Theory and practice in the boulders and rock blocks blasting in urban areas applied to civil engineering activities

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ABSTRACT: Blocks of rock are large fragments of the bedrock that have not suffered a strong erosive process and have remained in the soil horizons. They can be oval shaped, or nearly spherical. The calculation for blasting is different, as the volume between these blocks varies, and so does the number of holes required. Thus, a calculation method (Ayres da Silva, A. & Gianotti de Andrade, G. Method) was developed for the oval-shaped rock blocks. Finally, in the blasting of blocks using explosives, it is necessary to find what is the block's volume to be blasted, because this value is fundamental to obtaining a safe amount of explosives needed for a given specific charge.

Keywords: Boulders, Boulder blast, Rock block blast, Boulder blast design.

1 INTRODUCTION

It is important to note that when using explosives to blast rock masses or boulders (which are rock blocks without a predefined shape but with a volume of fragments bigger than 1 m^3), especially when carried out in urban areas, it is essential that all safety requirements in their execution are met.

The most evident risks resulting from this activity can be divided into three main types:

- *Flyrock* - launch of rock fragments beyond the areas circumscribed to the operations;
- *Vibrations that can produce damage to the structures in their surroundings* – buildings, and housing in general;
- Environmental Impacts - which may be a consequence of vibrations or noise resulting from the detonations of explosives used in rock blasting (rock mass and rock blocks).

Such risks are also the subject of internationally established technical standards or methodologies.

However, there is no standardization in the methodology of defining which charges to use and how many holes are defined for rock blocks and boulders blasts in order to meet the care defined in the above items.

The objective of this work is, therefore, to present a new blast design methodology to blast the boulders into fragments that could be thrown at safe distances, avoiding flyrocks.

Hence the authors of this study have dedicated themselves to systematizing the conclusions and the method that some of them have defined in important work carried out in extremely inhabited regions of São Paulo (Brazil), with great success (Figure 1).

Figure 1. Places where the described methodology for boulders blast was applied – Source: authors.

2 THEORETICAL DESIGN METHOD

Rock blocks are large pieces of matrix rock that have not suffered a strong erosive process and have remained in the soil horizons (Stephenson & Naylor, 2011). They may be oval or approximately spherical in shape. The calculation for blasting is different, as the volume between these blocks varies and the number of holes required. Thus, a calculation method was developed for oval rock blocks. Considerations for spherical rock blocks will be presented throughout the text.

Given an oval rock block with the following dimensions in a cross-section, considering the greatest length, along its geometric center (see Figure 2):

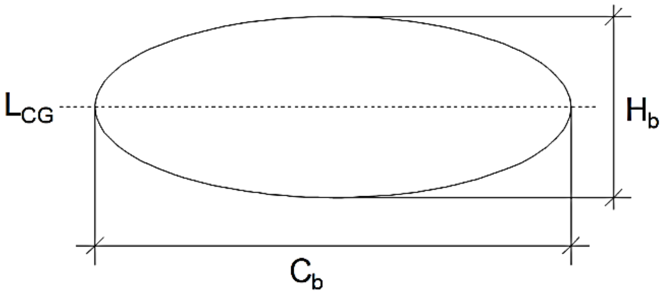

Figure 2. Parameters for the design calculation – Source: authors.

Where: H_b = Block Height; C_b = Block Length; L_{CG} = Center of Gravity Line.

This block can be subdivided into circles (number n of circles) of radius r, such that (see Figure 3):

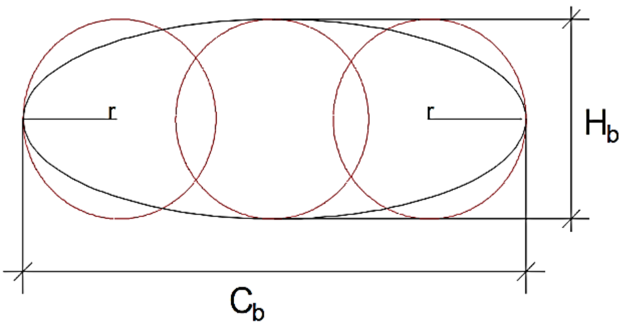

Figure 3. Sizing circles – Source: authors.

Where: r = Radius of the imaginary circle inside the block for possible n holes.

The condition for calculating this type of block is: $\boldsymbol{C_b \leq 3H_b}$

It is considered that the mine hole will have a depth equal to two thirds of the height of the block and the radius of each inner circle half the height, that is (see Figure 4):

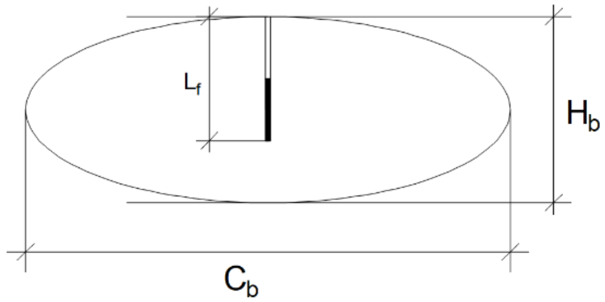

Figure 4. Hole length depending on the shape and dimensions of the block – Source: authors.

Where: L_f = length of the mine hole.

$$L_f = \frac{2H_b}{3} \tag{1}$$

$$r = \frac{H_b}{2} \tag{2}$$

Each end of the cross-section will have a distance r, so 2r will be subtracted from the length of the block. The resulting central section will have a size:

$$C_b - 2r = C_o \tag{3}$$

2.1 Checking the number of holes

In this central section, the centers of the imaginary circles are allocated, which are the points where the drilling for charging with explosives will occur, so:

$$\frac{C_b - 2r}{n - 1} = \mathrm{r} \tag{4}$$

Where: n = number of holes to be drilled in that section.

Using equation (4), we have:

$$n = \frac{C_b}{r} - 1 \tag{5}$$

Substituting (2) in (5), we obtain the expression that relates the number of holes with the dimensions of the cross section of the block.

$$n = \frac{2C_b}{H_b} - 1 \tag{6}$$

Test:
For a sphere with C_b = 2m and H_b = 2m (Spherical block):

$$n = \frac{(2 * 2)}{2} - 1 = 1 \text{ hole} \quad (7)$$

For a block with C_b = 6m and H_b = 1m, we have:

$$r = \frac{H_b}{2} = \frac{1}{2} = 0.5 \text{ m} \quad (8)$$

$$n = \frac{C_b}{r} - 1 = \frac{6}{0,5} - 1 = 11 \text{ holes} \quad (9)$$

The number of holes (n) has the condition $1 \leq n \leq 3$, if it is found by equation (5), or (6), that n>3, the risk of flyrock is significantly increased (there is a lack of control of the specific charge), therefore, $n \leq 3$ is fixed and, thus, the necessary spacing is verified. For example, for a single hole, the spacing is equal to zero, so, for approximately spherical blocks, only a central hole will be used without spacing.

2.2 Spacing check

For n = 2, or n = 3. Use the following expression for spacing between holes:

$$e = \frac{C_b - 2r}{n - 1} \quad (10)$$

Figures 5 and 6, below, show the blocks with two and three holes in the cross section.

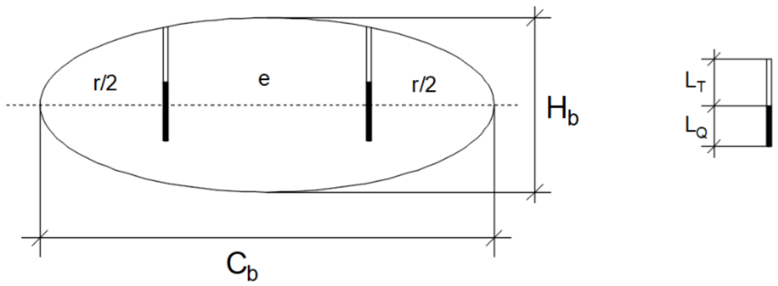

Figure 5. Spacing calculation for n=2 – Source: authors.

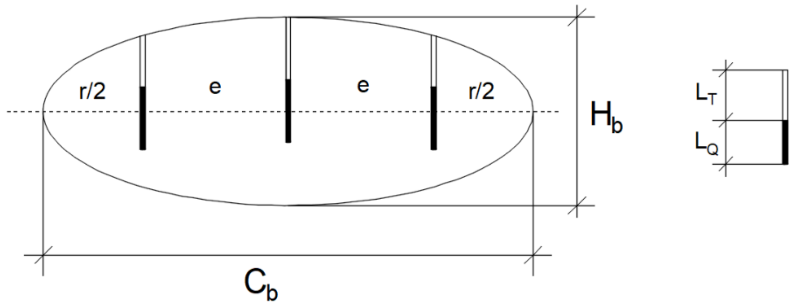

Figure 6. Spacing calculation for n=3 – Source: authors.

Where: e = spacing between holes; L_T = Stemming length; L_Q = Length of explosive in blasthole.

Finally, when blasting blocks using explosives, it is necessary to find the volume of the block to be blasted, as this value is fundamental to obtaining the number of explosives given a specific charge.

2.3 Calculation of Rock Block Volume

For approximately spherical blocks with $C_b = H_b = L_b$, the volume will be considered close to the volume of a sphere, like this:

$$V_b = \frac{4\pi r^3}{3} \quad (11)$$

Where: V_b = Block volume; L_b = Projection length from C_b to Rock block.

For blocks with $C_b >> H_b$ and $H_b \approx L_b$, the boulder volume will have a discount at its extremities due to the recurrent flattening:

$$V_b = \pi r^2 C_b - \frac{4\pi r^3}{3} \quad (12)$$

Once the volume of the rock block is defined, the amount of explosive required per wait to blast the boulder is found. The following expression shows the relationship between this obtained volume and the loading ratio.

$$Q_b = V_b * RC \quad (13)$$

Having, then, these data, the safe distance for an eventual flyrock is calculated, based on the tables and calculations according to the Swedish Model, which was developed by the Swedish Detonic Research Foundation in 1975. It is a theoretical model that allows the estimation of crater effects that could cause flyrock in bench blasting (Carlos Lopez Jimeno et al., 1995).

Three different densities (0.8 / 1.0 / 1.2) of explosives were considered for the calculation, mainly used in the blast design density equal to 1 g/cm^3.

The diameters of mine holes with values of 32, 38, 45, 51, and 64 mm were accepted as possible for use in this project, to choose the best alternative.

In the blasting of blocks, a greater variation in the diameters of the mine holes was used due to their volumes and their necessary specific charge (priority choice of a RC of 0.18 kg/m^3).

Observation:

In blocks, whose height cannot be determined (parameter H), it is recommended that the block be drilled until it crosses it and, before charging it, be filled with sand up to the height necessary for placing the charge.

3 CONCLUSIONS

The very high number of boulders blasts in which the ideas and calculations presented here were applied fully confirmed the initial premises and assumptions of this paper.

Although the trials developed by the Swedish Detonic Research Foundation and the associated collaborations (Bergeron, 1986; C. L. Jimeno, 1978; Lundborg & N., 1975; Melnikov & Chesnokov, 1969; Roth, n.d.; Tamrock, 1984) are related to flyrock phenomena associated with crater effects in open pit mining, the testing showed that the methodology proposed here was fully compatible with initial assumptions that referred to the rock mass blasting and not boulders blasting, hence the need for the proposal presented here of a method that creates a parameterization of data leading to the conclusive results verified in works.

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