RGNZ/MGPB

Impact of drilling angle on blasting costs in surface works

Rudarsko-geološko-naftni zbornik
(The Mining-Geology-Petroleum Engineering Bulletin)
UDC: 622.2
DOI: 10.17794/rgn.2022.4.6

Preliminary communication

Frashër Brahimaj[1]; Izet Zeqiri[2*]; Risto Dambov[3]; Shkurte Brahimaj[4]

[1] *University "ISA BOLETINI", Ukshin Kovaçica, Mitrovica, 40000, Kosovo, https://orcid.org/0000-0003-1470-4685*
[2] *University "ISA BOLETINI", Ukshin Kovaçica, Mitrovica, 40000, Kosovo, https://orcid.org/0000-0002-9727-2859*
[3] *University "GOCE DELCHEV", 89, Goce Delchev, Stip, 2000, North Macedonia, https://orcid.org/0000-0002-2592-9567*
[4] *Institute of Safety for Hazardous Materials and Fire Protection ISM, 213, Nazim Gafurri, Pristina, 10000, Kosovo, https://orcid.org/0000-0002-9602-8299*

Abstract

The removal of rock masses or their use with surface exploitation requires that this work be done at the lowest possible cost. The reduction of operating costs is done by analyzing each work action, working method, and the possibility of changing them, to have an impact on reducing costs. The drilling angle is one of the most important factors during surface exploitation by blasting. By changing the drilling angle, we achieve a reduction of the total drilling length, to have a reduction of the amount of explosives and other changes during the blasting process which do not greatly affect the cost of blasting. Determining the impact of drilling angle on the cost of blasting is determined by analytical methods and by comparing the results of applied drilling angle methods. During the analytical analysis of the blasting data and the comparison of their results, which was performed to determine the change in the cost of blasting depending on the drilling angle, and it concluded that for the removal of 200000 (m^3) rock material, 356167.98 (€) can be saved, by applying the 90° angle drilling method. This change of drilling angle from the projected angle of 63° to the angle of drilling 90°, reduces the total cost of blastings by about 10.69 (%).

Keywords:
drilling angle; blasting cost; surface exploitation; explosive; blasthole

1. Introduction

The execution of various projects in surface works (mining, the opening of canals, the opening of road trenches, etc.) requires that the work be performed at the lowest possible cost and successfully completed (**Brahimaj, 2013**).

It is also required that the dimensions of the pieces resulting from the blasting, be within the required norms, thus enabling the dynamics of work to develop smoothly.

Breaking the massif in optimal dimensions affects the project to be executed smoothly and with great dynamics, thus affecting the reduction of the cost of project implementation, due to the shortening of its implementation time (**Brahimaj, et al., June 2019**).

In the cost of projects in the surface, works have a very large impact on blasting and blasting results, which means that the geometric and organizational parameters of blasting have an impact on the project costs (**Popovic, 1984; Spasic, 1979**).

Corresponding author: Izet Zeqiri
e-mail address: izet.zeqiri@umib.net

The geometric blasting parameters that have an impact on blasting costs are the distance between drills in a row, the distance between rows, drilling diameter, drilling depth, and drilling angle. While in the organizational parameters of blasting, the time of realization of the drilling process, the number of workers engaged in the blasting and drilling process, the types of explosive materials that are selected, and the type of initiating system all have an impact on blasting costs (**Brahimaj, 2012; Brahimaj, 2008**).

All these parameters mentioned above are examined separately by blasting engineers, but the drilling angle parameter is sometimes not given much importance in the blasting cost, which is a parameter that should not be ignored when we have to do the calculation of the cost of blasting, because when we are dealing with large projects in which millions of cubic meters of massive rock or ore must be mined, the impact of this parameter on the monetary value will be very large.

The benefits of sloping drilling are better fragmentation, displacement, and swelling of the pile, fewer drillings and better use of explosive energy, lower vibration levels, and less risk of foot shapes appearing at the bottom (**Jimeno, et al., 1995; Kenedy, 1990**).

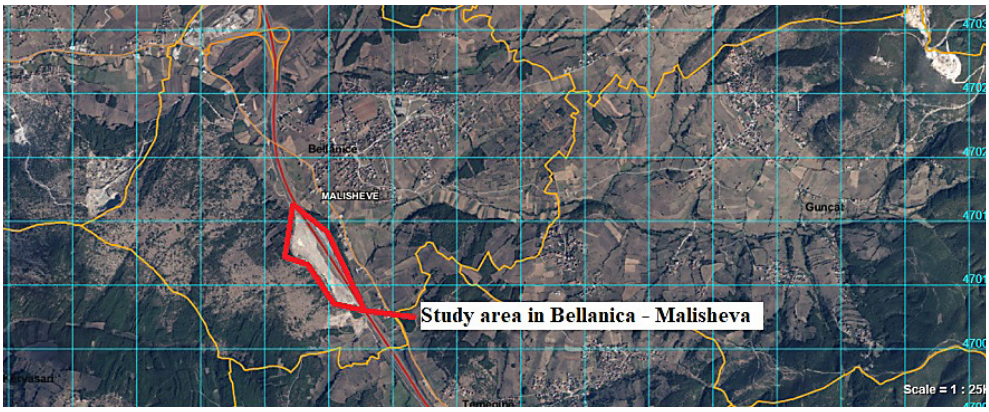

Figure 1: Geographical position of the study area

During the research, the possibilities of combining the drilling angle within a field will be examined, considering that at the limit of exploitation (removal) of rock or ore masses, benches are formed at the designed angle, to maintain the stability of the slope (**Brahimaj, et al., 2016; Borana, et al., 2018**).

For this reason, in this paper, we will examine the impact of drilling angle on the cost of blasting, and we will see the level of its impact on the cost of blasting, so we will understand how important it is to consider this parameter.

The objective of this paper is to determine the method with the lowest cost of blasting, depending on the combination of drilling angle on the drilling rows, always considering safety during the execution of blasting, while maintaining a certain size of the burden, to prevent the throwing of stones because of reducing the smallest burden to the first drilling row, by choosing the same drilling angle as the angle of the bench.

2. Materials and Methods

In this paper, the case of exploitation in surface works is considered, where the geometric parameters of the blasting field are: height of the bench h = 10 (m), angle of the bench α = 63°, the width of the exploitation block for a blast ranges from L_b = 11.2 (m) to L_b = 14 (m), and the length of the exploitation block for blasting will be variable. The opening of the Route 7 highway tranche in Bellanica, in which 2000000 (m^3) of plate limestones will be mined, was taken as a case study. The length of the track to be mined is 700 (m) and the number of benches is 8, with an average bench length of 450 (m), **Figure 1**. ANFO explosive with density ρ = 0.85 (g/cm^3) was selected for the blasting, while emulsion explosive with density ρ = 1.25 (g/cm^3) was selected as the striking cartridge (**Buhin, 2010; Brahimaj, et al., June 2019; Gashi, 2009**). The Nonel system has been selected for initiation.

2.1. Blastholes with angle according to the designed angle of the bench

In the case when the blastholes are drilled at an angle according to the designed angle of the bench, we are dealing with the same angle of the bench and in this case, all the blastholes are at the same angle (**Brahimaj, et al., 2019; Dambov, 2011**). One such case is shown in **Figure 2** and **Figure 3**, in which the blasthole parameters can be seen.

In **Figure 2** and **Figure 3**, we see that in this case due to the very paved blasthole angle, the distance between the rows varies with the distance between the rows upwards, thus conditioning us to make calculations to accurately determine the high distance between the rows, to accurately determine the real distance between the rows. Also, the same applies to the burden. **Formula (1)** was used to calculate the burden upward:

$$W_u = \frac{W}{sin\beta}, \quad (m) \qquad (1)$$

Formula (2) was used to calculate the distance between rows upward:

$$b_u = \frac{b}{sin\beta}, \quad (m) \qquad (2)$$

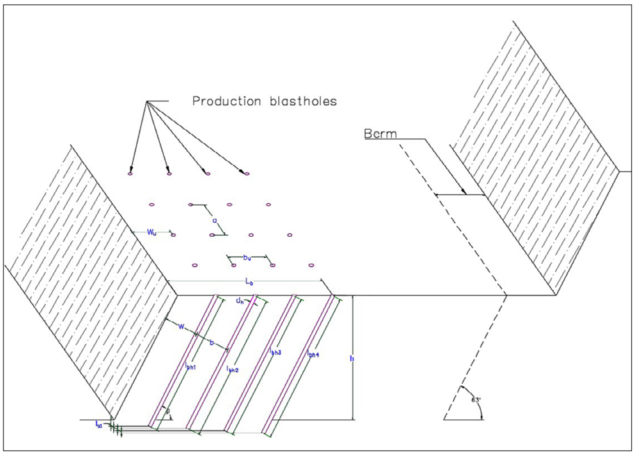

Figure 2: Schematic representation of the blastholes cut, for the case when the blastholes are at the same angle as the projected angle of the bench, for normal blasting. W - burden, b – the distance between rows, W_u – the up burden, b_u – the distance between rows up, h - bench height, l_{sd} - sub drilling length, d_h - diameter of blasthole, L_b - block width, β – blasthole angle, l_{bh} – blasthole length (**Brahimaj, 2013; Džodič, 1985; Milenko, 2000**)

Table 1: Geometric parameters of blastholes

Parameters	Symbol	Normal Blasting		Contour Blasting	
		Value	Unit	Value	Unit
Diameter of blastholes	d_{bh}	89	mm	89	mm
Diameter of contour blastholes	d_{cbh}			76	mm
Drilling angle	$\beta = \alpha$	63	°	63	°
Burden	W	2.8	m	2.8	m
Upper burden	W_u	3.14	m	3.14	m
The distance between drillings in row	a	2.8	m	2.8	m
The distance between rows	b	2.8	m	2.8	m
The upper distance between rows	b_u	3.14	m	3.14	m
The upper distance between production and contour row	b_{cu}			2.24	m
The distance between production and contour row	b_c			2	m
The length of sub drilling the first row	l_{sd}	0.5	m	0.5	m
The length of blasthole for the first row	l_{bh1}	11.8	m	11.8	m
The length of the blasthole for the second row	l_{bh2}	12.0	m	12.0	m
The length of blasthole for the third row	l_{bh3}	12.2	m	12.2	m
The length of blasthole for the fourth row	l_{bh4}	12.4	m		
The length of blasthole for contour row	l_{bhc}			12.4	m

Formula (3) was used to calculate the blasthole length:

$$l_{bh} = \frac{h + l_{sd}}{sin\beta}, \quad (m) \qquad (3)$$

Such a case with geometric parameters of blastholes is presented in **Table 1**.

In **Table 1**, the geometric data of the blastholes are presented, when all the blastholes are with an angle according to the projected angle of the bench, based on which the necessary calculations will be made later to determine the cost of blasting.

2.2. Blastholes with an angle of 90°, and with a combined angle

In the case of blastholes with a 90° angle, if the field is far from the designed bench (in the middle of exploitation), then all blastholes have the same angle, while if the blasting field is close to the designed bench, the last row of blastholes is with a projected angle of the bench, while the preliminary rows are with an angle of 90° (**Brahimaj, 2021; Brahimaj, et al., June 2019**).

In this case, the two rows before the last row are of shorter length, due to the proximity of the blastholes to

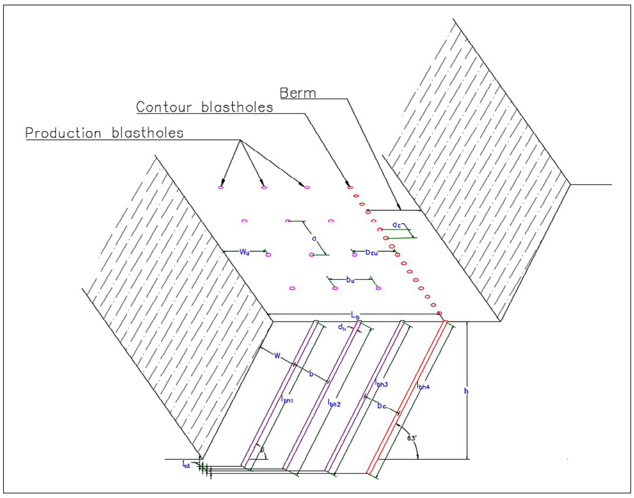

Figure 3: Schematic representation of the blastholes cut, for the case when the blastholes are at the same angle as the projected angle of the bench, for contour blasting. a_c – the distance between contour drillings, b_{cu} - the upper distance between production and contour row, b_c - the distance between production and contour row

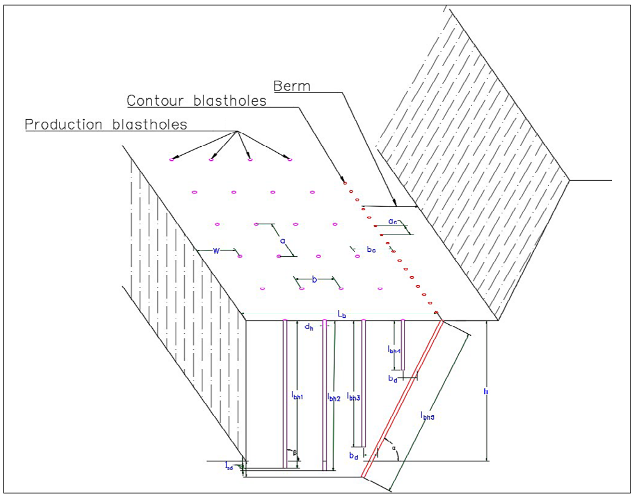

Figure 4: Schematic representation of the blastholes cut, for the case when the blastholes are at an angle of 90°, for blasting near the bench. b_d - distance between rows at the end of blastholes, α - last row blastholes angle, respectively bench angle, and β - blastholes angle of previous rows (**Brahimaj, 2021; Brahimaj, et al., June 2019**).

Table 2: Geometric blasthole parameters for the combined case, and the case when all blastholes are at an angle of 90°

Parameters	Symbol	Contour blasting		Normal blasting	
		Value	Unit	Value	Unit
Diameter of blastholes	d_{bh}	89	mm	89	mm
Diameter of contour blastholes	d_{cbh}	76	mm		
Drilling angle	β	90	°	90	°
Bench projected angle	α	63	°		
Burden	W	2.80	m	2.80	m
The distance between drillings in row	a	2.80	m	2.80	m
The distance between rows	b	2.80	m	2.80	m
The down distance between rows	b_d	1.00	m		
The distance between production and contour row	b_c	2.80	m		
The length of sub drilling for the first row	l_{sd}	0.50	m	0.50	m
The length of blasthole for the first row	l_{bh1}	10.50	m	10.50	m
The length of the blasthole for the second row	l_{bh2}	10.70	m	10.70	m
The length of blasthole for the third row	l_{bh3}	9.02	m	10.90	m
The length of blasthole for the fourth row	l_{bh4}	3.53	m	11.10	m
The length of blasthole for contour row	l_{bh5}	12.46	m		

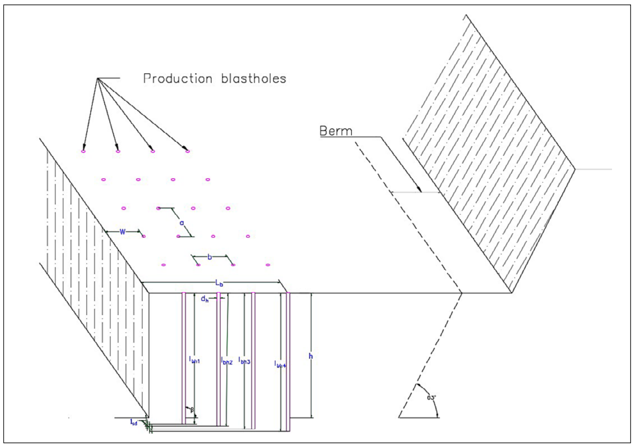

Figure 5: Schematic representation of the blastholes cut, when all the blastholes are at an angle of 90° (**Hustrulid, et al., 2013; Brahimaj, 2021**).

the bottom, or even due to the possibility of joining the blastholes at their bottom. Such a case is shown in **Figure 4** and **Figure 5**.

In **Figure 4** we see that due to the very stretched angle of the blastholes in the last row, blastholes of shorter lengths should be in both preliminary rows, in order not to join at the end with the blastholes of the last row and this enables them to form the bench in the designed parameters.

To calculate the length of blastholes in the first and second row, based on **Figure 4, formula (3)** was used, while **formula (4)** was used to calculate the length of blastholes in the third row, and **formula (5)** was used to calculate the length of blastholes in the fourth row.

$$l_{bh3} = tan\alpha \cdot b - tan\alpha \cdot b_d, \quad (m) \tag{4}$$

$$l_{bh4} = tan\alpha \cdot 2b - tan\alpha \cdot b_d, \quad (m) \tag{5}$$

While **Figure 5** presents the schematic representation of the blastholes cut, when all the blastholes are at an angle of 90°.

Figure 5 presents the schematic representation of the blastholes cut when we are dealing with the case in which all blastholes are at an angle of 90°, where it is seen that all blastholes are parallel while differing in length due to sub drilling.

Table 2 presents the geometric data of the blastholes for the case when the blastholes are at an angle of 90° in the front rows, while the last row is with a projected angle of the bench, and when all blastholes are at an angle of 90°. Based on these parameters, the necessary calculations will be made to determine the blasting cost, depending on the blasthole angle.

In **Figure 2**, **Figure 3**, **Figure 4**, and **Figure 5**, we can see that the length of subdrilling is shorter than usually used, but in this location, rock masses are with a plate structure, and for that we used this length of subdrilling, and for each sequent row is an increase of 0.2 (m). This increase is done for to have a flat floor of the bench. This method of subdrilling is used on the Kosovo Motorway Project.

2.3. Blastings and their parameters

To remove rock masses of 2000000 (m^3), a considerable number of blastings must be realized, depending on the method of orienting the blastholes according to the angle (**Brahimaj, 2013**).

For both cases mentioned above, the necessary number of blastings will be determined to achieve the goal of removing these rock masses according to a predicted dynamic.

We determined the required number of blastings based on the volume to be mined in each blast, thus taking the volume of each blast and this is determined based on **formula (6)**, **formula (7)** and **formula (8)**.

$$V_{i=1}^{n}=\left[\left(l_{bhi}\cdot sin\beta\right)-l_{sdi}\right]\cdot a\cdot b\cdot n_{bh},\quad (m^3) \tag{6}$$

Where:

$V_{i=1}^{n}$ – the volume by rows [m³],
l_{bhi} – the length of blastholes by rows [m],
a – the distance between blastholes in the row [m],
b – the distance between rows [m],
n_{bh} – the number of blastholes in a row,
l_{sdi} – the length of sub drilling by rows [m].

$$V_5=\left[\frac{b+b_d}{2}\cdot l_{bh4}+\frac{b+2b_d}{2}\cdot\left(l_{bh3}-l_{bh4}\right)+\right.$$
$$\left.+\left(\frac{tan\alpha\cdot b_d-h+l_{bh3}}{2tan\alpha}+b\right)\cdot\left(h-l_{bh3}\right)\right]\cdot a_c\cdot n_{bh},\quad (m^3) \tag{7}$$

Where:

V_5 – the volume of the fifth row [m³],
b – the distance between rows [m],
b_d – the down distance between rows [m],
l_{bh3} – the length of blastholes on the third row [m],
l_{bh4} – the length of blastholes on the fourth row [m],
h – the bench height [m],
α – the projected angle of the bench [°],
n_{bh} – the number of blastholes in a row.

$$V=\sum_{i=1}^{n}V_i \tag{8}$$

Where:

V – the volume of mined mass in one blast [m³],
V_i – the volume by rows [m³].

Based on **Equations 6**, **7** and **8**, the calculations in **Table 3** and **Table 4** were performed.

The excavated rock masses are presented by calculation method. The excavated rock masses based on the data from Kosovo Motorway Project are 1945637.8 [m³], by the geodesy department (for blastings area).

Based on **Table 1**, **Table 2**, **Table 3** and **Table 4**, calculations have been made for the material needed for each blasting.

Calculations for the required amount of explosive are made according to **Equation 9**, (**Zdravev, 1998; Brahimaj, et al., 2019**).

$$Q_e=\sum_{i=1}^{n}\frac{\pi\cdot d_h^2}{4}\cdot\left[\left(l_{bhi}-l_s\right)\cdot n_{bh}\right]\cdot\rho,\quad (kg) \tag{9}$$

Where:

Q_e – the amount of explosive [kg],
d_h – the diameter of blastholes [mm],
l_{bhi} – the length of blastholes [m],
l_s – the length of stemming [m],
n_{bh} – the number of blastholes,
ρ – the density of the explosive [g/cm³].

For calculations of the explosive for contour blastholes, **Equation 10** will be used:

$$Q_{ec}=\sum_{i=1}^{n}\frac{\pi\cdot d_p^2}{4}\cdot\left(\frac{l_{cbhi}}{l_p+l_e}+1\right)\rho\cdot l_p\cdot\quad\cdot n_{cbh} \tag{10}$$

Where:

d_p – the diameter of patrons [m],
l_{cbhi} – the length of drillings [m],
l_p – the length of patrons [m],
l_e – the length of empty parts [m],
ρ – the density of explosives [kg/m³],
n_{cbh} – the number of contour blastholes.

Table 3: The volume of the mined mass according to the blastings, for the case when all the blastholes are at the same angle with the projected angle of the bench

No. of blasting	The number of blastholes by rows (blastholes)					Total (blastholes/blasts)	Total drilling (m/blasts)	The volume by rows (m³/rows)					Total (m³/blasts)
	I	II	III	IV	Contour			I	II	III	IV	Contour	
1-14	61	61	61	61	0	244	2952.4	4789	4779	4768	4758	0	19094
Total 1-14	854	854	854	854	0	3416	41333.6	67047	66901	66755	66609	0	267310
15-27	80	80	80	80	0	320	3872	6281	6267	6253	6240	0	25041
Total 15-27	1040	1040	1040	1040	0	4160	50336	81649	81471	81294	81116	0	325530
28-58	100	100	100	100	0	400	4840	7851	7834	7817	7800	0	31301
Total 28-58	3000	3000	3000	3000	0	12000	145200	235526	235014	234501	233988	0	939029
58-73	100	100	100	0	386	686	8386.4	7851	7834	7817	0	5760	29262
Total 58-73	1600	1600	1600	0	6176	10976	134182	125614	125341	125067	0	92163	468185
Total	6494	6494	6494	4894	6176	30552	371052	509836	508726	507616	381713	92163	2000054

Table 4: The volume of the mined mass according to the blastings, for the case when the blastholes are at an angle of 90° and for the case when in some blastings the preliminary rows have an angle of 90°, while the last row has an angle according to the projected angle of the bench

No. of blasting	The number of blastholes by rows (blastholes)					Total (blastholes/blasts)	Total drilling (m/blasts)	The volume by rows (m³/rows)					Total (m³/blasts)
	I	II	III	IV	Contour			I	II	III	IV	Contour	
1-14	60	60	60	60	0	240	2592	4704	4704	4704	4704	0	18816
Total 1-14	840	840	840	840	0	3360	36288	65856	65856	65856	65856	0	263424
15-27	80	80	80	80	0	320	3456	6272	6272	6272	6272	0	25088
Total 15-27	1040	1040	1040	1040	0	4160	44928	81536	81536	81536	81536	0	326144
28-55	100	100	100	100	0	400	4320	7840	7840	7840	7840	0	31360
Total 28-55	2800	2800	2800	2800	0	11200	120960	219520	219520	219520	219520	0	878080
56-75	80	80	80	80	298	618	6413.08	6272	6272	5657	2214	5112	25527
Total 56-75	1600	1600	1600	1600	5960	12360	128261.6	125440	125440	113147	44280	102239	510546
76	61	70	70	70	271	542	5644.66	4782	5488	4950	1937	4649	21807
Total	6341	6350	6350	6350	6231	31622	336082	497134	497840	485009	413130	106888	2000001

Calculations for emulsion explosive are made according to **Equation 11**, where it is determined that for each blasthole, a minimum of 1 (kg) emulsion explosive is used as a striking cartridge (**Nako, 2001; Balasubramanian, 2017**):

$$Q_{Emulsion} = Q_p \cdot n_p \cdot n_{bh}, \quad (kg) \qquad (11)$$

Where:

$Q_{Emulsion}$ – the amount of emulsion explosive [kg],

Q_p – the weight of the patron [kg],

n_p – the number of patrons for each blasthole,

n_{bh} – the number of blastholes for each blasting.

While the calculations for the amount of explosives ANFO are calculated according to **Equation 12**:

$$Q_{ANFO} = Q_e - Q_{Emulsion}, \quad (kg) \qquad (12)$$

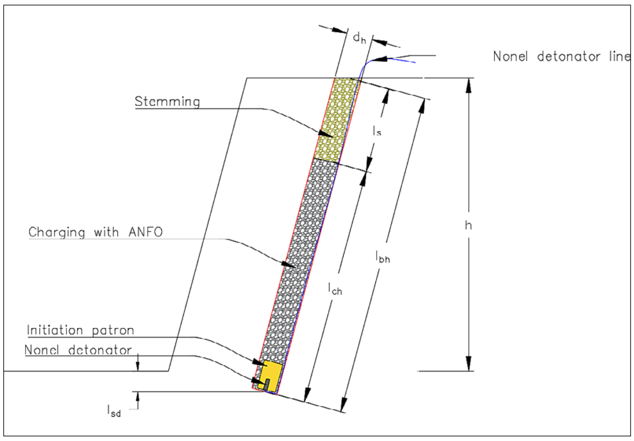

Figure 6: Schematic presentation of blasthole charging of the product, used for initiation of the Nonel system

For the required amount of initiating material, 1 Nonel detonator, 1 Nonel connector, plus 2 Nonel spare connectors, and 300m of Dynoline tube were taken for each blasting.

Calculations are made with Excel software, in table form, according to **Equations 9 - 12**, and the results of the calculations are presented in **Table 5** and **Table 6. Figure 6** below presents a scheme of the charging of a production blasthole, and **Figure 7** presents a scheme of the charging of a contour blasthole.

Based on parameters that are presented in **Table 1, Table 2, Table 3**, and **Table 4,** we can see that, the quan-

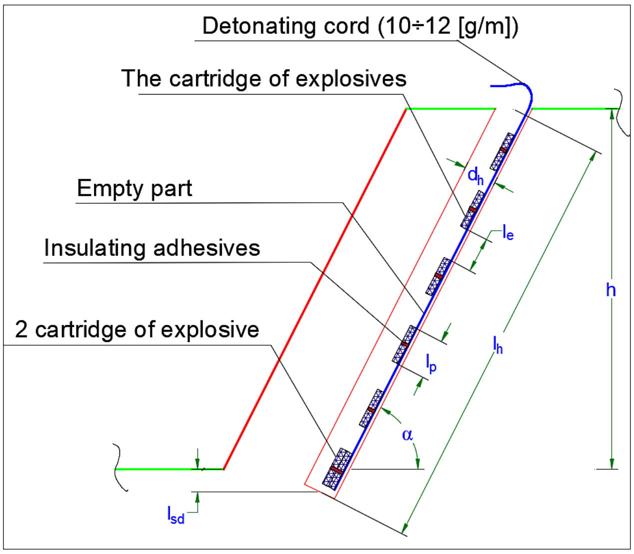

Figure 7: Schematic presentation of contour blasthole charging

Table 5: The amount of material for the realization of blastings in the case where blastholes are at the projected angle of the bench

No. of blasting	Anfo (kg)	Emulsion (kg)	Nonel Detonator (pcs.)	Nonel Connector (pcs.)	Dynoline (m)	Detonating Cord (m)	Powder factor (kg/m³)
1-14	12375	250	244	246	300	0	0.66
Total 1-14	173250	3500	3416	3444	4200	0	0.66
15-27	16225	325	325	327	300	0	0.66
Total 15-27	210925	4225	4225	4251	3900	0	0.66
28-58	20300	400	400	402	300	0	0.66
Total 28-57	609000	12000	12000	12060	9000	0	0.66
58-73	14600	1060	300	304	300	5250	0.54
Total 58-73	233600	16960	4800	4864	4800	84000	0.54
Total	1226775	36685	24441	24619	21900	84000	0.63

Table 6: The amount of material for the realization of blastings in the case where production blastholes are at an angle of 90°, and contour blastholes are at the projected angle of the bench

No. of blasting	Anfo (kg)	Emulsion (kg)	Nonel Detonator (pcs.)	Nonel Connector (pcs.)	Dynoline (m)	Detonating Cord (m)	Powder factor (kg/m³)
1-14	10675	250	240	242	300	0	0.58
Total 1-14	149450	3500	3360	3388	4200	0	0.58
15-27	14250	325	320	322	300	0	0.58
Total 15-27	185250	4225	4160	4186	3900	0	0.58
28-55	17800	400	400	402	300	0	0.58
Total 28-55	498400	11200	11200	11256	8400	0	0.58
56-75	10075	925	320	324	300	4250	0.43
Total 56-75	201500	18500	6400	6480	6000	85000	0.43
76	8450	825	271	275	300	3750	0.43
Total	1043050	38250	25391	25585	22800	88750	0.54

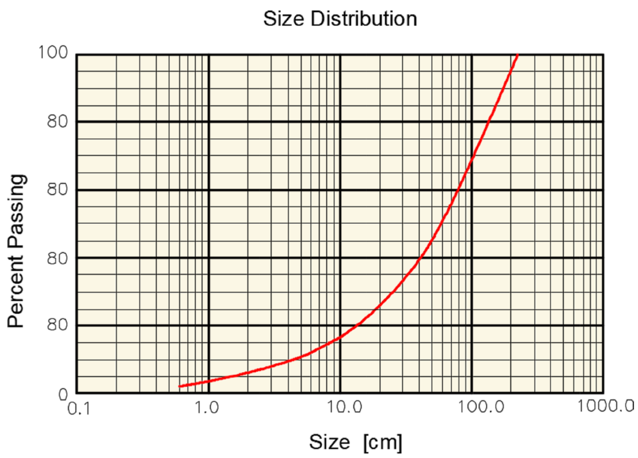

Figure 8: The diagram of fragmentation for the case of blastholes in the projected angle of the bench

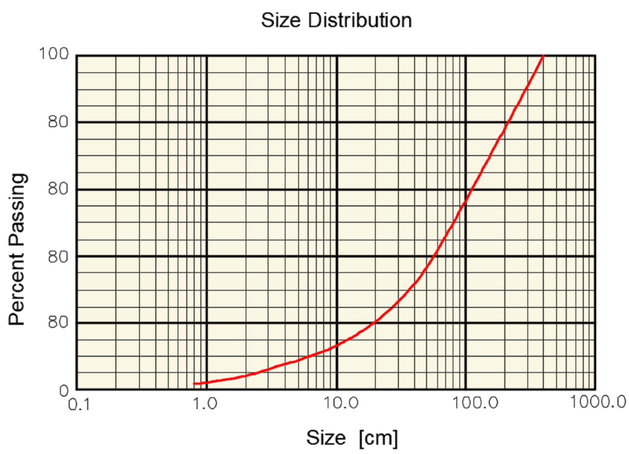

Figure 9: The diagram of the fragmentation for the case of the blastholes at an angle of 90°

tity of blasted material for the length of 1 (m) of drilling is more for blastholes with an angle of 90°, than for blastholes with an angle of 63°, and the powder factor is lower for blastholes with an angle of 90°, than for blastholes with an angle of 63°.

This is due to the fact that in order to achieve a 10m height of the bench in blastholes with an angle of 63°, it is necessary to drill longer lengths than in blastholes with an angle of 90°.

Below are presented calculations for two cases, for a volume of mined material for a length of 1 (m) of drilling.

Calculations for the case of blastholes with an angle of 63°, in the projected angle of the bench, are made using **Equation 13**:

$$V_{1m} = \frac{V_t}{l_d} = \frac{2000054}{371052} = 5.39\left(\frac{m^3}{m}\right) \quad (13)$$

Where:

V_{1m} – the mined volume for the length of 1 (m) of drilling,

V_t – total mined volume,

l_d – total length of drilling.

Calculation for the case of blastholes with the angle 90°, **Equation 14**:

$$V_{1m} = \frac{V_t}{l_d} = \frac{2000001}{336082} = 5.95\left(\frac{m^3}{m}\right) \quad (14)$$

Below, diagrams of fragmentation are presented for two cases.

3. Results and Discussion

After analyzing the blasting data in Chapter 2, for the reviewed cases, we then calculate the blasting cost, and the total blasting cost for the removal of the rock masses presented above.

Equation 15 and **Equation 16** will be used to calculate the blasting cost and overall blasting cost:

$$C_b = \sum_{i=1}^{n} Q_{mi} \cdot p_{mi}, (€) \quad (15)$$

Where:

C_b – the cost of blasting [€],

Q_{mi} – the quantity of material [unit],

p_{mi} – the price of material [€/unit].

$$C = \sum_{i=1}^{n} C_{bi}, (€) \quad (16)$$

Where:

C – the overall cost of blastings [€],

C_{bi} – the cost of blasting [€].

The results of the calculations for the overall cost of blastings are presented in **Table 7** and **Table 8**:

The results of the cost of removal of rock masses, for the examined cases, are presented in **Figure 10**, in which it is seen that the difference between the variants examined is quite large, and if these rock masses are managed to extract with a dynamics of 12 months, then it turns out that the difference between the blastholes variant according to the project and the variant with angle 90°, to be 356167.98 (€/annual), which is quite high, and thus manages to save on average 29680.67 (€/month).

Figure 11 presents the material expenses, according to the cases reviewed.

In **Figure 10** we see that the blasthole variant with an angle of 90°, has a much lower cost in drilling and ANFO, compared to the blasthole variant according to the project, while in other materials it has a higher cost

Table 7: The cost of removing the rock masses, in the case when the blastholes are according to the projected angle of the bench

No.	Named	Quantity	Unit	Price	Amount
1	Drilling	371052	m	€ 4.00	€ 1484208.00
2	ANFO	1226775	kg	€ 1.25	€ 1533468.75
3	Emulsion	36685	kg	€ 2.35	€ 86209.75
4	Nonel Detonator	24441	Piece	€ 3.85	€ 94097.85
5	Nonel Connector	24619	Piece	€ 3.47	€ 85427.93
6	Dynoline	21900	m	€ 0.34	€ 7446.00
7	Detonating Cord	84000	m	€ 0.50	€ 42000.00
Total:					€ 3332858.28

Table 8: The cost of removing rock masses, in the case of blastholes at angle 90° and combined blastholes

No.	Named	Quantity	Unit	Price	Amount
1	Drilling	336082	m	€ 4.00	€ 1344328.00
2	ANFO	1043050	kg	€ 1.25	€ 1303812.50
3	Emulsion	38250	kg	€ 2.35	€ 89887.50
4	Nonel Detonator	25391	Piece	€ 3.85	€ 97755.35
5	Nonel Connector	25585	Piece	€ 3.47	€ 88779.95
6	Dynoline	22800	m	€ 0.34	€ 7752.00
7	Detonating Cord	88750	m	€ 0.50	€ 44375.00
Total:					€ 2976690.30

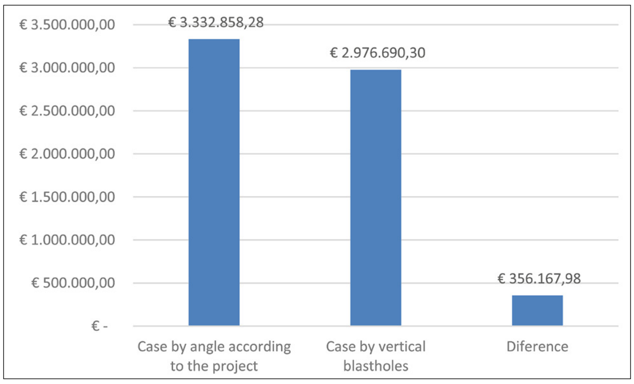

Figure 10: The difference of cost by cases

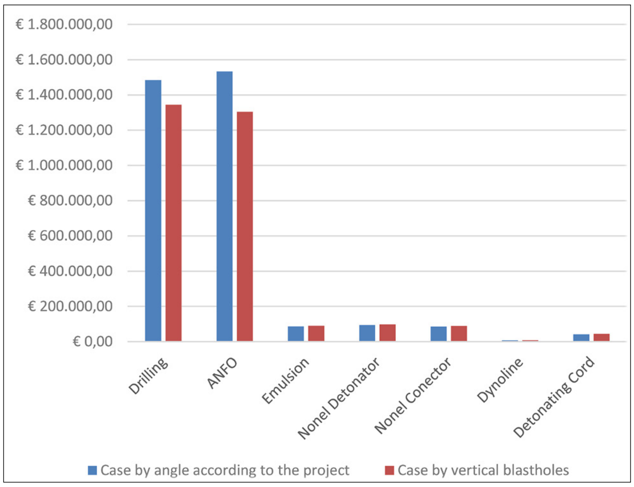

Figure 11: Presentation of the cost of materials according to the reviewed cases

or approximately equal. From what can be seen, the biggest expenditures on blasting are in drilling, and in ANFO.

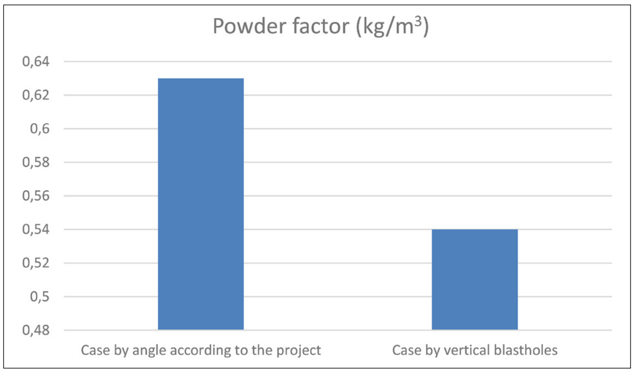

Figure 12: The powder factor for two cases

Figure 12 presents the powder factor for two cases.

As we can see on **Figure 12,** the powder factor in the case when blastholes are at an angle of 90° is lower by 0.09 (kg/m^3) than in the case when blastholes are at an angle according to the project.

4. Conclusion

By changing the drilling angle from the projected angle to an angle of 90°, it has been achieved to reduce the total drilling length, wherein this case it is influenced to have less drilling work, less machine depreciation, less fuel consumption, fewer drilling heads, less time for drilling, etc. With this change of drilling angle, the drilling length is reduced by 34970 (m) or by about 10 (%).

This change in drilling angle also affects the reduction of the required amount of ANFO explosives, and this change is 183725 (kg) less, or about 15 (%).

As for the emulsion explosive, we have an increase in the quantity, since the number of drillings in blastings by an angle of 90° is greater because, in the explosions near the bench, the last row must be according to the designed angle of the bench, and the two previous rows are shorter, so as not to meet the end of the drilling. This increase is for 1565 (kg), or about 4 (%).

The number of Nonel detonators and Nonel connectors also increases due to the increase in the number of blastholes and this increase is about 4 (%). The amount of dynoline tube increases by about 4 (%), because of the increase in the number of blastings, but this change can be avoided if for each blasting a larger number of blastholes are mined, thus reducing the number of blastings. The amount of detonating cord increases by about 6 (%), because of the increase in the number of blastings.

The impact of the drilling angle on the total cost of removing rock masses, for the cases reviewed above is about 10.69 (%), or if we convert this into a monetary value, it is 356167.98 (€). This change is quite large and should not be ignored, given that saving these funds will reduce the cost of project implementation.

Acknowledgement

Most of the data is taken from the “Jaha Company”, which we thank for the excellent, and correct cooperation. We also thank the blasting engineers of different companies who helped in the data collection.

5. References

Balasubramanian, A. (2017): *Rock blasting for mining.* Mysore: Centre for Advanced Studies in Earth Science, University of Mysore, 23 p.

Borana, S. L., Yadav, S. K., and Parihar, S. K. (2018): Image Processing Analysis of Blast Fragmentation: A Case Study of Sandstone Mining Area of Jodhpur. *International Journal of Research in Advent Technology, 6*(10), 2584-2589. doi:DOI: 10.13140/RG.2.2.24151.73120

Brahimaj, F. (2021): Придонес за унапредување на контурните минирања при формирање на завршни косини на патиштата и површинските копови (*Contribution for improvement of contour blastings in forming final slopes on the roadways and surface mines).* PhD thesis, Stip: University “Goce Delcev”, 200 p. (In Macedonian - It have abstract in English).

Brahimaj, F., Dambov, R., and Brahimaj, A. (2019): The optimal parameters determination of drilling in the Kosovo motorway project in Bellanica. *XV International Conference of the Open and Underwater Mining of Minerals*, Varna, 39-45.

Brahimaj, F., Dambov, R., and Brahimaj, S. (2019): The contour blasting aplication in the Kosovo motorway project in Bellanica. *XV International Conference of the Open and Underwater Mining of Minerals*, Varna, 46-53.

Brahimaj, I. (2008): Përcaktimi i parametrave teknik dhe ekonomik, në avansimin e plasjeve masive në shfrytëzimin e Boksiteve të Kosovës (*Determination of technical and economic parameters in advansing the massive blastings in discovery of Kosovo Bouxites). Master thesis.* Mitrovicë: University of Pristina "Hasan Prishtina", 75 p. (In Albanian).

Brahimaj, I. (2012): Kontributi në përzgjedhjen e parametrave optimal të plasjeve masive në gëlqerorët e Gremnikut (*Contribution in optimal parameters selected for the massive blasting's in limestone of Gremnik).* PhD thesis, Mitrovica: University of Prishtina "Hasan Prishtina" 94 p. (In Albanian).

Brahimaj, I., and Brahimaj, F. (2019): Plasjet masive dhe speciale (*The massive and special blastings).* Mitrovicë: University of Mitrovica "Isa Boletini", 348 p. (In Albanian).

Brahimaj, I., Brahimaj, F., & Brahimaj, S. (2016): Drilling & blasting optimal parameters and the results in the dismemberment of limestone in Volljak. *Journal of International Environmental Application & Science, 11*(1), 87-91.

Brahimaj, S. (2013): Hapja dhe oregaditja e transheve në autostradën Morinë - Merdare (*Opening and preparation of trenches on the highway Morine - Merdare). Master thesis.* Mitrovicë: University of Prishtina "Hasan Prishtina", 67 p. (In Albanian).

Buhin, M. M. (2010): *Final geotechnical design - Kosovo Motorway Project.* Zagreb: Institut IGH, 184 p.

Dambov, R. (2011): Методи на минирање (*Method's of blasting).* Stip: University "Goce Delcev, 270 p. (in Macedonian).

Dambov, R. (2013): Дупчење и минирање (*Drilling and blasting).* Stip: University "Goce Delcev", 366 p. (in Macedonian).

Dambov, R. (2015): Специјални минирања (*Special Blastings).* Stip: University "Goce Delcev", 257 p. (in Macedonian).

Džodič, R. (1985): Tehnologija bušenja i miniranja (*Technology of drilling and blasting).* Pristina: University of Pristina, 191 p. (In Serbian).

Gashi, Z. (2009): Projekti i minierës sipërfaqësore "vëllezërit e Bashkuar" në Zhur (*Project of surface mine "Vellezerit e Bashkuar" in Zhur).* Prizren, 65 p. (In Albanian).

Hustrulid, W., Kushta, M., and Martin, R. (2013): *Open Pit Mine Planning & Design.* USA: CRC, Balkema, 992 p.

Jimeno, C. L., Jimeno, E. L., and Carcedo, F. J. (1995): *Drilling and Blasting of Rocks.* Rotterdam: AA Balkema, 389 p.

Kenedy, B. A. (1990): *Surface mining.* USA, 1207 p.

Koçibelli, R. (2001): Minierat sipërfaqësore të materialeve ndërtimore (*Surface mining of construction materials).* Tirane: Pelioni, 217 p. (In Albanian).

Milenko, S. (2000): Miniranje na površinskim kopovima *(Blastings in surface exploitations).* Bor: Institut of Bakar, 278 p. (In Serbian).

Nako, I. (2001): Sistemi i inicimit Nonel (*Nonel initiation system).* Tirane: Polytechnic University of Tirana, 98 p. (In Albanian).

Popovic, N. (1984): Naucne osnove projektovanja površinskih kopova (*The Scientific Basis of Surface Mining).* Sarajevo: University of Tuzla, Institut of Faculty of Mining and Geology, 971 p. (In Serbian).

Spasic, N. (1979): Tehnologija površinske eksploatacije mineralnih sirovina (*Technology of Surface Exploitation of Mineral Resources).* Pristina: University of Kosova, Faculty of Mining and Metalurgy, 398 p. (In Serbian).

Zdravev, S. (1998): Основи на рударството (*Basis of Mining).* Stip: University "Sv. Kiril i Metodij", Faculty of Mining and Geology, 420 p. (In Macedonian).

SAŽETAK

Utjecaj kuta bušenja na troškove miniranja u površinskim radovima

Uklanjanje stijenskih masa i njihovo dobivanje u površinskoj eksploataciji zahtijeva da se taj posao obavi uz najniže moguće troškove. Smanjenje operativnih troškova postiže se analizom svake radnje, načina rada i mogućnosti njihove promjene kako bi se utjecalo na smanjenje troškova. Kut bušenja jedan je od najvažnijih čimbenika tijekom miniranja u površinskoj eksploataciji. Promjenom kuta bušenja postiže se smanjenje ukupne duljine bušenja, smanjenje količine eksploziva te druge promjene tijekom procesa miniranja koje ne utječu bitno na cijenu miniranja. Određivanje utjecaja kuta bušenja na cijenu miniranja utvrđuje se analitičkim metodama i usporedbom rezultata primijenjenih metoda kuta bušenja. Analitičkom analizom podataka o miniranju i usporedbom njihovih rezultata utvrđena je promjena cijena miniranja ovisno o kutu bušenja, što je rezultiralo da se pri kutu bušenja od 90° za uklanjanje 200 000 m^3 stijenskoga materijala može uštedjeti 356 167,98 €. Promjena kuta bušenja od predviđenoga kuta od 63° do kuta bušenja od 90° smanjuje ukupne troškove miniranja za oko 10,69 %.

Ključne riječi:
kut bušenja, cijena miniranja, površinska eksploatacija, eksploziv, minska bušotina

Author's contribution

Frashër Brahimaj (1) (Assistant teacher, Dr.sc. in blasting, Manager of blastings) prepared drawings, tables, diagrams, and equations. **Izet Zeqiri (2)** (Full Professor, Dr.sc.) data analysis, calculations and wrote the manuscript. **Risto Dambov (3)** (Full Professor, Dr.sc.) analyses of results, and presentation of the results. **Shkurte Brahimaj (4)** (MSc. in mining engineering, Technical Director) performed the field work, contributing with the data collection of the prices of works and materials.