



TECHNO – ECONOMICAL ANALYSES OF THE METHODS FOR PRODUCING OF DIMENSION STONE BLOCKS

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Abstract

The Modern way of exploitation of dimension stone is offering possibilities, technologies and methods for economical and high effective production of the final product into quarry with surface exploitations. It is very important during projecting of mine for exploitation of dimension stone to determine parameters of machines and technologies which may be used for final definition which technology is going to be used.

Until now known methods for exploitation of dimension stone are offering many varieties for making choice of technology and machines which can be used for exploitation of dimension stone. Technical characteristics of the chosen machines given by the manufacturers, but also and experience data from using those machines in other mines are offering possibilities during determining of technology and machines for exploitation of dimension stone.

During the process of deciding which technology is going to be used, there is appropriate usage of multi criteria methods for optimization.

KEYWORDS: *Dimension stones, exploitation, methods, production, drilling machine*

1. INTRODUCTION

The choice of technology and methodology for stone blocks and reduce their costs and optimizing them has always posed a major problem.

This paper will be analyzed the factors that affect the choice of technology and methods for getting the stone blocks using the information and parameters from machines that will be used, the cost of energy at the present time, spare parts, normative materials associated with their

exploitation and technical characteristics of machinery and equipment for mining of stone blocks.

System optimization consists in choosing a solution that would be optimal in comparison with other alternatives offered. Calculation parameters are determined based on researched data and performed statistical analysis of the results of tests of capacities of machines and equipment.

Multi criteria optimization provides the ability to optimize not only major function (e.g. minimum cost for stone blocks), but also including other features with a different character.

The optimization of the offered variants of exploitation for stone blocks are made by the method of PROMETHEE I and PROMETHEE II.

2.0 Methods for exploitation of the architecture - decorative stone blocks (AUK)

- Getting the stone blocks with drilling – blasting works

Drilling – blasting works are apply from the start of opening a mine for AUK. Structural features and thickness of the overburden (decomposed mass) depends of the method of removal.

For removal of waste stone, commonly used the method of *drilling – blasting works*.

If the place for exploitation is in compact rock mass for separate of productive stone massif commonly used and apply the following procedure (Figure 1).

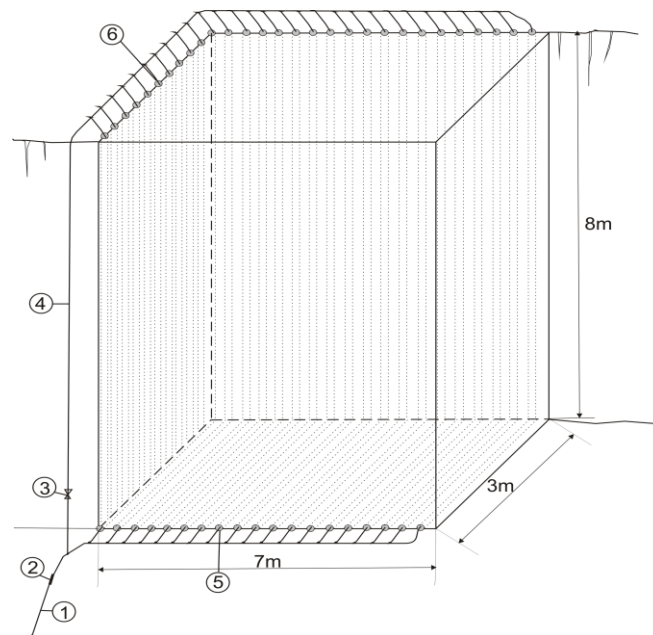


Figure 1. *Productive primary block with specified dimensions, preparation for separation from the massive with drilling and blasting.*

1 – slow burning cord, 2 - detonating cap no.8, 3 – millisecond detonator cap, 4 - detonating cord, 5 - horizontal holes, 6 - vertical holes.

- *Method of Receiving productive plate with a combination of diamond wire saw and stonecutting chainsaw*

To start normal operation of productive floor, it is need of the to have two free vertical sides on the floor. The places where the forehead is with one free area, the second free area must be to gain by making the cut section. With preparation of the cut section the floor will progress left and right, when it gets to the intensity of the work. Good productive floor to prepare for more cutting sections which would give higher production of commercial blocks.

The use of diamond wire sawing and diamond chain saw, the procedure for opening new cut section is more simplified and accelerated, and the height, length and width of the cut section is determined by the technical needs of quarry mine. The position of the cut section of productive floor in practice to be compact stone blocks, because with the opening of the cut section are obtained and productive plate, and thus the cost of opening cut section would be equal to the cost in normal operation and is a model for getting productive plate.

The cut section is made perpendicular to the forehead of floor and should be wide enough for at least 4 - 4,5m to ensure smooth entry and operation of machinery, and sufficiently long length of excavation front to provide a smooth regular exploitation. Apply different methods for constructing the cut section depending of the technology used.

Schematic figure for preparation of cut section in stages with a combined application of diamond wire saw and *stonecutting* chainsaw is shown in Figure 2.

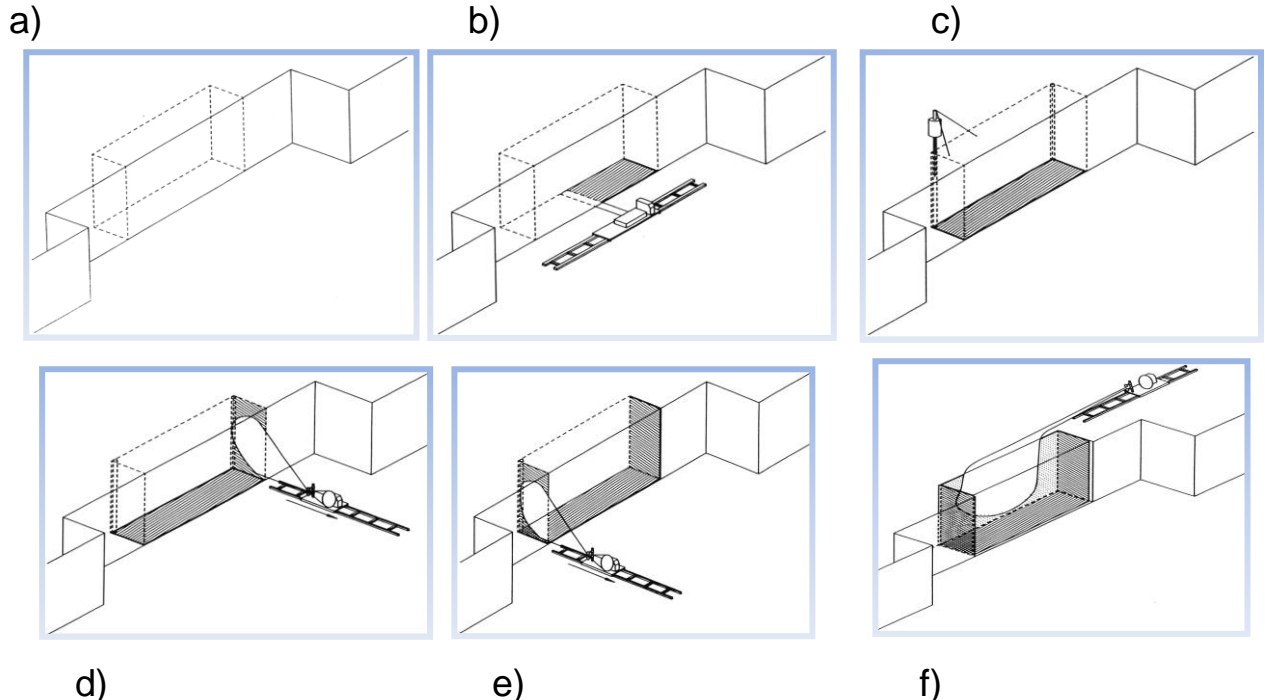


Figure 2. *Stages of making a cut with combining of stonecutting chain saw and diamante wire saw.*

Receiving productive plate with a combination of diamond wire saw and *stonecutting chain saw* is very productive methods because can combined advantages of either (two) machines.

Thus in principle can be applied two schemes work on both machines as follows:

- Cutting vertical cuts with *stonecutting chain saw* and horizontal cutting with diamond wire saw,
- Cutting horizontal cuts with *stonecutting chain saw*, and a vertical cutting with diamond wire saw.

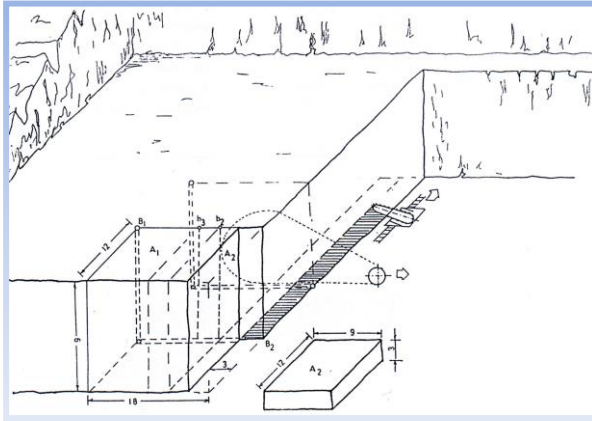


Figure 3. Optimum usage of the diamante wire saw and stonecutting chain saw during cutting of the larger cuts in order to get primary blocks.

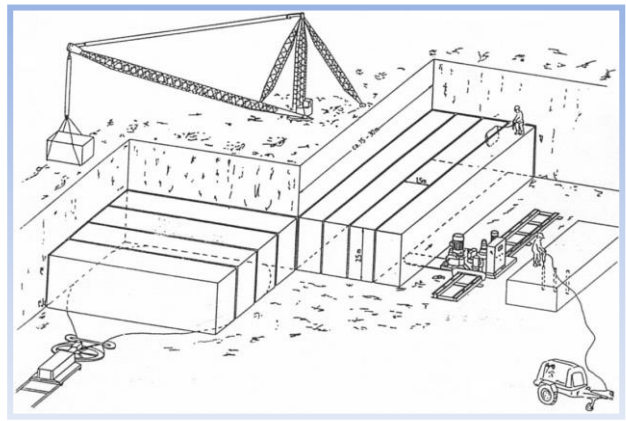


Figure 4. Combined usage of diamante wire saw and stonecutting chain saw into depth floor

- Method of Receiving productive plate with stonecutting chain saw

This method is most productive in terms of getting the stone blocks. But here there are some flaws and limitations in the use of this machine.

There are high-tech machines of *stonecutting chain saw* for exploitation of AUK. One of these machines is *stonecutting chain saw* show in figure 5. It is highly productive machines and have high speed cutting stone table. Can used from the beginning of the exploitation of floor or for removal of overburden, opening the first floor, as well as underground mining of AUK.



Figure 5. Stonecutting chain saw.

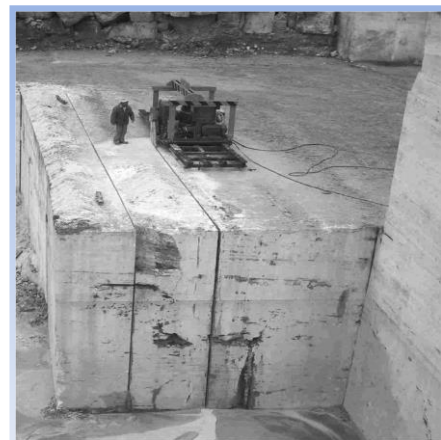


Figure 6. Getting of primary block combining two stonecutting chain saws.

Preparation of cut section just with *stonecutting chain saw* is justified if in further exploration productive floor are used diamond wire saw, which need two free vertical sides of floor for easier cutting productive plate of compact rock massifs.

The application only with *stonecutting chain saw* no need of making the cut section, because the exploitation of productive floor only with *stonecutting chain saw* for productive plate is no problem cutting the closed rear section of productive plate.

This method is general and can be modified, it would be made vertical cutting (incisions) with greater length according to the needs and possibilities of quarry mine for AUK.

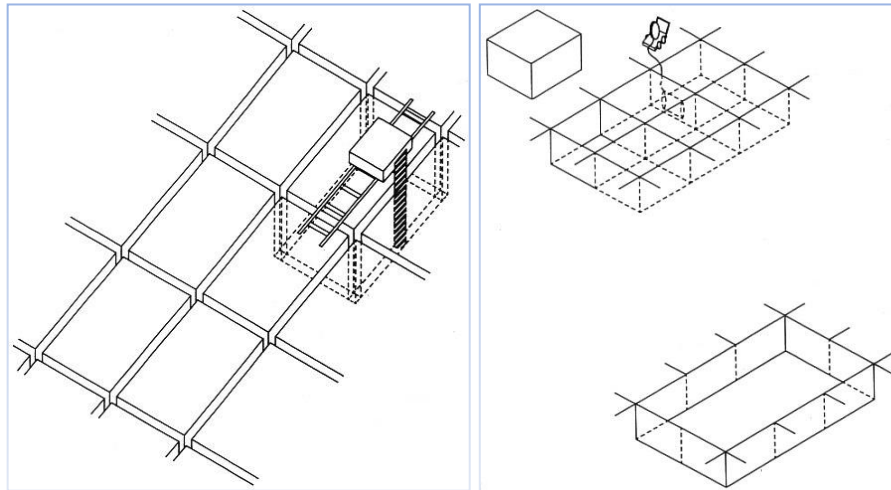


Figure 7. Opening a deep cut using stonecutting chain saw.

6. PROCEDURE FOR SELECTING THE OPTIMAL METHOD AND TECHNOLOGY FOR THE EXPLITATION OF STONE BLOCKS

The modern way of exploitation of AUK (architectural decorative stone) offers opportunities, technologies and methods for economical and highly productive getting finished in quarries in surface or underground mining.

It is very important when designing the mine exploitation AUK to see parameters of machines and technologies that could be considered the final definition which technology is applied.

The previous known methods for exploitation of AUK offer a wide range in the choice of technology and machinery which may be used for exploitation of AUK. More apparent necessity of involving complex engineering calculations, modeling, monitoring and management of the work process. Given that the process of planning and design are made a number of alternative solutions, that leads to more alternatives, and as a solution is imminent choice of only one, it is necessary to introduce a process of decision making.

Deciding how the procedure is a choice between several possible alternatives from a set of predefined alternatives or choice between several possible alternatives to the present problem as

optimal to obtain commercial stone blocks. The optimization of the proposed three alternatives (methods) will be made using the methods of Multifactor optimization. This optimization give opportunities for optimizing not only one function as the lowest price for cut 1 (m2) stone table, but also including other features with a different character.

The process of optimization is directly related to subjective decision-maker. Most of the criteria have their advantages, but it has its drawbacks. The disadvantages are caused by a number of criteria, how their definition, defining their influences or weights in the model, which in turn makes the process complex mathematical modeling. Even in today's development of mathematics as a science there is no one method would be characterized by generalization and power in solving the model.

This optimization methods are quite complex, however, they have some common features, such as:

- A lot of number of criteria that create an engineer-decision maker
- Existence of conflicts between criteria,
- Each criterion has its own unit of measurement and weight
- Subjectivity in optimization, i.g. the influence of the decision maker

6.1 Identification of factors that have influence on the setting and problem solving

Based on extensive research on the criteria that influence the choice of technology and the method to be applied for the stone blocks are grouped and allocated to the following factors would have a significant impact on setting and solving the problem:

- Cost for 1 (m2) cut surface
- Loss of useful stone table in the process of cutting or cleavage,
- Scale and speed of preparatory work,
- Degree of utilization of applied equipment
- Capacity of applied equipment for cutting or division of 1 (m2) surface of the stone table
- Getting a sufficient amount of exploitation floor,
- Level of training available to the operating personnel involved,
- Tectonic framework of discontinuities in the rock mass,
- Work in winter and hot conditions in the open pit mine,
- Safety at work of effective equipment,
- Environmental aspects and environmental impact,
- Degree of real fulfillment of the option – decision.

The application of the theory of ranking using Multifactor optimization is performed for several known alternative solutions. The Multifactor optimization will get a list of variant solutions, sorted according to the criteria under which the optimization is performed.

It makes sense that the cost of 1 (m²) cut or cleft area is main criteria function, but not unique, but it would get the greatest weight in deciding. Therefore there is a need to introduce Multifactor optimization in determining the selection of optimal technologies and methods for obtaining commercial stone blocks.

The application of the theory of ranking using Multifactor optimization is performed for several known alternative solutions. The Multifactor the optimization will get a list of variant solutions, sorted according to the criteria under which the optimization is performed.

In this paper methods of getting separated as described above and are commonly used in obtaining the stone blocks which are

- Method of drilling – blasting works
- Method with combination of diamond wire saw and *stonecutting chain saw* and
- Method with *stonecutting chain saw*

6.2 Selection and identification of criteria

Taking into account the previously defined factors that affect the installation and problem solving , are selected and identified criteria that have the greatest impact in solving the model. Selected criteria that have the greatest impact in solving the model based alternatives are given in Table 1.

Table 1. *Criteria*

No	Criteria	Mark
1	Costs of 1 (m ²) cut, separated surface	K ₁
2	Lost of useful stone component	K ₂
3	Capacity of the used equipment	K ₃
4	Usage of the mining equipment for working with cracked stone mass	K ₄
5	Working discipline or precision during preparation for work	K ₅
6	Cost of the additional training and education of the engaged operative workers	K ₆
7	Ecological consequences of using the equipment	K ₇
8	Working in winter conditions	K ₈
9	Safety aspects of the used equipment	K ₉

6.3 Identification of impacts (weights) of the criteria

Each of the criteria has its effect (weight) on alternative solutions. To make the definition of weights of functions for alternative solutions were made:

- Techno - Economic Analysis for the three alternatives (methods) ,
- Consultation and survey of experts in the field of surface mining for stone blocks
- Calculation of mean values of the weights obtained from the above procedures.

In this way are obtained the following weights of functions of criteria (Table 2).

Table 2. *Importance of criteria functions.*

No.	Criteria	Mark	Importanc	Target
1	Costs of 1 (m ²) cut, separated surface	K ₁	10	<i>min</i>
2	Lost of useful stone component	K ₂	4	<i>min</i>
3	Capacity of the used equipment	K ₃	8	<i>max</i>
4	Usage of the mining equipment for working with cracked stone mass	K ₄	5	<i>max</i>
5	Working discipline or precision during preparation for work	K ₅	4	<i>max</i>
6	Cost of the additional training and education of the engaged operative workers	K ₆	5	<i>min</i>
7	Ecological consequences of using the equipment	K ₇	4	<i>min</i>
8	Working in winter conditions	K ₈	5	<i>max</i>
9	Safety aspects of the used equipment	K ₉	5	<i>max</i>

6.4 Solution of multi criteria model

Table 3. Transformed multi criteria model.

Alternatives		Criteria								
		Costs of 1 (m ²) cut, separated surface (€)	Lost of useful stone component (mm)	Capacity of the used equipment (m ² /h)	Usage of the mining equipment for working with cracked stone mass	Working discipline or precision during preparation for work	Cost of the additional training and education of the engaged operative workers	Ecological consequences of using the equipment	Working in winter conditions	Safety aspects of the used equipment
		K ₁	K ₂	K ₃	K ₄	K ₅	K ₆	K ₇	K ₈	K ₉
Target		<i>min</i>	<i>min</i>	<i>max</i>	<i>max</i>	<i>max</i>	<i>min</i>	<i>min</i>	<i>max</i>	<i>max</i>
Alternative I	A ₁	10,7	40	4,3	9	9	7	5	9	3
Alternative II	A ₂	1,5	11	11	7	7	5	1	0	3
Alternative III	A ₃	5,37	40	7	5	6	7	3	8	9
Weight	w _j	0,2	0,08	0,16	0,1	0,08	0,1	0,08	0,1	0,1

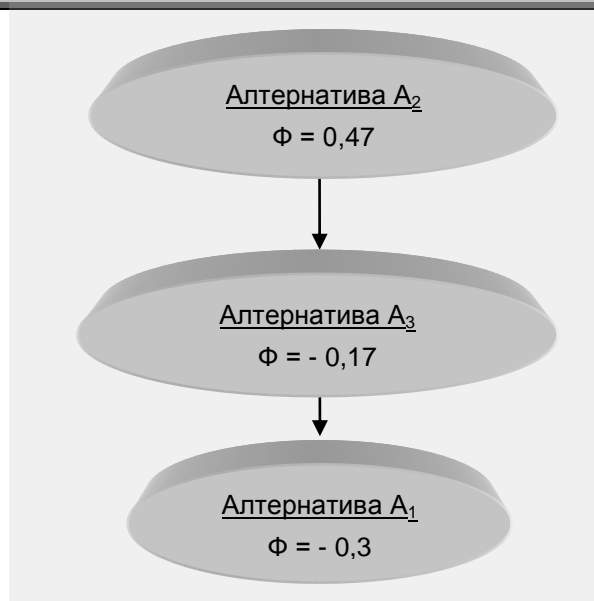


Figure 8. Graph for ranking of the alternatives under PROMETHEE II method.

The final order of ranking of the three alternatives under multi criteria optimization method PROMETHEE II will be presented in table 4 as following:

Table 4. *Final order of ranking according to the method PROMETHEE II.*

Alternative (Method of producing)	Mark	Φ	Rank
Producing of stone blocks using drilling-blasting works,	A ₁	- 0,3	3
Producing of stone blocks using diamante wire saw and stonecutting chain saw,	A ₂	0,47	1
Producing of stone blocks using stonecutting chain saw.	A ₃	- 0,17	2

The final ranking of the three alternatives is: A₂ → A₃ → A₁. According to the results obtained by solving multicriteria model as the optimal solution for the stone blocks is the alternative A₂, i.e. getting the stone blocks using diamond wire saw and stonecutting chain saw.

7. CONCLUSION

Based on the results obtained by analyzing the proposed alternative solutions, defining and solving this optimization model, and the results of optimization can obtain the following conclusion:

The analysis suggested three alternative solutions:

A₁ - getting the stone blocks using drilling – blasting works;

A₂ - getting the stone blocks using diamond wire saw and stonecutting chain saw;

A₃ - getting the stone blocks using stonecutting chain saw.

The proposed three alternative solutions have their advantages and disadvantages.

Alternative solution A₁ is characterized in that it can be run throughout the year without any major problem on weather conditions, but the high cost of diesel fuel and explosives materials, makes this alternative less competitive than the other two alternatives.

However given the long and cold winter this alternative would have its own success because we know that in conditions with temperatures is below 0 ° C the option A₂ is not possible to apply because the process of cutting the stone massif is closely connected with the use of potable water.

Alternative A₂ solution is characterized by a much lower cost cutting 1 (m²) surface of the stone table, compared to the other two alternatives, making it competitive alternatives before A₁ and A₃. Alternative A₂ is characterized by higher cutting speed, less weight loss during cutting stone because it cut the minimum width, minimum environmental impact, low cost training and re-training of operating personnel.

The criteria to evaluate please note that all three alternatives and applying multicriteria method of optimization, alternative A3 is ahead of alternative A2. The cost of elements in present circumstances, make this option less competitive than the **option A2**. However, this alternative has its advantages. Stonecutting chain saw, can work independently without the use of other machines in combination with it, like opening overburden floor, and the exploitation of productive floor.

By applying the methods of optimization PROMETHEE I and PROMETHEE II for the given three alternatives are getting that the alternative A2 is the optimum solution for the exploitation of AUK, i.e. the combined application of diamond wire saw and stonecutting chain saw.

REFERENCES

- [1] **Costa C.** (1988) MODERN TREND OF TECHNOLOGY FOR MARBLE QUARRYING AND PROCESSING, Associazione costruttori italiani machine per il marmot e affini
- [2] **Cotman I.** (2001), Podzemna eksploatacija arhitektonsko – gradjevinskog kamena u Istri, Magisterski rad (pp 100) Rudarsko- geoloski-naftni fakultet, Zagreb, Hrvatska
- [3] **Cotman I. Damijan A.** (1991), Nova otkopna metoda u eksploataciji slojevitih lezista arhitektonskog kamena, Rudarsko- geoloski-naftni zbornik, Vol. 3 (69-76), Zagreb, Hrvatska
- [4] **Calvin J. Konia,** (1995) Phd, Rock Blasting and overbreak Control, IDC Montville
- [5] **DIREKTORY 2009** (2009), Confindustria marmomachine, Verona, Italy
- [6] Major mine project for exploitation of marble stone on the quarry mine "Bela Pola", s. Nebregovo, Prilep, R. Macedonia
- [7] MODERN TECHNOLOGY AND MACHINERY FOR MARBLE QUARRYING, Benetti machine S.R.L 96 Avenza, Italy
- [8] **N. Rzanikoski,** (2012) **Техно – економска анализа на методите за добивање на камени блокови и оптимирање на трошоците при примена на дупчечко – минерски работи и каменорезна ланчана пила, Магистераска работа, УГД –ФПТН, Штип, Р. Македонија**
- [9] **R. Dambov,** (2011), Methods of blasting, Book, UGD-FNTS, Institute of Mining, Stip, R. Macedonia
- [10] **R. Dambov, S. Bosevski** (2011) Blasting technique in special conditions, Monograf, SRGIM, Skopje, R. Macedonia
- [11] **Sinisa Dunda** (1995), Tehnolski proces povrinske eksploatacije arhitektonskog kamena karbonatnog podrijetla, Cleantech d.o.o. Zagreb, Hrvatska
- [12] **Sinisa Dunda,** (1990) Tehnologija dobijanja arhitektonsko gradeznog kamena, RGNF – Zagreb, Hrvatska
- [13] **STONE 2010** (2010), World Marketing Handbook, Business media, Milano, Italy