4th BALKAN MINING CONGRESS

18th - 20th October 2011
Ljubljana, Slovenia

General sponsor
PAPER’S BOOK

4th BALKAN MINING CONGRESS

18th - 20th October 2011
Ljubljana, Slovenia
CIP - Kataložni zapis o publikaciji
Narodna in univerzitetna knjižnica, Ljubljana

622(082)

BALKAN Mining Congress (4 ; 2011 ; Ljubljana)

Paper’s book / 4th Balkan Mining Congress, 18th-20th October
2011, Ljubljana, Slovenia ; [editors Milan Medved, Milivoj Vulić].
- Velenje : Coal Mine, 2011

1. Medved, Milan, 1960-
258079488
PROCEEDINGS

4th BALKAN MINING CONGRESS 2011, LJUBLJANA, SLOVENIA

Editors:
Doc. Dr. Milan MEDVED, Velenje Coal Mine, Slovenia, Doc. Dr. Milivoj VULIĆ, University of Ljubljana, Faculty of Natural Sciences and Engineering, Slovenia

International Balkanmine Congress Coordination Committee:
Msc. Marjan HUDEJ – President, Prof. Dr. Slobodan VUIJIC, Serbia, Dr. Doru CIOCLEA, Romania, Dr. Miodrag GOMILANOVIĆ, Montenegro, Dr. Stefko BOSHEVSKI, Macedonia, Grad. Eng. Emmanouel FROGOUDAKIS, Greece, Dr. Tzolo VOUTOV, Bulgaria, Grad. Eng. Tomo BENOVIĆ, Bosnia and Herzegovina, Prof. Dr. Jani BAKALLBASHI, Albania, Prof. Dr. Tevfik GÜYAGÜLER, Turkey

International Balkanmine Congress Scientific Committee:
Doc. Dr. Željko VUKELIĆ – President, Slovenia, Prof. Dr. Uroš BAJŽELJ, Slovenia, Dr. Damijan HANN, Slovenia, Doc. Dr. Evgen DERVARIĆ, Slovenia, Doc. Dr. Jože KORTNIK, Slovenia, Prof. Dr. Jakob LIKAR, Slovenia, Doc. Dr. Milan MEDVED, Slovenia, Doc. Dr. Goran VIŽINTIN, Slovenia, Doc. Dr. Milivoj VULIĆ, Slovenia, Prof. Dr. Vasil JORGIJ, Albania, Prof. Dr. Thoma KORINI, Albania, Prof. Dr. Nadežda ČALIĆ, Bosnia and Herzegovina, Prof. Dr. Nemanja POPOVIĆ, Bosnia and Herzegovina, Prof. Dr. Petar DASKALOV, Bulgaria, Prof. Dr. Vencislav IVANOV, Bulgaria, Dr. Filip VUKOVIC, Montenegro, Prof. Dr. Sophia STAMATAKI, Greece, Prof. Dr. Dimitrios KALIAMPAKOS, Greece, Prof. Dr. Stefko BOSHEVSKI, Macedonia, Dr. Stojan ZDRAVEV, Macedonia, Prof. Dr. Borče ANDREEVSKI, Macedonia, Prof. Dr. Nicolae DIMA, Romania, Prof. Dr. Ioan DUMITRESCU, Romania, Academic Prof. Dr. Marko ERCEGOVAC, Serbia, Prof. Dr. Slobodan VUIJIC, Serbia, Prof. Dr. Bahtiyar ÜNVER, Turkey, Prof. Dr. Tevfik GÜYAGÜLER, Turkey

International Balkanmine Congress Scientific Reviewers:
Prof. Dr. Uroš BAJŽELJ, Slovenia, Doc. Dr. Evgen DERVARIĆ, Slovenia, Msc. Marjan HUDEJ, Slovenia, Dr. Damijan HANN, Slovenia, Doc. Dr. Jože KORTNIK, Slovenia, Prof. Dr. Jakob LIKAR, Slovenia, Doc. Dr. Goran VIŽINTIN, Slovenia, Doc. Dr. Željko VUKELIĆ, Slovenia, Doc. Dr. Milivoj VULIĆ, Slovenia, Prof. Dr. Slobodan VUIJIC, Serbia, Dr. Doru CIOCLEA, Romania, Dr. Miodrag GOMILANOVIĆ, Montenegro, Dr. Stefko BOSHEVSKI, Macedonia, Grad. Eng. Emmanouel FROGOUDAKIS, Greece, Dr. Tzolo VOUTOV, Bulgaria, Grad. Eng. Tomo BENOVIĆ, Bosnia and Herzegovina, Prof. Dr. Jani BAKALLBASHI, Albania, Prof. Dr. Tevfik GÜYAGÜLER, Turkey, Grad. Eng. Mehmet TORUN, Turkey

Balkanmine Congress Organizing Committee:

Balkanmine Congress Editorial Committee:
Doc. Dr Milan MEDVED, Msc. Marjan HUDEJ, Msc. Ludvik GOLOB, Doc. Dr. Milivoj VULIĆ, Doc. Dr. Željko VUKELIĆ, Damjan KONOVIŠEK, Marko RANZINGER, Msc. Matjaž KAMENIK, Tadeja MRAVLJAK JEGRIŠNIK, Msc. Saša JELEN

Publisher:
Velenje Coal Mine

For Publisher:
Doc. Dr. Milan MEDVED

Technical design:
Damjan KONOVIŠEK, Ivo Hans AVBERŠEK

Printed by:
Velenje Coal Mine

Copies:
250

Web: www.balkanmine.si
E-mail: info@balkanmine.si

Publishing is approved by University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geotechnology and Mining, Ljubljana, Slovenia.
All papers are designed and reviewed.
INFLUENCE OF HORIZONTAL BLAST HOLES ON DRILLING AND BLASTING COSTS OF "ČELINA" QUARRY NEAR SIRAČ

Davor ANTOLJAK1, Ivo GALIĆ2, Branimir FARKAS3

1Kamen Sirač, Sirač, Croatia, davor.antoljak@kamen-sirac.hr
2Mining, geology and petroleum engineering faculty, Zagreb, Croatia, ivo.galic@rgn.hr
3Mining, geology and petroleum engineering faculty, Zagreb, Croatia, branimir.farkas@rgn.hr

ABSTRACT
Exploitation of mineral resources is dependent on the characteristics of the environment and the type of technology applied. The optimal way of obtaining raw mineral material is one that provides the lowest operating costs and the best prepared material unit for further use. In terms of costs, blasting is generally the most economical way of production of raw mineral materials used for the technical-building stone and lime. Influence of the blasting holes position on costs of exploitation of raw mineral material was analyzed for open pit Čelina, where exploitation of technical-building stone and carbonate raw materials is conducted for industrial processing. Raw material for production of technical-building stone and lime is obtained by blasting the limestone rock, by drilling the vertical and horizontal drilling blast holes. This paper presents an analysis of drilling and blasting parameters, which are an important factor in the product unit costs. The greatest attention is focused on the impact of horizontal blasting holes on costs of exploitation. Impact of costs, in case of mass blasting without horizontal blasting holes, has been elaborated, and the results were compared with the costs that are currently present.

KEYWORDS
Open pit, Blast hole position, Exploitation costs

1 INTRODUCTORY DISCUSSION
To get dolomite and limestone, which are used for technical-building stone and carbonate raw material for industrial processing, is done by drilling and blasting the rocks on open pit quarries. With that, the geometrical parameters of the quarry, and prior the bench height and the inclination of bench slope, have to the coordinated with the technology of exploitation (digging up) the raw mineral material.

Any kind of deviation in the technological term of solutions and projected parameters will bring a serious imbalance in the organization of work and finally in the production price of the raw mineral material.

According to the structure, it is obvious to distinguish direct and indirect cost of production. Since drilling and blasting is considered as one of the methods for getting raw mineral material, structurally those technological costs can be called direct costs. Accompanying costs, such as loading and shipping, in that case represent indirect costs. But, that kind of structure doesn't necessarily mean that indirect costs will be lower than the direct costs. Exactly that possibility occurs when the designed parameters of the surface pit are not respected, that is when the technology of the drilling is not in tune with the planned length of the blast hole. Because of that, an increase of expenses occurs during drilling, and after blasting even with loading-shipping work operations.

Also, an imbalance can occur when the geological conditions in the bearing are disregarded, firstly with the location of the discontinuity, that is, the slope of the layer and cracking systems. Consequently, a large portion of the oversized parts of the rock appears, after blasting. [2]

An unnecessary increase of production cost, caused by an imbalance of the bench height and the capabilities of the drilling equipment and improper development of the mining works in respect to the spread and the slope of the layers, happened on the surface quarry “Čelina” next to Sirač. Ten years ago, on the surface quarry “Čelina”, blasting was done only on steep blast holes, under a 70° angle (Figure 1). [5]
The bench height was 25 meters, which was in tune with the designed parameters. But, after a certain time, an increase of the bench height occurred, and due to limited technological capabilities, sub-drilling of the benches started, with sub horizontal drills (Figure 2).

![Figure 1: Schematic overview (cross section) of the projected blast hole on the surface quarry "Čelina".](image1)

<table>
<thead>
<tr>
<th>H</th>
<th>a</th>
<th>w</th>
<th>Lc</th>
<th>Lc′</th>
<th>Lb</th>
<th>D</th>
<th>a</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>70</td>
<td>3.3</td>
<td>24.8</td>
<td>3.3</td>
<td>29.1</td>
<td>86</td>
<td>4.3</td>
</tr>
</tbody>
</table>

*Figure 2: Schematic overview of the mining drills, with sub-drilling on the surface quarry "Čelina"*
Today’s benches, in certain parts total over 30 meters (Figure 3). Without sub-drilling, with “increase” of the bench height, thresholds and bumps appear regularly. For loading of blasted rock wheel loaders, for which the mined surface with numerous bumps is not suitable due to an increase of the load on the differentials, shock-absorbers, load box, etc., are used.

On Figures 1, and 2 are the following explanations of the symbols [6]:

- H – bench height
- α – angle of the slope of bench
- w – burden
- Le – explosive charge length
- Lč – length of cap
- Lb, Lbk – total length of the sloped blast hole
- Lbh – total length of the horizontal blast hole
- D – diameter of the blast hole
- a – distance between the sloped blast hole
- x – distance between the horizontal blast hole

The existing surface DTH drill rig Sandvik DI 200, in its standard equipment has 8 drilling rods, with the length of 4 meters. So, the maximum length of the blast hole is 32 meters and on the benches from 30 meters high it is very difficult to do sub drilling with which the negative effect of thresholds would be softened at least a bit.

With the mentioned, the direction of the progress is parallel with the slope of the layers, which is adverse in regards to the desired granulation and the portion of the big parts of rocks (Figure 4), and a shift of the mining front is necessary, in order to lower the secondary costs of rock fragmentation. [3,4]

Figure 3: A photo of a part of the surface quarry “Čelina”, with the bench height of about 30 m

In any case, sub-drilling additionally adds to production costs (explosive and explosive materials, mining and blasting time, wearing-out of the parts of the drill, wages, etc.), and is necessary to organizationally and technologically find more efficient solutions. [1]
2 INFLUENCE OF THE HORIZONTAL BLAST HOLES DRILLING ON THE PRODUCTION COSTS

Generally, the influence of any part of the technological process (drilling and blasting, loading, shipping, screening, etc.) on the production price of the raw mineral materials can be described and expressed in couple of ways and methodological approaches.

For this case, the authors have chosen empirical methods (analytical and graph-analytical), and methods based on hypothesis (logical engineering solutions and solutions according to analogy). Based on collected data of the length and the speed of the drilling of the blast holes, a numerical model can be done and the effect of sub-drilling on the drilling costs can be obtained.

During last couple of month’s data on drilling parameters of the blasting bore holes was collected on six blasting fields. But the number of the mining drills is not identical on all mining fields, so it was assessed that, for the relevant data, that the following parameters would be used:

- Location of the blast holes
- Number of the blast holes on the blasting field
- Total length of the blast holes
- Time of drilling
- Speed of drilling

Under summary, respectively mean values, tables have been made that show the parameters for the steep and horizontal blast holes (Tables 1 and 2).

Table 1: Parameters of the drilling of steep blast holes (70°)

<table>
<thead>
<tr>
<th>Blasting field number</th>
<th>Number of blast holes</th>
<th>Total length of drilling [m]</th>
<th>Time of drilling [h]</th>
<th>Average speed of drilling [m/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>120</td>
<td>6.58</td>
<td>18.25</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>248</td>
<td>12.33</td>
<td>19.87</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>252</td>
<td>12.70</td>
<td>19.91</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>288</td>
<td>16.15</td>
<td>17.89</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>192</td>
<td>9.66</td>
<td>19.92</td>
</tr>
<tr>
<td>6</td>
<td>13</td>
<td>411</td>
<td>22.91</td>
<td>18.21</td>
</tr>
<tr>
<td>Total</td>
<td>48</td>
<td>1511</td>
<td>80.33</td>
<td>19.00</td>
</tr>
</tbody>
</table>
Table 2: Parameters of the drilling of horizontal blast holes (0°)

<table>
<thead>
<tr>
<th>Blasting field number</th>
<th>Number of blast holes</th>
<th>Total length of drilling [m]</th>
<th>Time of drilling (T&lt;sub&gt;emp&lt;/sub&gt;), [h]</th>
<th>Average speed of drilling, (v&lt;sub&gt;emp&lt;/sub&gt;), [m/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>40</td>
<td>1.85</td>
<td>21.80</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>86</td>
<td>3.96</td>
<td>21.72</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>52</td>
<td>2.28</td>
<td>23.35</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>88</td>
<td>4.41</td>
<td>19.99</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>59</td>
<td>2.66</td>
<td>22.72</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>116</td>
<td>5.36</td>
<td>21.09</td>
</tr>
<tr>
<td>Total</td>
<td>72</td>
<td>441</td>
<td>20.52</td>
<td>21.77</td>
</tr>
</tbody>
</table>

Drilling results from tables 1 and 2 represent numerical values without the losses which occur when the drill is being moved. With that, for the final evaluation of the relationship between the horizontal and steep drills, it is necessary to include the loss of time with standstills. Here it is important to mention that standstills with horizontal drilling are much longer because the drill has to be moved from the position of drilling steep drills to the lower bench. Furthermore, with that, indirect costs of loading-shipping mechanization occur because a change of the work location happens.

A comparison of real effects of horizontal and steep blast holes is shown in Table 3, while the effect of the horizontal blast holes on the drilling costs is shown in Tables 4 and 5.

Table 3: The effect of horizontal blast holes on the total length and time of drilling

<table>
<thead>
<tr>
<th>Option</th>
<th>Position of the drills</th>
<th>Total length of drilling, [m]</th>
<th>Time of drilling (T&lt;sub&gt;emp&lt;/sub&gt;), [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>horizontal</td>
<td>441</td>
<td>20.52</td>
</tr>
<tr>
<td></td>
<td>steep</td>
<td>1511</td>
<td>80.33</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td>1952</td>
<td>100.85</td>
</tr>
<tr>
<td>2</td>
<td>Only steep</td>
<td>1511</td>
<td>80.33</td>
</tr>
<tr>
<td>Relationship between option 1 and 2</td>
<td></td>
<td>23%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Table 4: The effect of horizontal blast holes on direct costs of drilling

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>23.36</td>
<td>28.95</td>
<td>20.52</td>
<td>479.34</td>
<td>594.16</td>
</tr>
</tbody>
</table>

Table 5: The effect of horizontal blast holes on direct costs of drilling in a period of one year

<table>
<thead>
<tr>
<th>Average drill efficiency, [m/year]</th>
<th>Average drill work time, [h/year]</th>
<th>Total length of horizontal blast holes, [m/year]</th>
<th>Necessory time for drilling of horizontal blast holes, [h/year]</th>
<th>Fuel savings, [l/year]</th>
<th>Savings on drilling costs, [kn/year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>26500</td>
<td>1900</td>
<td>6095</td>
<td>380</td>
<td>8876.80</td>
<td>11003.14</td>
</tr>
</tbody>
</table>

Data about average fuel consumption, average costs of the drill, average yearly efficiency, as well as the average work drill work time were obtained by following the consumption and costs of the drill throughout the year, reduced to a yearly production of 1,000,000 t. Wages were not included in the total costs.

3 INFLUENCE OF THE MINING FRONT IN REGARDS TO ORE LAYER ORIENTATION ON THE PRODUCTION COSTS

It was noted that the position of the mining front works in relation to the elements of the layer has a substantial effect on the production cost. [2] That effect reflects through an increased amount of the over sided rock parts which, by the process of secondary fragmentation, has to be brought to an acceptable granulation for further
use. Experiences have shown that, proper orientation the mining front in regards to the drop of the layer, the amount of the oversized rock parts can be reduced to fewer than 5%. Also, by orienting the front of the operating point in regards to the spread of the layers which fall towards the front, the amount of the oversized rock parts can be increased up to 10% of the total volume of the blasted rock. [3,4]

It is certain that the question of rock layer position on the amount of the oversized rock parts and the economic effects should be dealt with in detail; this paper only addresses potential problems and possible solutions.

4 CONCLUDING DISCUSSION

In this paper the time of drilling and total lengths of blast holes have been followed on six blasting fields on the dolomite quarry “Čelina”. Due to complex conditions of exploitation (parallel orientation of the digging front in regards to the spread of the layers and a bigger bench height than projected) and removal of bumps (thresholds) on bench, during each drill of steep blasting holes, horizontal blasting holes are being drilled as well. In the paper, a comparison of costs in the case of combined steep and horizontal blast holes, and in the case of just steep blast holes has been made. The results shown in Table 3 show that by drilling horizontal blast holes, the total length of drilling increases by 23%, respectively, time of drilling by 20%.

Also, fuel consumption of the drill has been considered on the given example and an increased consumption has resulted of 479.34 l. The financial amount of the fuel has not been taken into consideration due to the changes of fuel prices. Furthermore, the increase of the total drill costs have been followed, but without the added wages, and the same example resulted in an increase of the costs by 594.16 €.

Taking into consideration results from Table 5, which were obtained under the assumption that 23% of the total length of the drill, respectively 20% of the drill work time falls on the horizontal blast holes, yearly losses add up to 11003.14 €.

In terms of reducing the costs resulting from horizontal drilling, proposed solutions are as followed:

- procurement of an crawler excavator to replace wheel loaders,
- an attempt to reduce the benches height at the projected 25 meters where sub drilling could be accomplished thus eliminating thresholds,
- rotating the front of the progression perpendicular to the spread of the layers,
- use of high energy explosives in lower parts of the vertical mining drills (especially in sub drilling part of the blast holes), and in that way trying to eliminate the thresholds.

5 ACKNOWLEDGEMENTS

We would like to thank the drillers of the company Kamen Sirač d.d., mr. Neven Rozman and mr. Ivan Balder on their patient collection of data during drilling of the blasting field.

6 REFERENCES


