASTING

The process of transporting explosive materials (EM) and their loading into the prepared blastholes is performed by the blasting company SSE (Figs. 7, 8) or MAXAM. The blasting company loads the holes in accordance with the adopted guidelines and, next, connects the loaded holes into a blasting grid.

The process of performing blasting works is related to the strict observance of OSH rules.

The firing of explosive charges is preceded by sound signals in accordance with the applicable regulation. Every person on the premises of the mine during blasting works is obliged to comply with the rules of conduct to be observed during blasting. The end of

blasting works is signalled by appropriate sound signals and it is not until the signals have been transmitted that people can leave safe places – shelters.

Fig. 7. Blasting rig produced by SSE [6]

Fig. 8. Blasting works performed by SSE

8. LOADING OF MINED ROCK

In the initial operation of the "Zalas" Porphyry Mine, Skoda E-303 single-bucket rope-electric front shovels were used to load mined rock (Fig. 9).

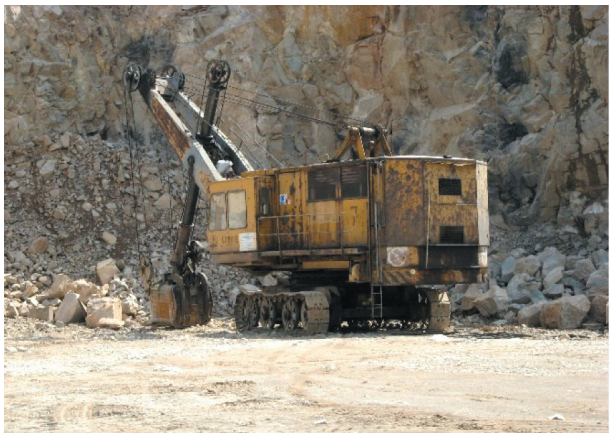

Fig. 9. Skoda E-303 single-bucket rope-electric front shovel

These machines, popular especially in the 1950s in Polish opencast mines of rock materials, were basic loading machines that worked very well in difficult conditions in quarries.

The working mechanisms of the machines were driven by three electric motors.

The excavator was connected by means of a high-voltage (6,000 V) sheathed cable to a transformer located in the rear of the machine cabin.

Currently, the blasted spoil is loaded with single-bucket hydraulic front shovels.

These are more efficient machines, characterized by high performance capabilities, high cost-effectiveness, low failure rate and high flexibility, which means that they can be used for various works. The operation of these machines guarantees the continuity of production.

Currently, Caterpillar (CAT) 385C FS (Fig. 10) and Bola LB-600 single-bucket hydraulic front shovels are used for loading (Fig. 11).

Fig. 10. CAT 385C FS single-bucket hydraulic front shovel

Fig. 11. Bola LB-600 single-bucket hydraulic front shovel

9. MAIN TRANSPORT SYSTEM

In each open-pit mine, the spoil that has been separated from the face is transported to its destination, where it can be stored or further processed. In the “Zalas” Porphyry Mine, the spoil and overburden in spoil tips or excavations is mostly transported on temporary roads.

Temporary technological roads are made on a stone base. The main vehicles used to transport the excavated material are Biełaz rigid dump trucks (Figs. 12, 13).

Fig. 12. Biełaz 7547 rigid dump truck

Fig. 13. Biełaz 75454 rigid dump truck

Permanent technological roads are located between the exploitation levels.

Temporary roads on a soft base (loose overburden level, spoil tip) are hardened with a stone material derived from solid overburden or weathered rock, and, if necessary, refined with aggregate.

The traffic of motor vehicles on exploitation levels, overburden levels, yards and spoil tips is compliant with the rules of the Highway Code. Speed limits, the prescribed direction of traffic and roads without right of way are marked with road signs compliant with the Highway Code [3].

10. PORPHYRY PROCESSING

After blasting, the rock material is transported to the processing plant (Figs. 14, 15).

First, the spoil goes to the first crushing stage (primary crushing) to DCJ jaw crushers, from where it is directed after initial separation to the second crushing stage (secondary crushing), where Metso C-110 jaw crushers and Metso HP-300 cone crushers are installed.

Fig. 14. Mineral aggregates production plant

Fig. 15. Processing plant of the “Zalas” Porphyry Mine

11. ASSORTMENT OFFER

Currently, the assortment offer of the “Zalas” Porphyry Mine is as follows:

Porphyry grits available in many fractions are used for wearing, binding and levelling layers in road construction (in the production of mineral and asphalt mixtures).

Porphyry and mineral crushed stone for road construction and voussoir are designed to be used in the foundations of roads with heavy and very heavy traffic and other engineering structures. In addition, they are used as a subbase of yards and in drainage works.

Stone mixes are used for road works (roadbase and mechanically stabilized subbase, anti-frost layers, concrete). In addition, they are used as a subbase of yards and pavements. They can be used as a levelling – stabilizing layer on the previously applied thicker material (e.g. crushed stone).

Crushed porphyry for the railways (31.5–50 mm), for track works, has a Certificate of Conformity issued by the Railway Institute and a Certificate issued by the Chief Railway Inspector, allowing 31.5–50 mm crushed porphyry to be used as a ballast material for the construction and maintenance of railway surfaces. It is also used in the construction of tram tracks.

The 0–100 mm; 0–200 mm; 0–300 mm mineral blends are materials used for earthworks and embankments.

The sorted crushed stone (90–250 mm) is mainly used in hydrotechnical construction (cladding of river banks, construction of river bars, groynes). It is also used in building works. Due to the high decorativeness resulting from its natural colours, the material is suitable for the construction of fences, flower beds and yards. Its hardness and frost resistance allow the construction of street furniture elements that are resistant to weather conditions.

12. LOADING OF FINISHED MATERIALS

Finished materials are loaded using Caterpillar (CAT) 972H, 972M (Fig. 18), 980K and Hyundai HL-770 wheel loaders.

Finished materials are loaded onto both cars (Fig. 16) and wagons (Fig. 18).

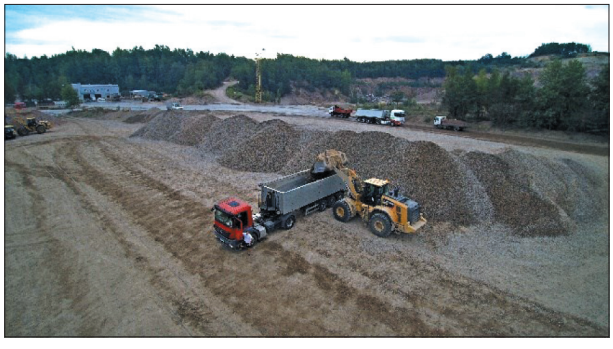

Fig. 16. Loading on a yard with a CAT 972M loader

Apart from loading works, loaders are also used for all kinds of auxiliary works, such as: cleaning works (Fig. 17), the shaping of piles at storage yards, ongoing maintenance of permanent and temporary roads.

Fig. 17. Loaders during cleaning works

Fig. 18. Loading of railway wagons

13. SUMMARY

The processing of volcanic origin rocks is complicated due to their properties.

On the one hand, their parameters are advantageous with regard to their functional properties. However, in processing terms, the same parameters should be considered a drawback. This does not change the fact that despite difficulties generated in the processing of these rocks, they have a wide range of applications in many branches of the construction industry, as well as road and railway engineering.

A wide range of aggregates produced in the "Zalas" Porphyry Mine are used in road and railway engineering, the construction industry and in landscape architecture.

They are mainly used for:

- the construction of railway and tram tracks,
- subbase of roads and yards,
- the construction of embankments,
- land stabilization,
- hardening the surface of yards,
- soil replacement,
- production of bituminous masses and cement concretes.

References

[1] Molenda R., Sierpień M., Tarkowski R.: *Kopalnie Porfiru i Diabazu Sp. z o.o. w Krzeszowicach*, Krzeszowice 2015.
[2] Zako Zaczernie: *Co to jest porfir*, https://www.kamieniarstwo.rzeszow.pl/co-to-jest-porfir/ [30.11.2022].
[3] Bęben A.: *Legendarne maszyny. Z historii koparek łyżkowych do procesów wydobywczych w odkrywkowym górnictwie skalnym*, www.kieruneksurowce.pl/Resources/art/2581/bmp_4b94f0-98deb6f.pdf [30.11.2022].
[4] *Plan of the "Zalas" Porphyry Mine Operation* [unpublished].
[5] E-górnik – Serwis górnika odkrywkowego: *Nowe rozporządzenie strzałowe*, https://egornik.pl/nowe-rozporzadzenie-strzalowe/ [30.11.2022].
[6] SSE Polska: *Materiały wybuchowe luzem*, https://www.sse-polska.pl/produkty/materialy-wybuchowe-luzem [30.11.2022].

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