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DESIGN AND EXECUTION OF DRILLING AND BLASTING WORKS USING MODERN SCANNING TECHNIQUES

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Abstract: *The basic principles for the design of the parameters of the shooting techniques are: the exact definition of the technical and economic objectives and especially those related to the granulometry of the demolished material, knowledge of the characteristics of the rock massif (degree of cracking and local fracturing, compressive and tensile strength of the rocks, the degree of homogeneity and their compactness), knowing in detail the possibility of executing the firing holes for loading and crushing the demolished material, knowing the explosive used and its behavior in the concrete conditions of the quarry, specifying the restrictions imposed by the protection of the environment (distances from the surrounding objectives, the maximum accepted levels of vibrations, noises, dust). In order for all these principles to be fulfilled, there are methods of designing and executing the drilling and shooting works so that the results of the shooting works are those expected in conjunction with a rational exploitation in safe conditions. The paper presents a case study where the design and execution of drilling and blasting parameters was successfully applied using modern equipment.*
Keywords: *explosives, blasting parameters, quarry, blasthole*

1. Introduction

In order to have the desired results when carrying out quarry blasting work, special attention must be paid to the design of the blasting technique used. [1]

All technical aspects that can influence the outcome of a shot job carried out in a quarry must be taken into account. All the necessary information must be analyzed, an action that leads to the achievement of the previously established objectives of carrying out the demolition works with the help of civil explosives. [2]

When designing the shot, all the geometrical and placement parameters of the shot holes are determined, the type of explosive that will be used and how to load it into the shot holes, the delay scheme, etc. [3]

The necessary parameters to be determined when designing a shot are (Figure 1): the height and inclination of the slope of the step, the diameter and inclination of the hole, the line of resistance to the hearth (anticipatory), the length and depth of the drilled hole, the distance between the holes of the same row and between the rows of holes, explosive construction / distribution of the explosive in the hole, the length of the blast and the firing sequences of the charges. [4]

In order to obtain the most accurate data from the field regarding the main characteristics of the working bench (bench height, angle of inclination of the bench, geology of the area, etc.), various methods of scanning the surface of the working bench have been developed in the last 20 years using 2D or 3D laser, GNSS, Boretrack, drone.

These scanning equipment together with various specialized software have led to a very high accuracy of the data collected from the field, their processing and the correct design of the perforation scheme. [5]

This paper presents the way of designing and evaluating the drilling and shooting works in order to optimize the shooting parameters with a direct impact on the results obtained.

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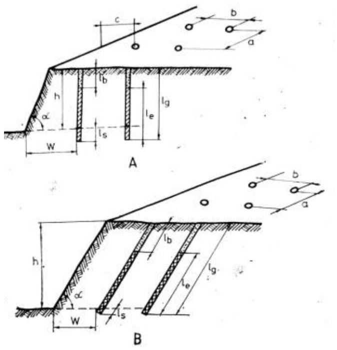

Fig. 1 Blasting technique parameters

For these actions, modern means of scanning, design and processing were used, which made it possible to obtain exceptional results.

Thus, the design-evaluation method was applied in the Hoghiz Quarry, mainly having the following execution stages:

- scanning the work front can do using measuring equipment such as Laser 2D, 3D, Drone, GNSS;
- the use of a specialized software for determining drilling parameters (hole length, hole inclination, hole azimuth, drilling network);
- the transposition of the projected data on the drilling scheme, which includes for each shooting hole, the length, the drilling angle and the azimuth of the hole and which is transmitted to the operator on the drilling;
- marking in the field the position of the shooting holes according to the designed drilling scheme;
- drilling shot holes, checking them using Boretrack scanning equipment, inclinometer, compass, flashlight or laser device;
- establishing the explosive charge for each hole and designing the delay scheme;
- carrying out the shooting work and filming it with a video camera or drone;
- verification of shooting results by visual control immediately after the shooting operation and photographic analysis of the shooting

2. Methods of evaluation

2.1. Scanning the work front using Drona-type measuring equipment

For the initial scanning, a Drona-type equipment (Mavick 3 was used, with the help of which the blasting front was photographed. (Figure 2)

The obtained information was downloaded and processed with a specialized software design (QarryX), with the help of which the blasting holes were designed.

Fig. 2 Scanned front

2.2. Design of blasting holes

The operator is required to know the actual depth, inclination, azimuth and lead for each borehole before charging it with explosive. For the front row, the information from the drill monograph is used in conjunction with the face profiling data to calculate the correct anticipation both upslope and around each borehole along the front row.

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For an optimal design of the drilling monograph, the specialized software QuarryX was used, with the help of which the design of each blasting hole in the first row was analyzed, in relation to the real surface of the front slope.

With the help of the QX software - Profile mode, the holes are designed - (distance from the ridge, length of the hole, angle of inclination, azimuth) so that all the holes, depending on the calculated theoretical anticipation, touch as many points as possible in the real profile of the working step. (Figure 3).

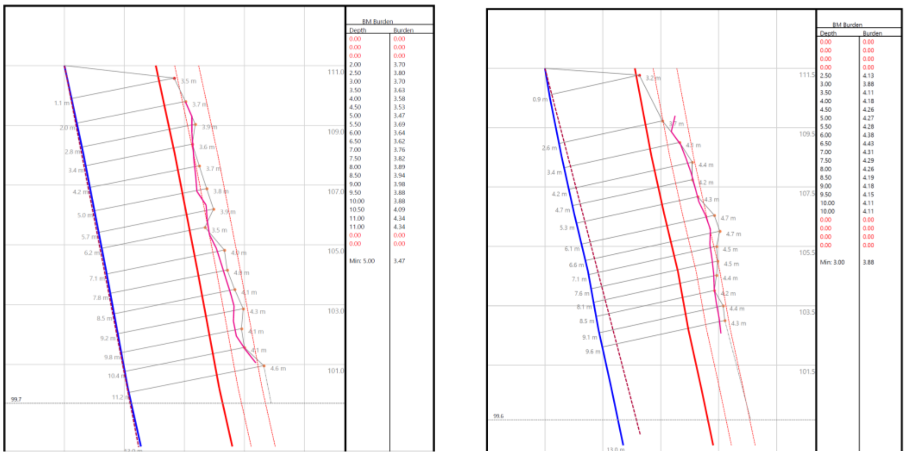

Fig. 3 Design blasting holes

Taking as a reference the design of the first row of blasting holes, the distribution of blasting holes for the entire shot front was generated. (Figure 4)

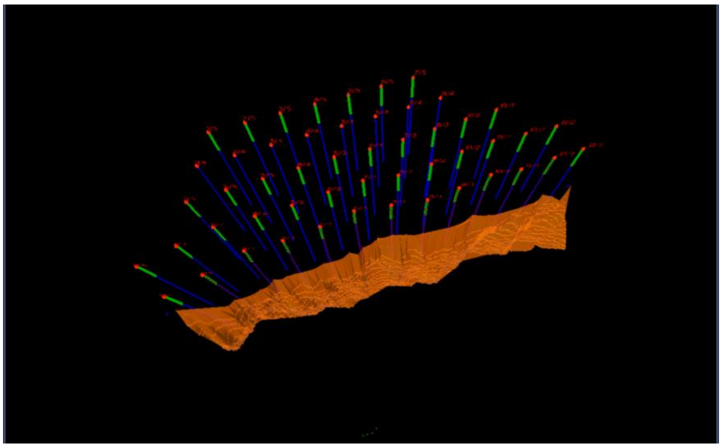

Fig. 4 The distribution of blasting holes

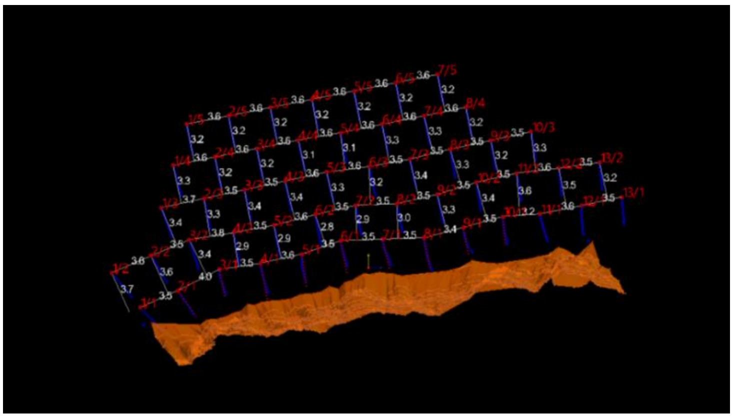

Fig. 5 Drilling monograph

The distribution of the holes in the front and their coordinates, respectively the drilling monograph (Figure 5), was sent to the drilling operator.

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2.3. Design of blasting holes

If the holes are straight, then in most cases the depth of the hole is easy to measure. Inclination and azimuth can be checked by optical survey, i.e. flashlight, compass and inclinometer.

A modern method of checking the execution of blasting holes is electronic measuring tools (MDL – Cabled Boretrak System) should be used (Figure 6).

Fig. 6 MDL – Cabled Boretrak System

Boretracking is a method of measuring "as drilled" holes. A probe is lowered into the drilled hole that meaures the pitch and role of the probe sensor at pre-set intervals. [6]

This information can be added to specialized softwere 3D model of the bench. This allows the software to calculate actual burdens of the holes at different locations and measure hole separations for optimized loading.

With the help of the specialized software (QuarryX), the accuracy of the execution of the holes in Figure 7 was verified, the results being presented in the table 3. [7]

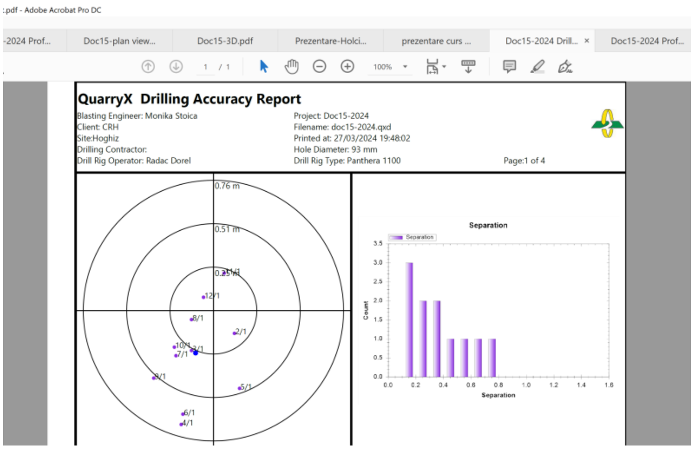

Fig. 7 Drilling accuracy

It can be compared to a shot plan designed in QuarryX on the bench to measure drilling deviations.

3. Results and discussions

The following parameters are highlighted for each hole [8]:
geolocation of the hole (lat, & long.), z-elevation, azimuth of the hole, angle of inclination, length of the hole, drilling diameter, sub-sinking, anticipation, bore, hearth level). (Tabel 1 and Tabel 2)

Table 1. Parameters for blasthole no. 1÷5

Parammeters	**BLASTHOLE**				
	1	2	3	4	5
East	982.01	985.55	989.02	992.51	995.78
North	1025.57	1027.35	1027.87	1028.66	1029.78
Elevation	112.1	111.7	111.5	111.69	111.56
Drill Azimuth (°)	146.9*	165.9*	165.3*	170.9*	164.9*
Search Azimuth (°)	146.9	165.9	165.3	170.9	164.9
Drill Angle (°)	11.5*	10.0*	11.8*	11.0*	10.3*

Hole length	13.0m*	13.0m*	13.0m*	13.0m*	13.0m*
Subdrill	0.4m	0.7m	0.8m	0.7m	1.0m
Diameter	93mm	93mm	93mm	93mm	93mm
Offset	-2.2m	-3.4m	-3.3m	-3.4m	-3.9m
Horizontal Offset	0.8m	0.0m	0.1m	0.3m	0.3m
Vert.Face Height	11.6m	11.8m	11.6m	11.7m	11.3m
Profile Area	41.1m²	49.4m²	50.7m²	51.0m²	51.7m²
Planned Burden	4.0m	4.0m	4.0m	4.0m	4.0m
Tolerance	10.0%	10.0%	10.0%	10.0%	10.0%
Floorlevel	99.8	99.6	99.6	99.6	99.8
Critical Burden	3.0 m	3.0 m	3.0 m	3.0 m	3.0 m
Stemming	2.7m	2.7m	2.7m	2.7m	2.7m
BurdenMaster Settings: Search Width BM Grid (H x V) Burden To Report Excessive Burden	 4.0m 0.5mx 0.5m 3.3m 6.0m				

Table 2. Parameters for blasthole no. 6÷11

Parammeters	**BLASTHOLE**					
	6	7	8	9	10	11
East	999.32	1002.81	1006.14	1009.49	1012.64	1016.15
North	1029.91	1030.02	1030.9	1031.83	1032.04	1032.75
Elevation	111.42	111.28	111	111.01	110.88	111
Drill Azimuth (°)	161.1*	165.7*	160.5*	170.0*	164.9*	176.9*
Search Azimuth (°)	161.1	165.7	160.5	170.0	164.9	176.9
Drill Angle (°)	11.1*	13.3*	11.8*	11.2*	11.2*	11.5*
Hole length	13.0m*	13.0m*	13.0m*	13.0m*	13.0m*	13.0m*
Subdrill	1.1m	1.2m	0.8m	1.5m	1.7m	1.4m
Diameter	93mm	93mm	93mm	93mm	93mm	93mm
Offset	-3.4m	-2.9m	-3.3m	-3.3m	-3.1m	-2.8m
Horizontal Offset	0.4m	0.4m	0.1m	1.2m	1.1m	1.8m
Vert.Face Height	11.2m	10.9m	11.6m	10.7m	10.6m	10.9m
Profile Area	49.5m²	46.4m²	50.7m²	46.1m²	41.7m²	44.8m²
Planned Burden	4.0m	4.0m	4.0m	4.0m	4.0m	4.0m
Tolerance	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Floorlevel	99.8	99.8	99.6	99.8	99.8	99.7
Critical Burden	3.0 m	3.0 m	3.0 m	3.0 m	3.0 m	3.0 m
Stemming	2.7m	2.7m	2.7m	2.7m	2.7m	2.7m
BurdenMaster Settings: Search Width BM Grid (H x V) Burden To Report Excessive Burden	 4.0m 0.5m x 0.5m 3.3m 6.0m					

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Table 3. Drilling accuracy

Hole	MaxX	MaxY	Separation
1	0.12	-0.13	0.17
2	-0.13	-0.23	0.27
3	-0.19	-0.66	0.72
4	0.15	-0.45	0.48
5	-0.18	-0.60	0.65
6	-0.22	-0.26	0.35
7	-0.13	-0.05	0.14
8	-0.35	-0.39	0.53
9	-0.23	-0.21	0.32
10	0.06	0.22	0.23
11	-0.06	0.08	0.10
Min	0,06	0,50	0,10
Max.	0,35	0,66	0,72
Avr.	0,17	0,30	0,72

After measuring the holes located on row 1 with the help of the Boretrack equipment and the graphical overlay of the measured hole with the designed hole, minor deviations of the drilled holes on both the x and y axis can be observed, which do not exceed 0.3 m and do not influence the maximum anticipation taken into account.

After completing all the design-verification stages, the final conditions for carrying out the shooting work were established.

The main purpose of checking compliance with the drilling monograph is to highlight a possible risk situation that consists of shot holes drilled too close / too far from the free surface or shot holes that, in depth, reach too close / too far from each other.

These situations mean that in respective areas of the firing front, the quantities of explosives are oversized / undersized, as the case may be.

If they are not identified and resolved, such situations lead to the amplification of the effects of the shooting works (throwing rocks, scattering rocks, producing high-intensity vibrations) as well as cracks in the massif, obtaining an irregular shape of the front after shooting, unnecessary consumption of explosive.[9]

In the following, the geometric and quantitative parameters established considering the results obtained during the design-verification stages of the drilling monograph are presented.

- avg. step height: 11,8 m;
- inclination of the holes: 76 ÷ 78°;
- number of holes: 51;
- number of rows: 5;
- diameter of the holes: 92 mm;
- planned burden (w); 4 m;
- critical burden: 3 m
- distance from the edge of the beam to the first row of holes (c): 3,2 m;
- the distance between the holes on the same row (a): 3.6 m;
- distance between rows (b): 3.3 m;
- length under the recess (Lsub.): 0.7 m;
- hole length (Lg): 13 m;
- length of the explosive column: 9.3 m;
- civil explosives used:
• basic explosive charge, Blendex emulsion type explosive;
• explosive initiation charge; Dynamite
- means of initiation: non-electrical initiation system;
- amount of explosive / hole: 4386 Kg E TNT (Trotil equivalent), consisting of Blendex emulsion type explosive and explosives dynamite;
- quantity of explosive / delay stage: 86 kg. E TNT (1 shot hole / delay stage).

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Sequential rock detachment from the massif will be accomplished using network of delayed surface connectors to initiate staple shock tubes that transmit the detonation into the shot holes.

The initiation of the deployment of the firing front will be done from one of the flanks (left/right) or from the front depending on the conditions in the work stage.

The delay scheme presented in Figure 8 was also established

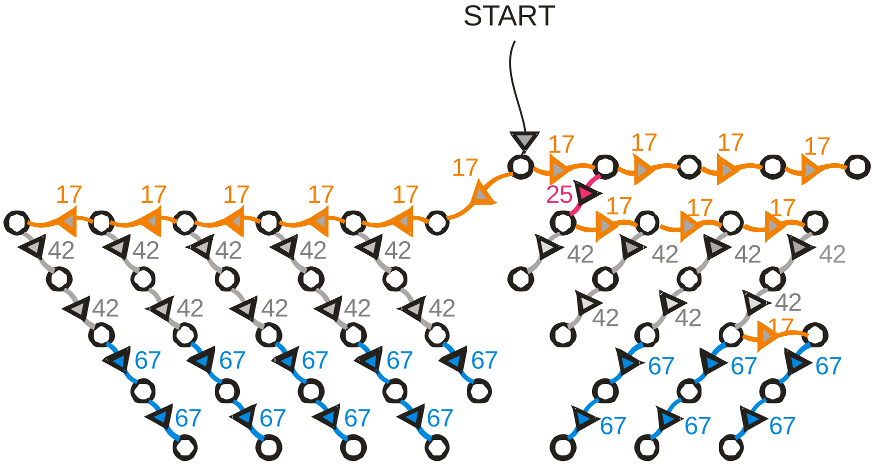

Fig. 8 Design delay blasting

The blasting results were very good, this can be seen in Figure 9.

The presence of oversizes rock was not found, the fragmentation of the rock was adequate, the material was good grouped and the shape of the step left after blast allows the preparation of the next front, without the need for additional work (contouring etc).

Fig. 9 Rezults of blasting

4. Conclusions

Application of the design-verification procedure led to very good blasting results.

The design-verification system of the blasting holes which consists of modern high-performance infrastructure (specialized software QuaryX, boretrack) allowed a detailed analysis of the execution of the blasting holes and the adaptation of the blasting conditions to the concrete situation in the field.

Even if the results presented were obtained, to be certain of obtaining consistently positive results it is still recommended to check each shot hole.

Every economic operator should use such a design-check system.

The use and implementation of such a design-verification procedure maintains adequate control of the blasting works in terms of their effects (fly rock, seismic effect), thus increasing the degree of safety when performing the blasting works.

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