INCREASING THE SECURITY ON PERFORMING BLASTING IN OPEN-CAST MINING, WITH THE ENSURANCE OF SEISMIC PROTECTION TO THE INDUSTRIAL / CIVIL OBJECTIVES SITUATED IN THEIR VICINITY

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ABSTRACT: Performance of blasting in open-cast mining, ensuring seismic protection to the industrial / civil objectives situated in their vicinity, represents a major challenge both internationally and nationally, in terms of regulating the assessment of seismic effect generated by blasting. The paper propose specific safety rules applicable for quarries and other surface blasting works regarding the risk generated by seismic waves which are generated by explosions.

KEYWORDS: security, blasting technique, seismic protection, seismic evaluation

1. INTRODUCTION

Performing blasting in open-cast mining, with the ensurance of seismic protection to the industrial / civil objectives situates in their vicinity, represents a major objective both at international level and national level, in terms of regulating the assessment of seismic effect caused by blasting [2].

Explosion seismic action produced by blasting of explosives for civil use in a quarries, can be measured by analyzing the values of the parameter represented by the speed of oscillation of the soil particles, only reproducible parameter for the entire range of natural frequencies of earthquakes of this type (1–100 Hz) and dependent to a lesser extent the properties of the rocks [1].

At the same time, on the basis of the analysis of values allowed for soil particle velocity oscillations, depending on the type of construction (civil or industrial) and the correlation between the level of seismic activity according to the STAS 3684-71, possible effects on building structures and oscillation speeds permissible for soil particles in the case of seismic blasting work, it may issue appreciations regarding the determination of the quantities of dangerous explosives and possible effects on structures when using large quantities of explosives. Thus, knowing the permissible speed of the oscillations can be determined the reduced distance, which is a quarry own size and of the technology used in blasting.

2. GENERAL CONSIDERATIONS OF THE BLASTING EFFECTS ON THE CIVIL/INDUSTRIAL AND ENVIRONMENTAL OBJECTIVES

Extracting hard rocks using explosives, given that these works are carried out at more closely distances from habitats, requires a focus on education in terms of the effect of these works [3].

Among the major effects of the work of displacement of rocks with explosives on the the surrounding area are to remember the following, without claiming to hierarchy depending of induced proportion:

- seismic effect;
- environmental pollution;
- morphological changes of the surrounding habitat.

The evaluation of the main effects of displacement of rocks using explosives:

I. The seismic effect besides disturbing action, has influence on the stability and security of civil and industrial objectives in the area.

In most cases, the evaluation of this effect is regulated by laws which vary from country to country. In most cases, evaluation is performed by measuring the rate of oscillation of the particle, the parameter considered the most reproducible.

Regarding the maximum permissible limit values of this parameter, there is no unity of with here are even relatively large differences between different regulations.

We believe that the maximum speed of oscillation of particles to adopt the appropriate amount of seismic zoning of the territory, if for the construction of the structure is known and are documents in this regard, or in the case of structures with special character the value imposed on them.

In case of structures with different limits will be adopted minimum protection to ensure full protection of all.

II. The effect of environmental pollution due to toxic gas explosion is considered very heterogeneous, differing assessment of national national legislation on environmental protection. It should however be noted that in this area, the European standards and the views are very different, being far from an acceptable approximation. In this respect problematic should be addressed mainly on two levels of action, primary and secondary.

Primary measures will be targeted on the regard to volume of toxic gas of explosion which must limited depending on the blasting position i.e. underground and aboveground.

When we talk about environmental pollution, we must consider the harmonization of regulations on maximum allowable concentrations for each specific toxic gasses of explosive materials.

Secondary measures should be mainly related to technical solutions that should be adopted for determining toxic gases or their dilution or limiting their diffusion.

III. Morphological changes, generates a series of complex effects, causing landslides or hydrogeology affecting the area, fauna, flora, airflow, etc.

Morphological changes with multiple effects that can generate mainly affect microclimate zones with specific consequences will either be controlled or exploited in the interest of local communities.

A consequence not insignificant of morphological changes is also the damage of local magnetic field, will be required assessed to have appropriate measures.

Besides multidisciplinary approach, should not be avoided even the "multilevel evaluation" from this point of research and inter-dependent parameters.

More exactly education on the major effects of the blasting will be approached as we said inter-dependent, with clear responsibilities for each actor: manufacturer of explosive materials;

- user
- public administration;
- community.

In this respect, there should be founded solutions for the development of departments, commissions or other entities with an educational responsibility and prevention of unwanted consequences in areas where using explosives for civil use. For these educational entities and responsible to function properly and concisely solutions must be found incentive in each tier and finally at zonal / regional / national level.

3. TECHNOLOGY ASSESSMENT OF BLASTING IN OPEN-CAST MINING, WITH THE ENSURANCE OF SEISMIC PROTECTION TO THE INDUSTRIAL / CIVIL OBJECTIVES SITUATES IN THEIR VICINITY

The quantities of explosives that can be used in a quarry, instantly / delay stage

can be determined based on the dependence of the oscillation speed soil particles - the distance between the epicenter of the explosion and where the measurement is made -the explosive quantity blasted expressed by the relation [4]:

$$V = K \cdot R_r^m \quad \text{(cm/s)} \qquad (1)$$

in which:

R_r - reduced distance

$$R_r = R / \sqrt{Q} \quad (\text{m.kg}^{-1/2}) \qquad (2)$$

where:

K and m - constants for a particular quarry and blasting process;

R - epicenter of the explosion and the distance between the measuring site or the protected objective , (m);

Q - quantity of explosive, (kg TNT).

If the ground speed measurement particle fluctuations is performed in the case a millisecond delay blasting, the reduced distance calculation will take into account the maximum amount of explosive stage delay reduced by reducing the value function of the explosion seismic action, according to the relation:

$$Q = Q_{\max.tr.int.} \cdot f(n) \quad \text{(kg ETNT)} \qquad (3)$$

where:

f(n) - reduction function for explosion seismic action:

- For instant blasting f(n) = 1;
- For blasts with millisecond delay:

$$f(n) = 1 - 12{,}9\ (n \cdot \Delta t)^2 \quad \text{if} \quad n\,\Delta t \le 0{,}15\ \text{s} \qquad (4)$$

$$f(n) = 0{,}275 / \sqrt{n \cdot \Delta t} \quad \text{if} \quad n\,\Delta t > 0{,}15\ \text{s} \qquad (5)$$

where:

n - number of time delay;

Δ t - time delay between steps, (s).

Sizes constants K and m are determined by the method of the least squares, statistically processing the values of at least 25 pairs of short distance and speed oscillations soil particles, measured at least two blasts using different explosive amounts.

Speed must be measured at the points of maximum interest located on the front that is blast and where is admitted the lower value of speed of oscillation of the ground particles.

Knowing the value of velocity oscillations permissible soil particles shall be determined the value of reduced distance which is proper to the quarry blasting technology used and the geological environment in which seismic waves propagate.

Reduced distance specific to a quarry and the blasting technology is calculated according to the speed of oscillation and constants K and m, with relation:

$$R_r = (V / K)^{1/m} \qquad (6)$$

Correlation between soil particles velocity fluctuations and their effects on structures are given in Table 1.

Table no. 1

Seismic Intensity (degrees) STAS 3684-71	Effects on structures	The speed of oscillation V* (cm/s)	
		permissible	limit
IV	Possible damage to constructions type rural, pipeline pressure oil and gas wells, mining pits, very fragile structures.	0,5	1,0
V	Fall off the paint layer. Small and narrow cracks in plastering to constructions type rural and urban areas. Possible minor damage to industrial buildings.	1,1	2,0
VI	Fall off the paint layer. Small and narrow cracks in plastering to constructions type rural and urban areas. Possible minor damage to industrial buildings.	2,1	4,0
VII	Fractures are produced at the resistance elements such as rural and urban type fracture in masonry with plaster peeling off large chunks and cracks in the plaster peeling off pieces of industrial type constructions. Subsidence in a few cases the roadway on steep slopes. Possible damage to piping connections. Damage to cars fitted.	4,1	8,0
VIII	Major fractures produces resistance elements rural and urban building type. Cracks occur in elements of industrial strength construction.	8,1	16,0
IX	Dislocations occur and collapse of connecting elements of urban and rural construction. Fractures occur in the construction elements of industrial strength. Failures of dams, underground pipes, possible deformations and significant damage to the roadway.	16,1	32,0
X	Destruction occurs rural construction type, collapse of elements related to construction of urban dislocation and fracture resistance elements for industrial buildings.	32,1	64,0

Note: V - maximum horizontal speed is measured on one of the two main radial direction- longitudinal (V_r) or tangential (V_t)*

Permissible vibration speed is the speed at which it is estimated are not exceeded the effects previously accepted on the building structures.

When conducting repeated blasting the speed of oscillation soil particles must fall within the values of permitted speed. The amount of explosive that can be instantly blast is calculated based on allowable speed oscillations determined by the type of construction that must be protected and / or the degree of destruction accepted using: $Q_{inst} = (R/R_r)^2 \cdot K_1$ (kg ETNT) (7)

where:

K_1 - coefficient depending on the number of blasts done in a year: up to 10 $K_1 = 0,98$

- from 11 up to 50 $K_1 = 0,90$
- from 51 up to 100 $K_1 = 0,72$
- from 101 up to 250 $K_1 = 0,64$
- over 250 $K_1 = 0,56$

When blasting millisecond, the amount of explosive that blast on the last stage is calculated using:

$Q_{tr.înt.} = 2/3 Q_{inst.} \cdot f(n)$ (kg ETNT) (8)

4. CASE STUDY ON BLASTING TECHNIQUE USED IN LIMESTONE QUARRY LESPEZI FROM THE HOLDING CARPATCEMENT S.A. ROMANIA

In the study [5], has been determined the maximum amount of explosive that can be used instantly and on delay stage, in limestone quarry Lespezi from the holding Carpatcement S.A. Romania, Cement Factory Fieni, to provide seismic protection of the objectives located near the quarry.

In the limestone quarry Lespezi it is using blasting technique with vertical boreholes / inclined combined with the horizontal borehole parallel to talus, drilled at the base of the talus;

Technical parameters for blasting:

- diameter of boreholes: max.102 mm;
- anticipated at the outsole vertical holes / inclined: max. 3,5 m;
- distance between holes placed on the same line: max. 3,2 m;
- distance between rows of holes: max. 3,5 m;
- hole length: - vertical / inclined: max. 22 m;
- length of sub-drilling of the vertical holes / inclined: max. 1,5 m;
- length of border: in vertical holes / inclined: min. 3,5 m;
- length of the explosive column: - in vertical holes / inclined: max. 18,5 m;
- construction load: - vertical holes: explosive mixture consisting of porous granular ammonium nitrate and diesel fuel (base load, approx. 6,5 kg/ml), initiated in two points at hole bottom - explosive AUSTROGEL (2500 g) + EMULEX 1 (3125 g) - and in the middle of the length of the column of explosives - unit load type booster (450 g) - priming charges are initiated by non-electrical system, with the same level of delay.

Explosive materials used:

- explosive - base charge: an explosive mixture of ammonium nitrate porous granular and diesel fuel, certified according to normative regulations; priming charge: AUSTROGEL (High Power explosive, TNT equivalence factor 1,3), EMULEX 1 (explosive medium power, TNT equivalence factor 1), unit load type booster (High Power explosive, TNT equivalence factor 1,3);
- means of initiation: non-electric initiation systems.

Features specific of seismic micro perimeter of the quarry Lespezi:

- soil particle oscillation speed, maximum permissible: 0,5 cm/s;

- reduced distance: 20,4;
  - seismic constant specific to perimeter and blasting technique: m = - 1,257; K = 8,980.
- No. of maximum annual primary blasting 50

For determination of the parameters (constants K, m and reduced distance R_r), underlying establishment of the amount of explosive hazardous in terms of seismic velocities were measured oscillation soil particle specific quarry micro condition Lespezi, 2 blasting monitored. Measurement locations at points of maximum interest, the objects in the area bordering quarry Lespezi (picture no.1).

Picture 1- Plan of situation for limestone quarry Lespezi

The results of measurements at the 2 blasts monitored are shown in Table. 2:

Blast	The maximum amount of explosive / delay stage $Q_{max.delay\ stage}$ (KgETN)	Locations of measure ment	Speed oscillations of environment particles [mm/s]	The distance from the epicenter location to explosion [m]	reduced Distance $R_{red.}$
I 1 Tr. 1360 West Front	$Q_{max.delay\ stage}$ 153,92 Kg	L1	0,2000	879,81	70,95
		L2	0,3175	843,80	68,04
		L3	0,1000	1059,84	85,47
		L4	1,9000	1037,84	83,69
		L5	0,2400	875,81	70,62
		L6	0,2000	981,83	79,17
		L7	2,4400	1031,84	83,21
		L8	0,0250	965,83	77,88
		L9	0,3000	861,81	69,50
		L10	1,6000	833,80	67,24
		L11	0,1000	759,78	61,27
		L12	0,1000	575,71	46,42
		L13	0,5080	665,75	53,68
I 2 Tr. 1375 East Front	$Q_{max.tr.înt.}$ 261,375 Kg	L1	6,0000	245,01	15,16
		L2	2,6670	479,49	29.67
		L3	0,6000	439,44	27,19
		L4	2,5000	461,47	28,55
		L5	0,5000	751,67	46,51
		L6	1,6800	973,75	60,25
		L7	0,4000	941,74	58,27
		L8	1,5400	1027,76	63,59
		L9	1,7145	949,74	58,77
		L10	0,5400	1045,76	64,71
		L11	0,1000	963,74	59,63
		L12	0,5100	1087,77	67,31
		L13	0,1000	1019,76	63,10

permissible oscillations soil particles.

The maximum quantities of explosives allowed blast instantly and $2/3Q_{inst.}$, to calculate the maximum allowable quantities to blast on delay stage, depending on the real distance between the fronts of blasting (epicenter of the explosion) and the nearest protected objective are shown in Table no.3.

Table no 3

No. crt.	Real distance[m]	$Q_{inst.}$ [kg E TNT]	$Q_{2/3}$ [kg E TNT]
0.	1.	2.	3.
1.	**200**	87	58
2.	300	195	130
3.	400	347	231
4.	500	541	361

The amount of explosive that is blast on delay stage is calculated with (8):

$$Q_{tr.înt.} = 2/3Q_{inst.} \cdot f(n) \quad \text{(kg ETNT)}$$

Where f(n) reduction function is calculated according to the duration of the blasting, relationships (4) / (5).

5. CONCLUSIONS

For the seismic action of blasting Lespezi career not to Affect the integrity of the Objectives at close range, it Requires proper management and coordination of Their compliance with the Quantities of explosives, maximum permissible to blast instantly / delay stage,: Depending on the actual distance Between nearest protected seismic objective - the epicenter of the explosion.

With characteristics change of blasting technique applied in Lespezi quarry or change of explosives used seismic effect reconsidered in order to determine the quantities of explosives to ensure nearby seismic protection the objectives.

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