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THE PROFITABILITY OF DIMENSION STONE DEPOSIT EXPLOITATION IN RELATION TO THE COEFFICIENT OF UTILIZATION

RENTABILNOST EKSPLOATACIJE LEŽIŠTA ARHITEKTONSKO-GRAĐEVNOG KAMENA OVISNO O KOEFICIJENTU ISKORIŠTENJA

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Abstract

Dimension stone is a highly valuable raw mineral material per unit of product. From the past experiences and literature it is known that for a certain quantity of commercial blocks, dimension stone a significantly larger volume of natural (raw) rock mass, should be dug (cut) out. Stone residue, resulting in gaining the commercial dimension stone blocks, is usually less value per unit of product. Profitability of the dimension stone exploitation in a deposit is directly dependent on the rock coefficient of utilization. It is therefore a priority task and a challenge to improve the efficiency of dimension stone deposits utilization and reduce the accumulation of mineral residue that would ultimately increase profits. Dependence of profitability on coefficient of utilization of dimension stone deposits can be best expressed by numerical models, as shown in this paper.

Sažetak

Arhitektonsko-građevni kamen je izuzetno vrijedna mineralna sirovina po jedinici proizvoda.

Iz stručne literature i prakse poznato je da je za određenu količinu komercijalnih blokova arhitektonsko-građevnog kamena potrebno eksploatirati znatno veći obujam stjenske mase u sraslom stanju. Kameni ostatak, nastao kao rezultat dobivanja komercijalnih blokova arhitektonsko-građevnog kamena, obično ima manju vrijednost po jedinici proizvoda. Isplativost eksploatacije arhitektonsko-građevnog kamena izravno je ovisna o koeficijentu iskorištenja ležišta. Stoga je prioritetni zadatak i veliki izazov poboljšati stupanj iskorištenja ležišta arhitektonsko-građevnog kamena te smanjiti količinu kamenog ostatka i time u konačnici povećati profit. Ovisnost profitabilnosti o koeficijentu iskorištenja ležišta arhitektonsko-građevnog kamena najbolje se može izraziti preko numeričkih modela, kao što je prikazano u ovom radu.

Introduction

For a deposit of natural stone to be ranked as a deposit of dimension stone, it must meet certain criteria (Dunda, S., 2003). There are primarily related to decorative criteria (colour, texture, features of components out of which rocks are built...), technical criteria (physical-mechanical properties of rocks), geologic criteria (frequency and location of discontinuities), the technological criterion (workability of the rock mass processing, i.e. cutting, polishing, grinding...).

Undoubtedly, the listed criteria under which a deposit of natural stone is determined (identified) as the deposit of dimension stone, jointly determine the material value (market price) of commercial blocks, but also the costs of exploitation of dimension stone. In other words, these are the criteria determining economic feasibility of exploitation of dimension stone in a deposit.

Further logical thinking leads to the assumption that all the above criteria may be reduced under the same heading and this is the economic criterion. Therefore, in order to value a deposit of natural stone as dimension stone deposit, it must meet the economic criteria; that is, the exploitation of that deposit must be profitable.

Profitability of the exploitation of dimension stone in a deposit directly depends on coefficient of utilization of that deposit, and any activity that can improve the exploitation of deposits of dimension stone may have a decisive impact on the economy of operations of the company which is engaged in the exploitation of dimension stone.

From the literature and practice it is well known that for a certain quantity of commercial blocks of dimension stone a significantly larger volume of rock mass, in natural condition, needs to be dug up (cut) (Galić, I., 2003).

Importance of ratio of the usable quantities of commercial dimension stone blocks and the total quantity of excavated rock is most vividly displayed in the case studies and models.

For orientation purposes, for 1,000 m^3 of dimension stone commercial blocks, with exploitation losses of 10% and correctional coefficient $k_c = 0.18$, a 6,173 m^3 of natural rock mass needs to be cut out.

The further work will analyse the impact of coefficient of utilization on profitability of dimension stone exploitation, in other words the sensitivity of mining project of dimension stone exploitation regarding the coefficient of utilization.

Basic concepts and terms of dimension stone reserves definition

In expert literature, and the Croatian legislation, there is some controversy and disagreement about the definition of concepts and calculation degree of utilization of dimension stone deposits. Recently, the degree of utilization of dimension stone deposits is usually defined by the coefficient of utilization and correctional coefficient and coefficient of exploitation losses.

Model 1 - Calculation of the reserves from the total quantity of rock

Coefficient of utilization (k_u) is, in general, the ratio of usable substances of raw mineral materials and the total quantity of excavated rock. In the case of dimension stone, the coefficient of utilization is the ratio of the volume of commercial blocks and the total volume of the rock mass that needs to be cut out for a commercial blocks to be formed (Galic et al, 2011; Dragicevic et al, 2009). The volume of commercial blocks is actually a volume of extraction reserves in a deposit. The coefficient of utilization is obtained by calculation from the expression (1).

$$k_u = \frac{O_{cb}}{O_t}, \quad m^3/m^3 \qquad (1)$$

Where is:
O_{cb} – volume of commercial blocks (m^3)
O_t – total volume of cut rock mass (m^3)

Correctional coefficient (k_c) is the loss of rock mass through the surface waste (unless separately calculated), rock mass in fragmented areas, and non-commercial pieces of stone. The correctional coefficient expresses the loss of rock mass of dimension stone caused by the conditions prevailing in the deposit, and it is used in calculating the balance reserves, according to the expression:

$$Q_{bal} = Q_t \times k_c, \ m^3 \qquad (2)$$

Where is:
Q_{bal} - balance reserve
k_c - correctional coefficient

For a large number of dimension stone deposits in the Republic of Croatia, waste rock located on top of exploitation reserves of rock mass is not separately calculated and is shown trough correctional coefficient. Usually this is the case in the deposits with no surface waste rock in the classical meaning of the word (humus, clay, earth, etc.) but it is the karst surface area that is not clearly separated from the exploitation rock parts (Archives, 2011).

When large quantities of waste rock are located on top of exploitation rock mass, the waste rock is usually calculated separately.

The correctional coefficientis directly dependent on geological conditions of deposit in which the exploitation of dimension stone is performed, and primarily on thickness of waste rock, structural-tectonic set of deposit, the size of rocks that have commercial value, etc.

The correctional coefficient is different for every dimension stone deposit, and in the Republic of Croatia, it is usually in the range between 0.18 and 0.22, extremely up to 0.54 (deposit “Kanfanar” in Istria).

Exploitation loss (E_l) is loss of rock mass caused by destruction of rock mass by various tools (chain saw, diamond wire saw, etc.) and it can be precisely calculated by statistical analysing data. Substituting exploitation loss in expression (2) we get the equation for calculating the exploitation reserves;

$$Q_{eks} = Q_{bal} - E_l, \ m^3 \qquad (3)$$

Quantity of exploitation losses, in contrast to correctional coefficient, is not dependent on deposit’s geological conditions in which the dimension stone exploitation is preformed but primarily on the thickness of cutting elements of chain saw and diamond wire saw, and ranges from 8 to 10% of the balanced reserves. Exploitation loss is calculated by the expression:

$$E_l = Q_{bal} \times p, \ m^3 \qquad (4)$$

Where is:
p – exploitation share loss, %.

Thus the difference between total cut volume of rock mass and volume of obtained dimension stone commercial blocks is shown through coefficient of utilization which integrates correctional coefficient and exploitation losses according to the expression (1).

Model 2: Calculating the total quantity of rock according to the planned quantity of blocks

In the introductory section the expressions and the process of calculating the exploitation reserves for any raw mineral material, including dimension stone, are clearly defined. However, when it comes to calculating capacity or planned production, the procedure is completely inverted.

In the Model 2 the assumed yearly dimension stone production is 1,000 m^3, the correctional coefficient k_c = 0.18 and exploitation loss p = 10%. The main task is to determine the total volume of the rock mass that needs to be cut out annually in order to obtain 1 000 m^3 of commercial dimension stone blocks.

Since the planned annual production is actually an annual exploitation reserves in the quantity of 1 000 m^3, it is therefore necessary to add that the exploitation losses and the annual balance reserves will be calculated by the folowing expression:

$$Q_{bal} = Q_{cb} \times \frac{100}{100\text{-}p}, \text{ m}^3 \quad (5)$$

It follows that the annual balance reserves are:

$$Q_{bal} = 1\,000 \times \frac{100}{100\text{-}10} \; 1\,111 \text{ m}^3$$

From that exploitation losses are:

$$E_l = 1\,111 - 1\,000 = 111 \text{ m}^3$$

To calculate the total annual quantity of the rock mass to be cut (dug) out it is necessary to predict the loss of rock mass through correctional coefficient in the form of surface waste rock, rock mass in fragmented areas.Therefore the total quantity of excavated rock mass will be:

$$Q_t = \frac{Q_{bal}}{k_c}, \text{ m}^3 \quad (6)$$

It follows that the total annual quantity is:

$$Q_t = \frac{1111}{0{,}18} \cong 6\,172 \text{ m}^3$$

Of which the stone waste is:

$$Q_{sw} = Q_t \text{-} Q_{bal} = 6\,172 - 1\,111 = 5\,061 \text{ m}^3$$

Coefficient of utilization in the Model 2 is:

$$k_u = \frac{O_{kb}}{O_u}$$

$$k_u = \frac{1000}{6172} \cong 0{,}162$$

Sensitivity of dimension stone exploitation regarding the correctional coefficient

The utilization coefficient has the crucial influence on profitability and investment return and operation of company which carries out exploitation of dimension stone in the deposit.

Coefficient of utilization is different for every deposit, and in the deposits in the Republic of Croatia it is usually in the range between 0.14 and 0.20, and exceptionally more.

Following the previously stated report, further analysis of dependence of investment profitability on the coefficient of utilization shows the economic sensibility of mining operation when the coefficient of utilization ranges from 0.14 to 0.20.

The input parameters of the test model

For the most realistic analysis a specific example from practice will serve as test model and the data from Supplementary mining project of dimension and technical building stone exploitation on deposit field "Dolit", which was vetted by relevant government bodies.

The basic input data taken from test model design, on which the analysis of the dependence of investment profitability on the correctional coefficient was done, are as follows:

- Planned production is 1,560 m^3 of commercial blocks;
- average market price of commercial blocks of all categories is HRK 2,200;
- total annual revenue from the block sale is HRK 3,432,000;
- initial investment amount is HRK 8,640,000;
- annual cost of exploitation for gaining 1,560 m^3 of commercial blocks is HRK 3,033,137;
- correctional coefficient is k_c= 0.20;
- exploitation losses E_l = 10%;
- coefficient of utilization k_u = 0.18.

Table 1 shows the value of investment in the preparatory work; dimension stone exploitation equipment and the facilities planed in the test model. The data are presented solely for the reason of accessing input data upon which the analysis of dependence of investment profitability on correctional coefficient was done, with no intention to review the investment in preparatory work, equipment and facilities planed in the test model.

Table 1. *Investment value in preparatory work, exploitation equipment and facilities planed in test model*

Tablica 1.*Vrijednost ulaganja u pripremne radove, opremu za eksploataciju i objekte predviđene projektnim rješenjima iz ispitnog modela*

Number	Type of machinery and equipment	Characteristics	Number of units	Unit value (HRK)	Total (HRK)
Machinery					
1.	Transformer station, other equipment	250 kW	1	1,000,000	1,000,000
2.	Diamond wire saw	37 kW	2	120,000	270,000
3.		45 kW		150,000	
4.	Chain saw	45 kW	1	600,000	600,000
5.	Drilling machine	75 kW	1	500,000	500,000
6.	Drilling probe	7,5 kW	1	100,000	100,000
7.	Compressor	22 kw	1	140,000	140,000
8.	Truck	205 kW	1	800,000	800,000
9.	Loader	200 kW	1	1,500,000	1,500,000
10.	Excavator	213 kW	1	2,500,000	2,500,000
11.	Hydraulic hammer	5,000 – 6,000 J	1	200,000	200,000
12.	Water pump	200 l/min,	1	30,000	30,000
13.	Break off machines		1	20,000	20,000
14.	High-pressure pump		1	30,000	30,000
Total (HRK)				**7,690,000**	
Facilities, infrastructure, land acquisition, reclamation, documentation					
15.	Infrastructure investment	-	-	100,000	100,000
16.	Fence around surface mine	1,000 m	-	100,00	100,000
17.	Other smaller facilities	-	-	50,000	50,000
18.	Study, projects	-	-	100,000	100,000
19.	Land purchase	5,000 m^2	-	20 kn/m^2	100,000
20.	Rehabilitation	40,000 m^2	-	10 kn/m^2	400,000
21.	Other investment				100,000
Total (HRK)				**950,000**	
Overall				**8,640,000**	

Table 2 shows the calculation of production price and annual exploitation costs of dimension stone planned in the test model, which are partly altered to comply with the new legal requirements (exploitation compensation and compensation for the occupied area of the approved exploitation field). These data are solely shown for reasons of accessing the input data on which the analysis of investment profitability depending on the correction coefficient was made. Also, these data may serve as reference data in reviewing economic-financial issues and finding the best solution, and in final making the decision to invest in the dimension stone exploitation.

Calculation of production price and annual dimension stone exploitation expenses planned in the test model was calculated in the way that the workforce was determined based on the number of wages and amortization is calculated as 10% equipment value. Spare parts costs are calculated as 6% from machinery amortization. Investment and on-going maintenance was calculated as 10% of the total amortization. Annual gross salary is taken as HRK 60,000 per employee. To achieve the required capacity of surface mine it is necessary to employ 9 employees.

Table 2. Production price calculation and annual exploitation costs

Tablica 2. *Proračun proizvodne cijene te godišnjih troškova eksploatacije*

Type of materialand equipment		Unit value	Value (KRK)	Consumption Unit value per year	Cost HRK/year
	Personal income (9 employees)	wages	-	-	540,000
Energy+water	Diesel	kg	6	57,400	344,400
	Motor oil	kg	10	1,148	11,480
	Differential oil	kg	15	287	4,305
	Other lubricants	kg	15	115	1,725
	Electrical energy	kWh	0,6	77,552	46,531
	Water	m^3	20	1,310	26,200
Other material and equipment	Drilling head	piece	7,000	1	7,000
	Drilling rod	piece	10,000	2	20,000
	Rotary Hammer	piece	10,000	-	-
	Bucketteeth	piece	1,200	5	6,000
	Rubber loader wheels	4 piece /1600 h	10,000	1	10,000
	Chainsuits (chain, cutters, inserts)	4 piece /1600 h	10,000	2	20,000
	Truck tyres	6 piece /3500 h	4,000	-	-
	Drilling head	piece	7,000	20	14,000
	Diamond wire	m	400	800	320,000
	rubber coating	piece	800	200	80,000
	Secondary round	piece	1,500	60	90,000
	Pillows (Hydro bags)	piece	300	400	120,000
Total (HRK)					**1,661,640**
Maintenance and renewal	Amortization	% of value	10	-	864,000
	Spare parts	% amortization	6	-	46,140
	Investment and on-going maintenance	% amortization	10	-	76,900
Total (HRK)					**987,040**
Preparation and sanitation	Previous investments	% from prev, inv,	20	-	5,000
Total (HRK)					**5,000**
Fees	Mineral resource exploitation fee	% from UP	5		171,600
	Exploitation field occupation fee	800 HRK/ha	16 ha		12,800
	Mineral reserves renewal				108,656
	Water fee	% from UP	-	-	-
	Insurance	% from equipment value	1	-	86,400
	Department for Environmental Protection	% from total income	-	-	-
Total (HRK)				**379,46**	
Overall (HRK)				**3,033,137**	

Output parameters for the test model

Based on the input parameters of the test model the total volume of rock mass is calculated which should be cut out in order to get the planned 1,560 m^3 of commercial blocks. Based on the exploitation loss E_l = 10% and correctional coefficient k_c = 0.20 it was calculated that 8,666.67 m^3 should be cut out. With these parameters coefficient of utilization is k_u = 0.180.

Analysis in Table 3 is created under the assumption that employees, machinery and equipment per year could cut out up to 8,666.67 m^3 gross volume of the rock mass and that the selling price of 1 m^3 block of all categories is fixed to the amount of HRK 2,200.00.

Table 3 shows profitable threshold of mining company which is carrying out dimension stone exploitation; under the given conditions on site it is when coefficient of utilization is in the range from 0.162 to 0.153.

It is significant to notice that the increase of coefficient of utilization from k_i = 0.180 to k_i= 0.207, that is, the increase of utilization of rock mass by 2%, increases the annual gross profit of the mining company from HRK 398,864.32 to HRK 913,664.52, that is the annual income is more than doubled.

Should the coefficient of utilization decrease from k_i= 0.180 to k_i= 0.162, that is, when utilization of rock mass is decreased by less than 2%, the annual profit of the mining company would decrease from HRK 398,864.32 to HRK 55,664.19, that is, the annual income would decrease by about eight times.

Diagrammatic presentation of business success depending on the coefficient of utilization is shown in Diagram 1.

Table 3. Output parameters of the test model

Tablica 3. *Izlazni parametri na testnom modelu*

Total volume – gross value (m^3)	Exploitation losses E_l (%)	Correctional coefficient k_c	Coefficient of utilization k_u	Volume of the obtained block – net (m^3)	Total cost of the gross cut-out volume (HRK)	Net cost of obtaining 1 m^3 block (HRK)	Market price of 1 m^3 block	Total revenue UP (HRK)	Profit (HRK)
8,666.67	10	0.23	0.207	1.794	3,033,137.00	1,690.71	2,200.00	3,946,801.52	913,664.52
8,666.67	10	0.22	0.198	1.716	3,033,137.00	1,767.56	2,200.00	3,775,201.45	742,064.45
8,666.67	10	0.21	0.189	1.638	3,033,137.00	1,851.73	2,200.00	3,603,601.39	570,464.39
8,666.67	10	0.20	0.180	1.560	3,033,137.00	1,944.32	2,200.00	3,432,001.32	398,864.32
8,666.67	10	0.19	0.171	1.482	3,033,137.00	2,046.65	2,200.00	3,260,401.25	227,264.25
8,666.67	10	0.18	0.162	1.404	3,033,137.00	2,160.35	2,200.00	3,088,801.19	55,664.19
8,666.67	10	0.17	0.153	1.326	3,033,137.00	2,287.43	2,200.00	2,917,201.12	-115,935.88
8,666.67	10	0.16	0.144	1.248	3,033,137.00	2,430.40	2,200.00	2,745,601.06	-287,535.94

Business profitability depending on the coefficient of utilization

Profitability is defined as an indicator of economic operating performance and is commonly based on loss and profit data. The most commonly used formula is:

$$P = \frac{PI}{TC}$$

Where is:

TI – total income (HRK),

TC – total costs (HRK).

Obtained result indicates:

P > 1 – profitable business,

P = 1 – business at the border of profitability,

P < 1– business is not profitable.

Determing the profitability threshold by computation

Determing business profitability threshold of mining company which carries out dimension stone deposit exploitation, in which the gross volume of 8,666.67 m^3 of rock mass could be cut out and the selling price of the 1 m^3 block of all the categories is HRK 2,200.00, may be done by computation or graphically.

To determine the profitability threshold, first the smallest quantity of commercial blocks should be calculated, which should be obtained from the given total volume of rock mass (in our case 8,666.67 m^3), the sale of which at market price (in our case HRK 2,200.00) would make the mining company profitable. In other words, we need to calculate the minimum quantity of blocks whose exploitation costs will be equal to revenue from their sale.

Following the stated, we set this relationship:

$$Q_{min} = \frac{T_c}{V_a}$$

Where is:

- Q_{min} – *minimal quantity of blocks from the total volume for company to be profitable (m³)*
- T_c – *total volume exploitation costs (HRK/m³)*
- V_a – *average sale value of 1 m³ block (HRK/m³)*

Substituting the output values obtained from the test model we obtain:

$$Q_{min} = \frac{3.033.137.00}{2.200.00} = 1379\ m^3$$

Thus, the minimum quantity of blocks that must be cut out from the total volume of 8,666.67 m³ and the average sale price of HRK 2,200.00, which put the company on the border of profitability is 1,379 m³.

By setting the relationship between minimum quantities of blocks that need to be obtained from the total volume so the business is profitable (Q_{min}) and the total volume (Q_{uk}) from which the minimum quantity of blocks was obtained, gives us marginal coefficient of utilization with which the business will be marginally profitable.

$$k_{mu} = \frac{Q_{min}}{Q_{uk}}$$

$$k_{mu} = \frac{1\ 379}{8\ 666{,}67} = 0{,}159$$

Thus, marginal coefficient of utilization – profitability threshold, at the fixed total volume of 8,666.67 m³ and fixed price of HRK 2,200.00 is k_{mu}= 0.159.

Marginal correctional coefficient of the coefficient of utilization k_{mu} = 0,159 and exploitation loss E_l=10% is:

$$k_{mu} = \frac{Q_{min} \text{ x } (\frac{100}{100-Ei})}{Q_{uk}}$$

$$k_{mu} = \frac{1379 \text{ x } (\frac{100}{100-10})}{8\ 666{,}67} = 0{,}177$$

Therefore, profitability threshold of mining company operations during the dimension stone exploitation with the fixed total volume of 8,666.67 m³ and fixed block price of HRK 2,200.00 per 1 m³ occurs when the coefficient of utilization k_u = 0.159 and correctional coefficient k_c = 0.177. Reducing the coefficient of utilization under 0.159 or correctional coefficient under 0.177 the mining company would operate with a loss.

Determing the profitability threshold graphically

Diagram 1 clearly shows the success of the mining company operations during dimension stone exploitation considering the coefficient of utilization. The diagram clearly shows that the business will operate with the minimum annual revenue of HRK 55,664.19 at coefficient of utilization k_u = 0,162, but with k_u = 0,153 mining company will create the annual loss of HRK 115,935.88.

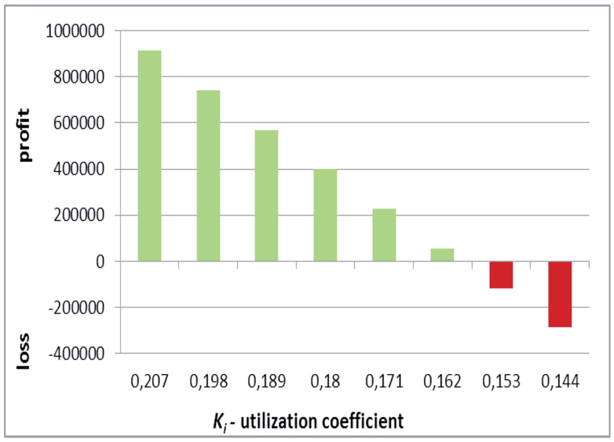

Figure 1. Diagram of business success depending on the coefficient of utilization

Slika 1. *Uspješnost poslovanja ovisno o koeficijentu iskorištenja*

Intersection of lines that show total annual costs (*TI*) and total annual revenue (*TC*) represents the mining company's business profitability. Diagram 2 clearly shows that total annual costs are fixed (HRK 3,033,137), and total annual revenue is reduced according to the reduction of coefficient of utilization.

Diagram 2 shows the profitability threshold of mining company business during dimension stone exploitation with the fixed total volume of 8,666.67 m³ and fixed block price of HRK 2,200 per 1 m³ where *TC* is total annual costs and *TI* total annual profit.

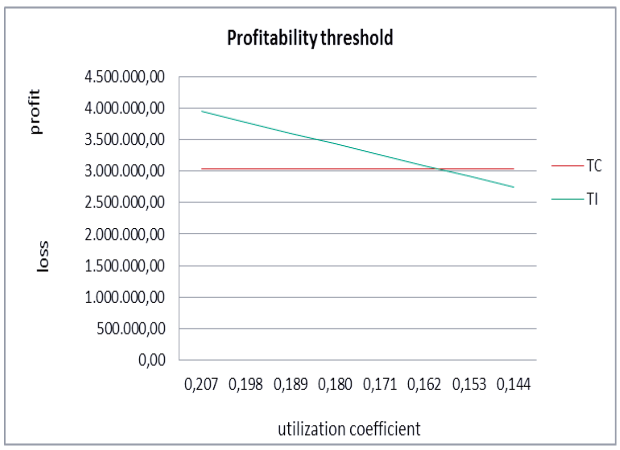

Figure 2. Diagram of profitability threshold

Slika 2. *Prag ekonomičnosti*

Diagram 3 shows the direct dependence of exploitation costs charging the product unit (H/m³) on the coefficient of utilization where the gross cut-out mass is limited to 8,666.67 m³ due to the capacity of the available machinery.

It is evident from Diagram 3 that with a fixed annual production, exploitation costs charging the product unit (HRK/m^3) increase almost proportionally as the rock mass coefficient of utilization is reduced.

With coefficient of utilization k_u= 0.207, exploitation costs are approximately 1,700.00 HRK/m^3, while with coefficient of utilization k_u= 0.144 exploitation costs are approximately 2,500.00 HRK/m^3.

Figure 3. Coefficient of utilization dependence on exploitation cost

***Slika 3.** Uspješnost poslovanja ovisno o koeficijentu iskorištenja*

Conclusion

This paper analyses the economic justification of dimension stone exploitation on the deposit, depending on the coefficient of utilization of that deposit which combines the correctional coefficient and exploitation losses.

This analysis showed a very large dependence of mining operation of dimension stone exploitation on the coefficient of utilization. This dependence is so large that it is recommended to express the coefficient of utilization with three decimal digits.

A real example from practise was taken as the test model, with planned annual exploitation of 1,560 m^3 of commercial blocks of all types and average market price of commercial blocks of all types in the amount of HRK 2,200.00. The planned coefficient of utilization on the deposit is k_u= 0.18 (correctional coefficient, k_c = 0.20, exploitation loss E_l = 10%). Based on the design solutions total gross cut out volume of the rock mass is 8,666.67 m^3.

Based on the analysed data from the test model, the obtained results can serve as reference data for making the final decision on economic justification of dimension stone exploitation in the deposit, but also for the optimization of investment, designed capacity and necessary equipment.

All the above shows the necessity of extremely cautious and detailed planning of the dimension stone exploitation in the deposit.

Particular attention should be paid to dimension stone deposits, the interpretation of research data, determination of rock structural set, space orientation of discontinuities and other data that influence the coefficient of utilization.

Therefore, before exploitation, it is necessary to explore and learn about the planned deposit, in other words to determine the coefficient of utilization as accurately as possible.

Mining engineers and geologist, who are engaged in exploration and exploitation of dimension stone, are the only ones capable and authorized to precisely determine the coefficient of utilization in the new dimension stone deposit, by using the existing and recognized methods (e.g. method of linear and spatial integrity), but also new scientific methods.

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