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Risk analysis in geotechnical works with the use of explosives

Crossref doi https://doi.org/10.56238/alookdevelopv1-182

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ABSTRACT
Analyzing Risk in Geotechnical Works is always a challenge for all specialists' designers. Uncertainties of soil characteristics, better explosive, time and execution. All information should be well analyzed and criticized. Experience counts a lot, because the mature knowledge of standards is vital. Search, analyze and evaluate is a good way to study the possibilities of answers and so chose a topic - explosives and tested it.

Keywords: Geotechnical, risk, explosive.

1 INTRODUCTION

This article was developed in the following stages: definition of the objectives, description of the method employed, conclusions and discussions and, finally, the bibliographic references.

2 OBJECTIVES

The main objective is to apply semi-quantitative method of risk analysis – Mosler or Penta method in geotechnical work. The challenge is to carry out the analysis based on experience, research and observations made.

We also highlight that the search for logical and simple methods to define the risks, analyze and evaluate, calculate the probabilities and adopt mitigating measures.

Researchers record that the first people to use gunpowder as pyrotechnic elements were the Chinese and later as projectile propellant (first cannons).

The monk Schwartz, 1354 AD, performed an explosive mixture similar to gunpowder, used for war purposes: mortars and others. Then, in 1847, Ascanio Sobreno introduced nitroglycerin, that which its explosion is many times greater than that of gunpowder, but is dangerous with sudden movements or friction. And in 1863, Alfred Nobel mixed Kieselguhr (absorbent inert base) with Nitroglycerin, creating Dynamite: explosive with good safety conditions.

It was from the accidents that were born more dangerous artifacts, as happened in 1923, city of Oppan (Germany) when dynamiting a match of Ammonium Nitrate cobbled by moisture, provoked a huge explosion.

It is necessary to observe the current legislation, for whom it can use and pay attention to the details, according to the following references:

- Ordinance N18, of November 7, 2005, presents the administrative rules related to activities with explosives and their accessories;
- Decree No. 3,665 (R105), of November 20, 2000, regulation for the inspection of controlled products;
- Normative Decision N 071/01 CONFEA, of December 14, 2001, competence for design activities and execution of rock dismantling with the use of explosives; and
- Regulatory Standard NR19, Ordinance No. 3,2014, of June 8, 1978, last updated in the D.O.U. of SIT Ordinance No. 228, of May 24, 2011.

3 METHOD USED

The use of explosives in the extractive industry has been a traditional practice since the destructive effect of these substances was verified, and has become widespread with the introduction of safety explosives.

Explosive substances that can be used in mines and quarries are divided into gunpowder and explosives, and may be in bulk or in shells.

The following are in common use:

Gunpowder:

- Black powder
- Smokeless gunpowder

Explosives:

- In bulk:
  - Granules (mixture of ammonium nitrate and diesel)
  - Emulsions (dispersion in water of explosive substances)
- Cartridges:
  - Powders (mixture of ammonium nitrate and additives)
  - Emulsions (dispersion in water of explosive substances)
  - Dynamite (nitroglycerin/nitroglycol-based compounds)

In geotechnical works explosives can be used in seismic prospecting; mining of mines (in the open, underground or quarries); civil construction (roads, tunnels, pipelines, foundations and others); increased flow of wells and others.

3.1 SEISMIC PROSPECTING

Seismic prospecting is based on the fact that elastic waves (also called seismic waves) move at different speeds in different rocks. From the release of seismic energy at one point and the observation of the arrival times of these waves to a number of other points on the earth's surface, it is possible to determine the velocity distribution and locate underground interfaces where the waves are reflected or refracted.

The frequency range of seismic waves generated by natural and artificial sources includes a wide spectrum, covering low-frequency terrestrial movements (0.01 – 2 Hz), caused by surface and volumetric waves from earthquakes, to high-frequency vibrations (10 – 105 Hz) generated by artificial sources that include a wide variety of explosive and non-explosive sources.

3.2 MINE MINING

Mining of mines (in the open, underground or quarries). The dismantling with explosives in one of the most relevant unit operations in the underground coal mining in Brazil requires care.

This operation aims to obtain a mass with an adequate particle size distribution, in such a way that the final impact in combination with the costs of drilling, cleaning and transportation are minimized.

3.3 CONSTRUCTION

The construction, demolition, renovation, expansion of building or any other improvement added to the ground or underground.

They are divided into two major branches:

Civil construction works - includes housing, commercial and public service buildings.

Heavy construction works - encompass the construction works of ports, bridges, airports, roads, hydroelectric plants, tunnels, etc.

The method aims to identify, analyze and evaluate the factors that may influence the occurrence of risk. It is divided into four phases: definition, analysis, evaluation and calculation of the risk class.

It is one of the most used for insurance calculation. One can obtain a very accurate indicator on the probability of materialization of any risk, which can affect the normal functioning of the company.

The complementation was necessary in order to adopt mitigating actions to seek solutions that minimize the potential risks identified.

4 STUDY

SCENARIO: Possible disastrous repercussion of the use of explosives in civil construction works causing an accident.

The first phase concerns the definition of risks. Table 5.1 presents a list of risks defined from research and selection of the main ones.

Table 5.1 – List of Risks

Item	Risk
1	Environment – Environmental license (conditions and actions)
2	Energy Claim – power supply network
3	Urbanization – conditions of contour, proximity and population.
4	Relief – explosive class, properties, execution of dismantling.
5	Geology – type of explosive, volume and fractures of rocks
6	Infrastructure – access, storage, excavation and handling equipment
7	Construction insurance – explosives and accessories
8	External and internal protection system – prevention plan
9	Transport – means and investment
10	Manufacturer – equipment, explosives and others

In the second phase, the criteria that will help us analyze the evolution of the risk are calculated. It comprises: identification of the variables and analysis of the factors obtained and of the variables and, to see to what extent it influences the criterion considering the Penta scale and according to the conventions.

Figures 5.1a, b and c present the risk analysis scales based on the criteria defined by the author, generating a table with values for each risk, as shown in Table 5.2.

Figure 5.1a - Penta scale by criterion

Very Serious	Serious	Averagely	Lightly	Very lightly		Very Difficult	Hardly	Without too many difficultie	Easily	Very easily
5	4	3	2	1		5	4	3	2	1
"F" Function The negative consequences of damage can alter and affect the different form of activity						"S" Substitution Difficulty in replacing goods and products				

Figure 5.1b - Penta scale by criterion

Very Severe Disturbance	Severe Disturbance	Limited disturbance	L Mild disturbance	Very mild disturbance		International Reach	National Character	Regional Character	Local Character	Individual character
5	4	3	2	1		5	4	3	2	1
"P" Depth Disturbance and psychological effects they could produce on the image						"E" Extension The extent of damage and loss at territorial level				

Figure 5.1c - Penta scale by criterion

Very much Discharge	Discharge	Normal	Low	Very low		Very much Discharge	Loud	Normal	Low	Very low
5	4	3	2	1		5	4	3	2	1
"The" Aggression The probability at which the risk manifests itself						"V" Vulnerability Probability that damage and loss actually occur				

Based on the Penta scale, each risk can be scored based on the established criteria.

Table 5.2 – Analysis of laughter by criterion

Second Phase – Risk Analysis		
"F" Function	"S" Replacement	"P" Depth
Punctuation		
5 4 3 2 1	5 4 3 2 1	5 4 3 2 1
4,3	4,6	4,5
3,9	4,0	3,9
4,4	4,8	3,9
4,2	4,3	4,1
1,5	3,3	1,5
1,5	2,1	1,7
2,0	4,0	3,0
3,6	3,1	3,6
4,8	3,8	3,6
2,6	2,4	1,8

Table 5.3 - Laughter analysis by criterion, complementing Table 5.2

Second Phase – Risk Analysis		
"And" Extension	"A" Aggression	"In" Vulnerability
Punctuation		
5 4 3 2 1	5 4 3 2 1	5 4 3 2 1
4,8	4,2	4,9
2,4	4,1	4,4
4,7	4,5	4,1
3,8	3,9	4,1
1,5	1,8	1,8
1,8	2,3	2,0
3,0	3,0	2,5
2,6	3,1	2,9
2,8	3,0	3,8
1,8	2,1	2,3

This phase aims to quantify the risk considering Table 5.4. This procedure dries the following calculation sequence:

a) Calculation of the character of the "C" risk. To use the data obtained in the previous phase and applying the equations:

1. C = R + D
2. I = Impact importance = F x S
3. D = Damage caused = P x E

b) Calculation of probability "P". For which we resort to the data obtained in the second phase applying equation (4):

4. Pb = A x V

c) Quantification of the risk considered. If you multiply the values obtained in (a) and (b) by applying equation (5):

5. ER = C x Pb

Table 5.4 - Risk Estimation

Third Phase – Risk Estimation			
Risk character "C", C = R + D			Probability "P"
I = Impact importance = F x S			Pb = A x V
D = Damage caused = P x E			
I	D	C =	Pb
19,8	21,6	41,4	20,6
15,6	9,4	25,0	18,0
21,1	18,3	39,5	18,5
18,1	15,6	33,6	16,0
5,0	2,3	7,2	3,2
3,2	3,1	6,2	4,6
8,0	9,0	17,0	7,5
11,2	9,4	20,5	9,0
18,2	10,1	28,3	11,4
6,2	3,2	9,5	4,8

This phase aims to classify the risks according to the values obtained in their evolution. Of this value one can understand between 2 and 1,250 and applying table 5.5.

Table 5.5 – Risk significance classification

Evolution of RE risk	Risk Class
2 a 250	**Very low**
251 a 500	**Small**
500 to 750	**Normal**
750 to 1,000	**Big**
1,000 to 1,250	**High**

4.1 THEORETICAL AND PRACTICAL CASE

For the purposes of risk analysis, we chose civil construction, a case of dismantling of slope rocks on a highway.

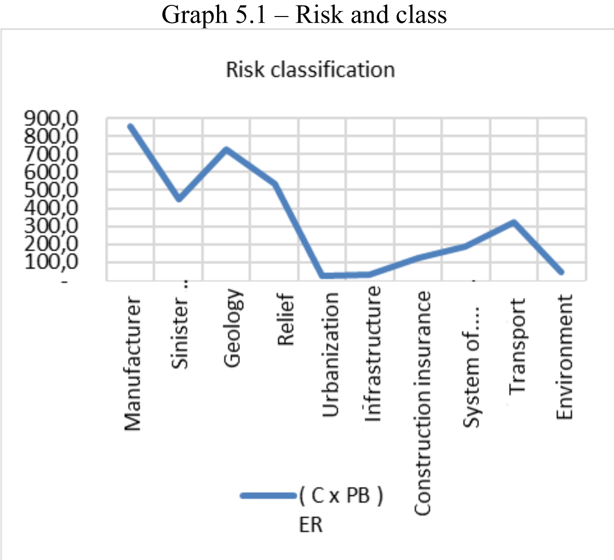
Table 5.3 presents the result of the risk class and the aspect in relation to the work.

Table 5.3 – List of risks and their class

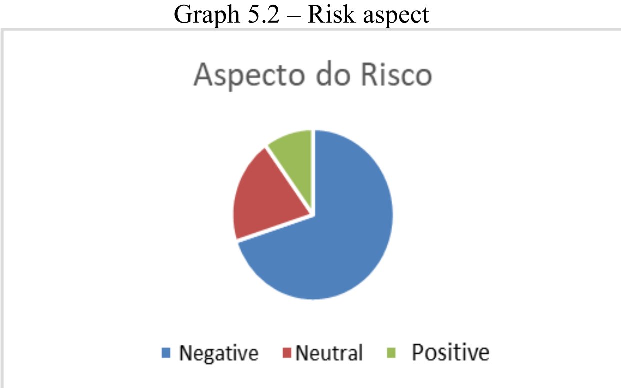
Item	Risk	(C x PB) ER	Risk class	Aspect
1	Manufacturer - Equipment & Explosives	851,6	Big	Positive
2	Energy Claim – power supply network	450,3	Small	Negative
3	Geology – type of explosive, volume and fractures of rocks	727,9	Normal	Neuter
4	Relief – explosive class, properties, execution of dismantling	537,9	Normal	Neuter
5	Urbanization – boundary conditions, proximity and population	23,3	Very low	Negative
6	Infrastructure – access, storage, excavation and handling equipment	28,6	Very low	Negative
7	Construction insurance – explosive and accessory	127,5	Very low	Negative
8	External and internal protection system – prevention plan	184,5	Very low	Negative
9	Transport – means and investment	322,8	Small	Negative
10	Environment – Environmental license (conditions and actions)	45,8	Very low	Negative

Graphs 5.1 and 6.3 show the relationship of the items with the risk class and distribution regarding the risk aspect.

Graph 5.1 – Risk and class



Graph 5.2 – Risk aspect



5 CONCLUSION AND DISCUSSION

In each engineering activity, especially in the planning phase, it is necessary to consider the risks that the works, people, materials and equipment can contribute to the work being carried out successfully and with the minimum of risk.

There are several risks analyzed and their classification is based on knowledge, training, experience and considering the financial aspect.

The set of related risks presents a worrying result, as 70% need mitigating action urgently. The affected items are crucial for the work since they are throughout the production chain, such as: the acquisition of explosives, energy claim, the occupation of the surrounding residence, the access infrastructures, the insurance coverage of the work, the contingency plan of protection, the means of transport of the explosive from the manufacturer to the work and the effect that the environment can suffer with the possible damages.

So, it is fundamental, necessary and mandatory the elaboration of analysis and risk plan by the companies that are acquiring explosives, because those that are being stolen or stolen are bringing a huge loss to society.

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