Professional paper
UDC: 622.235.2
DOI: 10.7251/afts.2015.0713.035M
COBISS.RS-ID 5439256

ECONOMIC COST ANALYSIS OF DRILLING AND BLASTING DEPEND OF DRILLING AND BLASTING PARAMETERS AT QUARRY "DOBRNJA" NEAR BANJA LUKA

Malbašić Vladimir[1], Kovačević Žarko[1], Čelebić Miodrag[1], Crnogorac Jovana[1]

[1]*Faculty of mining Prijedor, Bosnia & Herzegovina, e.mail: vladimir.malbasic@unibl.rs*

ABSTRACT

In the modern mining, best efficient organization by obtaining solid minerals, is getting with explosives utilization for blasting, with the growth of significance in the exploitation of mineral resources in the open pit mines with large capacities. In this paper technological stages of drilling and blasting, that are demanding from the technological aspect, had been economicaly analyzed, because of the specific working environment by limestone quarries. The aim is to arrive the optimal combination (with the technological and economic aspects) of explosives in an explosive charge that would be used in the future work of the quarry, where technical-technological efficiency follow and economical organizing of completely production process.

Key words*: economycs, exploitation, blasting, explosives*

INTRODUCTION

In the modern mining industry efficient and rational organization of solid and hard mineral raw materials obtaining depend essentialy of the proper explosive using . Drilling-blasting operations are one of the most influential factors on the cost of mineral resources exploitation because using of explosives in the process of obtaining minerals create the conditions for the application of other modern mining techniques [1].

Analysis of physical, mechanical and technical characteristics of the rock that makes the working environment at quarry "Dobrnja" in Banja Luka, defined the selection and definition drilling and blasting parameters and the choice od data sets for drilling and explosives.

According to well-established and accepted methods of drilling-blasting parameters choice and calculation, the paper elaborated different types (combinations) of explosives and their impact on other parameters (geometry of drilling, distance between blastholes, construction of blastholes, etc.).

The results of such development and different resolving issues of choice explosives, agreed with the specific conditions of the working environment, should show a great impact of working conditions and the utilization of certain types of explosives, not only on the effectiveness of the execution of drilling

and blasting works in technical terms, but also in economic terms, where can significantly affect the organization and costs of conducting these technological exploitation phase in mines and quarries.

DEPOSIT DESCRIPTION AND DEFINITION OF WORKING ENVIRONMENT

Deposit of technical building stone - limestone "Dobrnja" near Banja Luka is located on the northern slopes of the mountain Manjaca. Surface that is covered by exploration works is about 30 hectares. Altitudes in the deposit are 490 m.a.s.l. to 650 m.a.s.l.

Total balance reserves of $A+B+C_1$ categories amount of 4,286,315 m^3.

In geological terms this part of the mountain is built entirely of Cretaceous limestone. Distribution of the limestone massif is much broader than the study sites, so this deposit is a part of Lower Cretaceous limestone formations that are represented on an area of several square kilometers [2] .

On the basis of established technical characteristics of the stone in geological research and testing quality, and according to technical conditions of the applicable standards, rock mass of technical building stone - limestone "Dobrnja" near Banja Luka can be used for the production of concrete stone aggregates, all types classical and contemporary roadbackground, asphalt road surfaces, upper supporting layer pavement structures of bitumenyside materials. The structure represents the physical-morphological way of occurrence of rock mass ie. shape, size and arrangement of the individual pieces of which it was created, but rocks and limestones belong to the medium cracked rock mass.

Limestone on PK "Dobrnje" falls into the third category of Fissures. Figure 1 shows the open profile rock on "Dobrnja".

Figure 1. Open profile on quarry "Dobrnja"

Engineering- geological characteristics

Mineral resources presented limestone appears in the form of layers and banks. In surfaces parts was cracked, and the cracks are a different orientation and dimensions of microcracks to the centimeter . They are filled with clay with small limestone debris , rarely calcite , and surface zone below the humus and red earth . With the depth cracking decreases, and the rock becomes more compact. Caverns are mapped and they are somewhere empty and partially filled with clay mixed with limestone debris. The carstificated depressions are also somewhere filled with this material. All these characteristics of the working environment are reflected in the operating conditions and the slope stability [2].

By engineering-geological classification, deposit is represented with two types of rocks and rock masses:

1. solid rock and rock mass (limestone)
2. unbound rocks (eluvium, diluvium, prolluvium and mound).

By the study of physical and mechanical properties of limestone from research hole and investigation the following parameters of working environment were obtained:

- compressive strength in the dry state 127,5 MPa;
- compressive strength in water condition 96,9 MPa;
- compressive strength after freezing 103,6 MPa;
- porosity 1–3,4 %;
- water absorption 0,27 %;
- density 2,67 gr/cm^3

EXPLOITATION SYSTEM

The cyclic-discontinuous system of exploitation is applied at "Dobrnja" quarry, which includes the following operations:

- waste removal with bulldozer "CAT D6" or other machine with similar characteristics,
- drilling and blasting (on production- technical results have influence: the structure and rock fractures, blasting- technical characteristics of the rocks, properties of used explosives, blust field activation and others. Technical requirements depends on the selected loading and haulage equipment and on the equipment at the plant for crushing and grading of technical-building stone- in terms on "Dobrnja" they are: granulation up to 600 mm with a maximum of 10 % oversize 800 mm, and security, which includes harmonization of mining in terms of safety and flying rocks [3].
- loading of blasted rocks with hydraulic excavator “CAT 330” (bucket volume $V_K = 1.8$ m^3)
- excavator “CAT 320” (bucket volume $V_K = 1.5$ m^3 , haulage system with trucks “MAN” and “ Scania”(capacity 12 m^3) or with other trucks with similar characteristics,
- overburden materials dump (haulage of loaded overburden materials with trucks on the place for filling and waste disposal),
- loading of finished product – size classes and loading of techinological (from the dressing plant) with the loader “CAT 972” (bucket volume $V_K = 4.5$ m^3) alternatives to this loading unit are the wheel loaders from other manufacturers with similar characteristics).

DRILLING

According to the sized rock pieces conditions entering to the dressing plant we get drilling diameter d = 160 mm. Applying this diameter drilling may occur large amounts outsized pieces, which would create additional costs to fragmentation of raw materials. To avoid the possibility of large quantities of outsized rocks on "Dobrnja" will be used drilling diameters of 89 or 105 mm like most frequently used drilling diametr in quarries.

During the execution of drilling-blasting works in the real conditions on the field, it will come to the optimal parameters of drilling and blasting. In the selection of drilling equipment, make sure that the drill has the ability to drill inclined boreholes with different diameters, which allow the determination of the optimal diameter drilling. For drilling will be used Atlas Copco "ROC F6" drill machine.

BLASTING

The term "blasting " implies the devastating effects of explosives utilization, which are used in mining for rock blasting during mining works under ground and on the surface.

Determination of explosives

Selection of explosives for blasting is one of the basic and most important tasks in the design of blasting explosives as applied as a carrier of energy is the main instrumentality of blasting and the success of mining depends on [4].

During the design process of blasting selection the best types of explosives are made on the basis of physical and mechanical characteristics of the work environment that are expressed through the seismic characteristics and properties of explosives. Physical and mechanical properties of rocks have the primary influence for the selection of explosives and specific consumption of explosives. Utilization of explosive energy for a specific working environment depends on the ratio of acoustic impedance rock Zs and acoustic impedance of explosives Ze. The largest amount of energy has been used for crushing in cae the ratio is equal to one [5].

However, in practice is difficult realized ratio Zs = Ze and the main causes are heterogeneity of the working environment and explosives. Beside of that cracks and fractures have an important role on the absolute value of the speed of propagation of longitudinal waves through the rock massif. Because of all this we can say that between the acoustic impedance of explosives Ze and rocks Zs exist high correlation and dependence and through the calculation we have to consider and the reflection coefficient k = 0.5-0.7 [6].

Depending on the seismic characteristics (speed of propagation of longitudinal waves through the rock massif) and specific density of rcoks in the working environment we calculate the acoustic impedance of the rock mass: [7].

$$Z_s = v_u \cdot \gamma,$$

v_u – speed of propagation of longitudinal waves through the rock massif (3800–4500 m/s)

γ – rocks density kg/dm^3, (for limestone 2,67 kg/dm^3).

Acoustic impedance of limestone is 10000–12000 mkg/sdm^3.

Acoustic impedance Ze explosives we calculate as a product of explosive density δ and explosive velocity of detonation D:

$$Z_e = D \cdot \delta$$

In this paper, the calculation is done based on the working environment and of the characteristics of emulsion, powder and AN-FO explosives, Table 1, 2. It doesn't mean that in futher quarry work can not be used other types of explosives that have similar mining-technical characteristics, and it will all depend on the needs of the company that made the exploitation of that capacity, the current market price of explosives, balsting caps, detonating cords, etc.

Table 1. Technical characteristcs of used explosives

Characteristics	Emulsion	AN–FO	AMONEX 1
Density, kg/dm^3	1,15	0,925	1,05
Gases volume, dm^3/kg	847	1045	975
Energy of explosion, J/kg	3851	3872	4228
Temperature of explosion, kJ/kg	-	-	2740
Velocity of detonation, m/s	4500	2500	4100
Oxygen balance, %	-	0	+0,13

Table 2. Acoustic impedance of limestone, explosives and their ratio

Eksplosive	Velocity of detonation m/s	Density, kg/dm^3	Acoustic impedance of explosives, mkg/sdm^3	Max. Acoustic impedace of limestone, mkg/sdm^3	Ratio between impedances I_{rock}: I_{exp}
Emulsion	4500	1,15	5175	10000–12000	0,86 –1,03
AN–FO	2500	0,925	2313	10000–12000	0,41–0,50
AMONEX 1	4100	1.05	4305	10000–12000	0,68–0,82

CALCULATION OF DRILLING AND BLASTING PARAMETERS

According to the selection of explosives in a specific work environment is possible further define the drilling and blasting parameters ,where are in this paper anlyzed the variants with different drilling diameters and different combinations of explosives as a primary and auxiliary charges. Based on the results and analysis, we can determine the optimal combination of explosives and then the geometry of boreholes and blusting fields, and also the construction of an explosive charge in a borehole [8].

At the begginig of work on quarry will be used diameter of drill hole 105 mm and combination AMONEX as a main charges with AN–FO explosives as a auxiliary charges.

In the future is possible to aplly other drill diameter and other combination of explosive charges, to get better technical-technological parameters and better economical parameters of drilling and blasting what will be directly in relationship with capacities, market conditions, market prices, and other mentioned parameters, Table 3.

According to early mentioned calculation, it is clear that the best option is utilization of minehole diameter 105 mm and combination powdered-AN-FO explosives. This combination will give the best technicla and technological results [9].

ECONOMIC ANALYSIS FOR DIFFERENT BLASTING WITH DIFFERENT COMBINATION OF EXPLOSIVES IN EXPLOSIVE CHARGES

This econimic analysis is done on the basis of average prices costs of drilling holes, explosive prices and prices of initiating and detonating tools, Table 4, (prices currently on market june-july 2014):

- Drilling hole price - 8 KM/m,
- Explosive price:
  - AN-FO exsplosives 1,2-1,4 KM/kg,
  - powdered explosives 2,2-2,5 KM/kg,
  - Emulsion 2,5-2,8 KM/kg,
- Initiating:
  - detonation fuse - 0,7 KM/m,
  - Delay 20 ms - 4 KM/piece.

Table 3. Recapitulation of calculated drilling-blasting parametars

	Unit	Mineholes with diameter 89 mm, bench height 20,0 m		Mineholes with diameter 105 mm, bench height 20,0 m	
main charges		AN–FO	Powder	AN–FO	Powder
auxiliary charges		emulsion	AN – FO	emulsion	AN–FO
W	m	3,0	3,5	3,6	4,0
a	m	3,0	3,5	3,6	4,0
b	m	3,0	3,5	3,6	4,0
m		1,0	1,0	1,0	1,0
$L_{minehole}$	m	21,18	22,33	22,36	22,48
$L_{pitting}$	m	0,9	1,05	1,08	1,2
$L_{main\ ch.}$	m	17,5	3,37	18,0	4,0
$L_{aux.\ ch.}$	m	0,68	15,46	0,76	14,48
L_{cork}	m	3,0	3,5	3,6	4,0
$Q_{main\ ch}$	kg	100,65	17,84	144,1	26,62
$Q_{aux.\ ch.}$	kg	4,0	89,0	4,0	115,84
Q_{total}	kg	104,65	106,84	148,1	142,46
delay	ms	20,0	20,0	20,0	20,0
Material quantity	m^3	180,0	245,0	259,0	320,0
q	kg/m^3	0,581	0,436	0,572	0,446
capaties	m^3/m	8,11	10,97	11,58	14,23

Table 4. Costs for drilling and blasting and economic analyses for the best combination of explosives and charges

		Mineholes with diameter 89 mm, bench height 20,0 m		Mineholes with diameter 105 mm, bench height 20,0 m	
Main charges		"AN–FO"	Powder	"AN–FO"	Powder
auxiliary charges		emusion	AN–FO	emulsion	AN–FO
$L_{minehole}$	m	21,18	22,33	22,36	22,48
Q_{main}	kg	100,65	17,84	144,1	26,62
Q_{aux}	kg	4,0	89,0	4,0	115,84
Material quant	m^3	180,0	245,0	259,0	320,0
Drill costs	KM/m^3	0,94	0,73	0,69	0,56
Explosive costs	KM/m^3	0,78	0,65	0,76	0,67
Initiating costs		0,12	0,09	0,09	0,072
Det. fuse	KM/m^3				
Delay	KM/piece				
Σ	KM/m^3	1,84	1,47	1,54	1,32

CONCLUSION

From the analyzes results in this paper is possible to make the following conclusions:

1. Working environment and rock material where we making a drilling-blasting process, have a crucial significance when we want to define parameters of drilling and blasting phases at quarry like very important parameters in technical and also economical sense.

2. Physical, mechanical and technical characteristic of rock are used like inputs for further calculation, and they are directly conected with selection of all other drilling and blasting parameters.

3. It is a significant influence of blasting effects on other proces in mining, work of equipment in other exploitation phases–loading, haulage and procesing. Th all mining phases and working equipment are directly conected, respectively on drilling and blasting need to be compliant with characteristic of loading, haulage and mineral procesing eqiupment.

4. Through this analysis we can see that is better to use bigger diameter for dilling holes, there are better efects on that way.

In this paper is defined theoretically and economicaly best combinaotin of explosives in hole charge, with economic analysing of all other possible combination. However, it is possible that in the future Investor change some of this recomended solution, but that will be conected with changed condition on quuary, and condition on market. The analysis presented in this paper gives the possibility of quick calculating and defining of all the techno-economic parameters of drilling and blasting technological stages.

(Received Oktober 2015, November 2015)

REFERENCES

[1] Majstorović, S., Malbašić, V. (2013). Introduction to mining, Prijedor.
[2] Milosevic, A., Salcin. E. (2007). Geological study on classification, categorization and calculation reserves of technical building stone - limestone on the deposit Dobrnja near Banja Luka - state of 20.12.2007., Prijedor.
[3] Malbašić, V. (2008). The main mining project of exploitation of technical building stone-limestone at open pit "Dobrnja" near Banja Luka, Prijedor.
[4] Savic, M. (2000). Blasting in opencast mines, Bor.
[5] Popovic, S. (1984). Scientific basics of open pit designing, Sarajevo.
[6] Purtić, N. (1991). Drilling and blasting, Belgrade.
[7] Malbašić, V., Čelebić, M. (2010). Determination of the safety zones by drilling and blasting in order to maximally facilities protect in the case of quarries ,,Ljubačevo" in Banja Luka, the Archive of Technical Sciences, Bijeljina, No. 3, pp. 119-132.
[8] Kovačević, Ž. (2014). Analysis of the techno-economic feasibility of using different explosives by calculation drilling and blasting parameters, Final Paper-Master, Prijedor.
[9] Kovačević, Ž., Čelebić, M., Tosic, D. (2013). Calculation of drilling and blasting parameters for quarry Dobrnja near Banja Luka the Archive of Technical Sciences, Bijeljina, No. 9, pp. 35-42.