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TECHNOLOGICAL AND ECONOMIC JUSTIFICATION OF DIMENSION STONE EXPLOITATION TECHNIQUES IN UKRAINIAN GRANITE OR SIMILAR QUARRIES

Purpose. To determine the most acceptable primary-cut techniques at high-strength dimension stone deposits for Ukrainian shield conditions in terms of production efficiency. The use of these techniques would maximize the productivity of stone companies and maintain the rock mass integrity.

Methodology. The data were collected at several dimension stone deposits in Zhytomyr region. A total of several blocks with the volume 150-200 m^3 (height 3-4 m) were investigated. Trade blocks volumes fluctuated within 1-5 m^3. The primary cut of commercial blocks was analyzed, using respectively 4 alternative techniques and several their combinations. Operating costs, time expenditures, amortization, labor costs, services costs and expenditure of energy were analyzed and considered.

Findings. The parameters to be considered in primary cut technologies selection were justified. There were determined basic extraction costs, advantages and disadvantages of each technique. The exploitation costs for 1 m^3 of dimension stone were calculated afterwards.

Originality. Main primary cut techniques were justified in terms of technological and economic benefits for dimension stone quarries in the Ukrainian shield conditions.

Practical value. Data obtained in this study could be taken into account by similar dimension stone quarries in selection of techniques employed in some basins of dimension stone quarries in Ukraine. The use of offered techniques would allow to reduce the costs on primary cut techniques selection, achieve the largest stone output and the rock mass integrity preservation.

Keywords: dimension stone; primary cut techniques; diamond wire cutting; blasting techniques; chemical oxygen generators; exploitation economics.

The main conditions for the new technology success are its simplicity and low price in comparison with other techniques that have been previously used. However, the following significant aspects must be taken into account: utilization safety, universality, adaptation capability for the rock mass characteristics etc.

Primary cut is the first stage of the dimension stone production process. To assess its efficiency it is necessary to calculate the energy consumption, consumables quantity, mechanisms amortization, human resources costs that are variable depending on the technology type. The aim of the work is to assess the unit cost value for 1 m^3 of dimension stone extraction (EUR/m^3) using different techniques.

Techniques investigations were performed at several dimension stone quarries in Zhytomyr region (Kamianobridske North gabbro deposit, Chovnivske syenite deposit, Volodarsko-Volynske gabbro deposit, Osnykivske labradorite deposit). Several blocks of 150-200 m^3 were cut and then splitted into trade blocks of 1-5 m^3. Several primary cut techniques (drilling + detonating cord + black powder; drilling + detonating cord;

diamond wire sawing; chemical oxygen generators «Rocksplitter») were compared. Mechanisms` amortization, human resources costs, power resources and service costs were then taken into account. The principal costs` types and mission of them are shown in table 3.

Operating costs for each exploitation technique are calculated according to the formula 1.

$$O_c = \frac{n_w * T * s_c + (c_c * T_{tot}) + (n_{eq} * T_{tot} * A)}{V_{block}}, \text{EUR}_{м^3} \quad (1)$$

where: n_w – number of workers;
– time for 1 block primary cut, год;
s_c – salary for 1 worker, EUR/h;
c_c – consumables costs, EUR/h;
T_{tot} - the total operating time of each equipment unit, h;
n_{eq} - the number of equipment units;
– amortization costs, EUR/h;
V_{block} - block volume, m^3.

Primary cut costs changes for 1 m^3 of dimension stone is shown in Fig. 1.

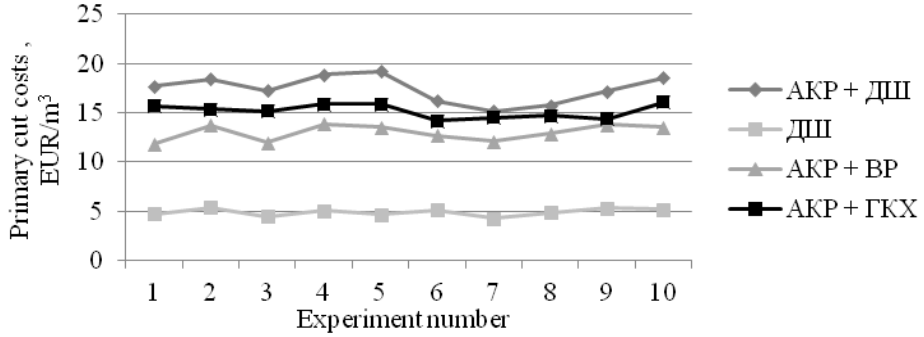

Fig. 1. Primary cut costs for 1 m^3 of dimension stone:
АКР+ДШ - diamond wire saw + detonating cord; ДШ - detonating cord;
АКР+ВР - diamond wire saw + explosives; АКР+ГКХ - diamond wire saw + chemical oxygen generators «Rocksplitter».

Specific costs for primary cut using explosives (detonating cord) is approximately 5 EUR/m^3, while for diamond wire sawing + detonating cord the cost is 17,5 EUR/m^3 in average. The use of detonating cord (DC) is the cheapest, while diamond wire saw + detonating cord (DWS+DC) is the most expensive technique according to the chart. Diamond wire saw + chemical oxygen generators «Rocksplitter» technique (DWS+COG) is slightly cheaper, that justifies its spread at Ukrainian dimension stone companies.

Primary cut costs for DWS+DC and DC techniques are shown in Fig. 2 as a function of trade blocks value. The two lines intersection point defines a transition point in which the use of the DWS becomes more beneficial with block value decreasing in comparison with the DC technique.

The use of black powder (BP) does not provide high process automation. Hence, it is necessary to take into account the significant labor costs. In addition, the problems

related to the noise, vibration and considerable separation of stone fragments limit this method use, especially in the close residential districts or motorroads allocation.

The average service life of modern diamond wires is 10-12 m^2/m in gneiss extraction. Diamond wires are not still fully competitive in comparison with detonating cord for hard rock cutting. However, there is a tendency to increase the diamond wire saw application on various technological operations [1].

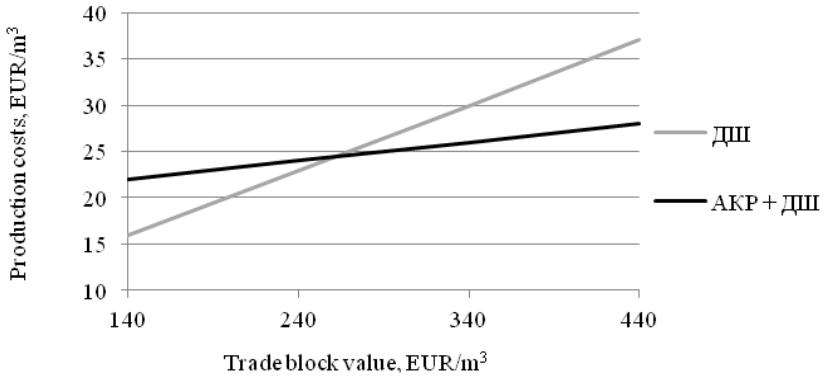

Fig. 2. Production costs change according to the trade block value

Conclusions. The explosives use is the most traditional, verified and "cheap" for dimension stone extraction. However, not only low financial costs, but also high-quality final product output should be considered, i.e. which stone volume will be really suitable for processing [1].

Comparison of the basic dimension stone exploitation techniques is shown in Tab. 1.

Table 1

Comparative analysis of the basic primary cut techniques` qualitative characteristics at dimension stone quarries

Characteristics	DC	DWS	DWS +DC	BP	BP+DWS	DWS+ COG
Surface quality	-	+	+	-	+	+
Productivity in rock mass, m^2/h	+ (7-10)	± (1-4)	+ (10)	+ (7-10)	+ (10)	+ (10)
Power consumption	-	±	±/-	-	±/-	±/-
Capital outlays	-	±	±	-	±/-	±/-
Tooling investment	-	+	+	-	+	+
Environmental impact	+	-	±	+	+	-
Waste volume (saw-cut, block surface damage), %	7-10	2-2,5	5	10-15	7-10	3-4
Mechanization level	-	±	±/-	-	±/-	±/-
Safety of works	-	±	±	-	-	±
Water consumption	-	±	±	-	±	±
Impact on the rock mass	±	-	±	+	±	-

"-" - low; «±» - average; "+" – high

Nowadays there is a need to use the techniques fitting a relatively low price and targeted for high-quality products in accordance with national and European standards in Ukraine. The low prices for technologies are often neglected in the world practice:

the maximum blocks yield and minimal waste volumes are important due to the dimension stone rareness and reserves scantiness [2].

For example, Italian enterprises are sometimes forced to separate blocks of 500 m length and of 25 m^2 diameter. Production costs for such blocks could be about 500000 EUR. However, the percentage of "useful" material is obtained the highest that ultimately results in the greatest profit in the result of the trade blocks sale. Consequently, the cheapest primary cut technique is not always the best. Thus, more sophisticated and, consequently, more expensive techniques becoming increasingly important in dimension stone sector.

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