## *4. Management covering blast design*

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# Blasting demolition of structures in power plants and urban areas: guidelines for a proper risk analysis

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ABSTRACT: The analysis of more than 100 blasting demolition yards, accomplished since 1994, statistically confirms that the main safety problem perceived from technical supervisors and persons in charge is due to the presence of high explosives on the field. This wrong way to evaluate the real safety problems in situations like blasting demolition of structures in active power plants or in thickly built -up urban areas, is often because of a wide technical unpreparedness of people delegated to manage and control our activities on the field. This is why it's very important, for the growth of all professionals, to focus our attention on the real risks involved, to trace helpful guidelines for a correct assessment and analysis of risks; the awareness and knowledge of different orders of risks, the effective approaches for their mitigation and the main features of materials and high explosives, might be included in the technical culture of those professionals delegated to plan and manage safety problems.

As the main output of their activity is the calculation of Safety distances for people and sensitive structures and plants, the only manner to evaluate them effectively is to assess and analyze risks and procedures in a proper way.

## 1. RISKS ANALYSIS OF BLASTING DEMOLITION OF STRUCTURES

The activities of blasting demolition inside of industrial working sites, active power plants (Figure 1) and crowded urban areas (Figures 2, 4 and 5), hide a lot of critical aspects not directly connected to the presence itself of high explosives on the field, as perceived by the most, but depending principally on the scenery's characteristics (for example, in case of underwater blasting in tanks, docks and dams or blasting using ropes and climbing techniques in chimneys, boilers and furnaces) and on the various effects

Figure 1. Decommissioning in active power plant.

caused by the blast (such as dust, flying fragments, vibrations and air-blast).

Figure 2. Demolition of building in urban area.

For a correct assessment and a proper analysis of safety problems, it's basic to define four different categories of risks: direct, indirect, induced and connected risks.

### *1.1 Direct risks*

This category is related to the handling of high explosives by authorized personnel on the field, that is to say to the direct interaction between workers and high explosives.

As a matter of fact, the interaction by inhalation and touch, especially during indoor operations, is the cause of a lot of reversible symptoms as weakness, strong headache and sickness; as reversible signs they can be effectively prevented or mitigated by wearing proper light safety masks and nitrile safety gloves.

### *1.2 Indirect risks*

They are closely related to the characteristics of the scenario in which we use high explosives; for example, in cases like underwater blasting in tanks, dams (Figure 3) and docks or blasting operations using ropes and climbing techniques on chimneys and inside boilers and blast-furnaces.

This category of risks, not related to the use itself of high explosives, can be effectively mitigated by the use of specific equipments and proper techniques of intervention.

### *1.3 Induced risks*

The induced risks are closely related to the effects of the detonation of high explosives; consequently, they are strictly depending on the features and conditions of materials (concrete, brick, iron, pig, slack), as well as on the features of the high explosives used.

Figure 3. Underwater blasting in dam.

Excluding circumstances caused by inexpertness and inattention, because of the highly skilled technicians involved on the field, as well as events related to terrorism and sabotage acts, the induced part of risks in such blasting demolitions comes from the over-output of phenomena like:

- rising of dust (incidental obstruction of suction and absorbing filters);
- flying fragments (incidental heavy injury/damage to people and properties);
- air-blast (incidental breakage of glasses and diaphragms);
- vibrations (incidental damages to weak structures, plants and precision equipments).

### *1.4 Connected risks*

This class refers to problems connected to a failure of the blasting demolition process.

These risks, like the indirect ones, are not related to the use itself of high explosives, but imply a wide range of safety problems (Figure 6) to assess and evaluate very carefully like, for example:

- danger of sudden collapse of the building;
- incidental recovery of high explosives and detonators in the rubble to crush with excavators or mobile crushers.

Figure 4. School building in thickly populated area.

Figure 5. Blasting demolition of school building in thickly populated area.

Figure 6. Demolition failure - danger for the demolition crew.

## 2. PASSIVE/ACTIVE MITIGATION APPROACHES

Focusing on the category of induced risks, we have two different kinds of approach available to mitigate an incidental over-output of the blasting effects: the passive protection approach and the active one.

### *2.1 Passive protection approach*

As passive protection approach, we mean the whole safety procedures we can prepare to mitigate an over-output of the blasting effects soon afterwards the detonation of high explosives in the blasting demolition process.

It is possible to carry into effect practices like, for example:

- to use water fog nozzles;
- to wrap pillars with steel mesh and textile (Figure 7);
- to create protective banks with activities of ground excavation (Figure 8);
- to stop production cycles;
- to evacuate neighbours.

Figure 7. Wrapping of concrete pillars with steel mesh and textile.

It's obviously true that all these safety procedures will increase decidedly the general safety level of the process, but it's not the right way to pursue our purpose!

Figure 8. Creation of protective banks.

The aim we all must attain is to accomplish blasting demolition in sensitive contexts without using passive protection procedures or, at least, reducing them as much as possible, answering for top levels of safety by the careful examination of the project phase of the blasting demolition process.

*2.2 Active protection approach*

The active protection approach is the right way we all might follow to guarantee top safety levels, through the deep knowledge of the characteristics of materials, by studies and tests on and off-site, and the knowledge of the main features of the high explosives available on the market.

To accomplish an effective mitigation of both induced and connected risks, it's possible to examine carefully the main characteristics of the materials objects of the action of high explosives by using practices like:

- geo-radar techniques to investigate the quantity and quality of concrete and its reinforcements (Figures 9 and 10);
- test blasts to test the hardness and the matter type of structural steelwork and reinforced concrete;
- on-site schlerometer tests (Figure 11) to study the scratch hardness of concrete and on-site ultrasonic tests (Figure 12) to investigate the degradation level of materials;
- analysis of air-blast/acoustic expected values using software tools (Figure 13).

Figure 9. On-site analysis using geo-radar techniques.

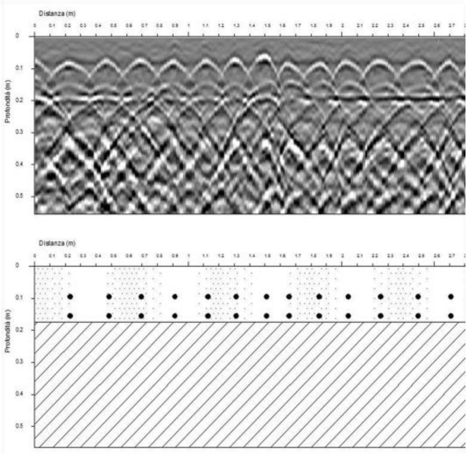

Figure 10. Outputs of the geo-radar analysis.

The additional step to the examination of the main characteristics of materials, to complete an effective way to mitigate the induced part of risks, is the study of the main

Figure 11. Schlerometer for on-site tests.


Figure 12. Equipment for ultrasonic on-site tests.

**Air-Overpressure Regression Analysis**

**Regression Statistics**

PAOP = a * (Scaled Distance) ^ b

| | |
|---|---|
| Number of Blasts | 19 |
| Correlation Coeff | 0,977 |

| | a | b |
|---|---|---|
| Best Fit | 27400,9 | -1,092 |
| 95% | 42325,6 | -1,092 |
| 99.9% | 62019,2 | -1,092 |

**AOP Predictions**

| | | |
|---|---|---|
| Cord Size | 25 | (gm/m) |
| Length | 15 | (m) |
| MIC = | 0,375 | (kg) |

Distance Inc = 10

| Distance | Scd.Dist. | Mean AOP | | AOP @ 95% CL | | AOP @ 99.9% CL | |
|---|---|---|---|---|---|---|---|
| (m) | (m/kg^1/3) | (Pa) | (dB) | (Pa) | (dB) | (Pa) | (dB) |
| 14,0 | 19,4 | 1074,4 | 155 | 1659,7 | 158 | 2431,9 | 162 |
| 24,0 | 33,3 | 596,4 | 149 | 921,3 | 153 | 1350,0 | 157 |
| 34,0 | 47,1 | 407,8 | 146 | 629,8 | 150 | 922,9 | 153 |
| 44,0 | 61,0 | 307,7 | 144 | 475,3 | 148 | 696,4 | 151 |
| 54,0 | 74,9 | 246,0 | 142 | 380,0 | 146 | 556,9 | 149 |
| 64,0 | 88,8 | 204,4 | 140 | 315,7 | 144 | 462,6 | 147 |
| 74,0 | 102,6 | 174,4 | 139 | 269,4 | 143 | 394,8 | 146 |
| 84,0 | 116,5 | 151,9 | 138 | 234,6 | 141 | 343,7 | 145 |
| 94,0 | 130,4 | 134,3 | 137 | 207,5 | 140 | 304,0 | 144 |

Figure 13. Analysis of air-blast/acoustic expected values.

features of high explosives; those features that state their effectiveness and, relating to the materials, their efficiency.

## 3. EFFECTIVENESS OF HIGH EXPLOSIVES

The performance potential of high explosives cannot be expressed by means of a single characteristic parameter. It is determined by:

- the amount of gas liberated per unit weight, the energy evolved in the process;
- the propagation rate of the energetic material.

The main parameters and their resulting properties of high explosives, straight 'performance indicators' that influence very much the output effects of blasting, in connection to the materials subject of the fragmentation, are basically:

- Detonation velocity;
- Detonation pressure;
- Heat of explosion;
- Brisance;
- Strength.

A number of conventional tests and calculation methods exist for determining the comparative performance of different explosives; the determination of the detonation rate and density do not require conventions, since they are both specific physical parameters.

### *3.1 Detonation velocity*

The detonation velocity is the rate of propagation of a detonation in an explosive. If the density of the explosive is at its maximum value, and if the explosive is charged into columns which are considerably wider than the critical diameter, the detonation velocity is a characteristic of each individual explosive and is not influenced by external factors; it decreases with decreasing density of packing in the column.

### *3.2 Detonation pressure*

The detonation pressure in the wave front is proportional to the product of the density, the detonation rate, and the fume velocity or, since the fume velocity is proportional to the detonation rate, to the square of the detonation rate. For a given explosive, the detonation velocity rises with increasing density; the detonation pressure increases very considerably if the initial density of the explosive can be raised to its maximum value (by casting or pressing) or if the density of the explosive is intrinsically high (TNT, RDX, HMX). High density of the explosive is important if high brisance is needed, whereas the blasting performance is less affected by it.

### *3.3 Heat of explosion*

The heat of explosion of an explosive material is the heat liberated during its explosive decomposition. Its magnitude depends on the thermo-dynamic state of the decomposition products; the data used in practical calculations usually have water (which is a product of the explosion) in the form of vapor as the reference compound. The heat of explosion may be both theoretically calculated and experimentally determined: the calculated value is the difference between the energies of formation of the explosive components (or of the explosive itself if chemically homogeneous) and the energies of formation of the explosion products.

### *3.4 Brisance*

Brisance is the destructive fragmentation effect of a charge on its immediate vicinity. The relevant parameters are the detonation rate and the loading density (compactness) of the explosive, as well as the gas yield and the heat of explosion. The higher the loading density of the explosive is (molding or pressing density), the higher its performance concentration is per unit of volume; also, the faster the reaction rate is, the stronger the impact effect of the detonation is. Moreover, an increase in density is accompanied by an increase in the detonation rate of the explosive, while the shock wave pressure in the detonation front varies with the square of the detonation rate. Thus it's very important to have the loading density as high as possible.

### *3.5 Strength*

If an explosive is to be detonated in a borehole, the relevant parameter is its 'strength'.

Here the criterion of the performance is not so much a high detonation rate as a high gas yield and a high heat of explosion; if, on the other hand, a strong disintegration effect in the nearest vicinity

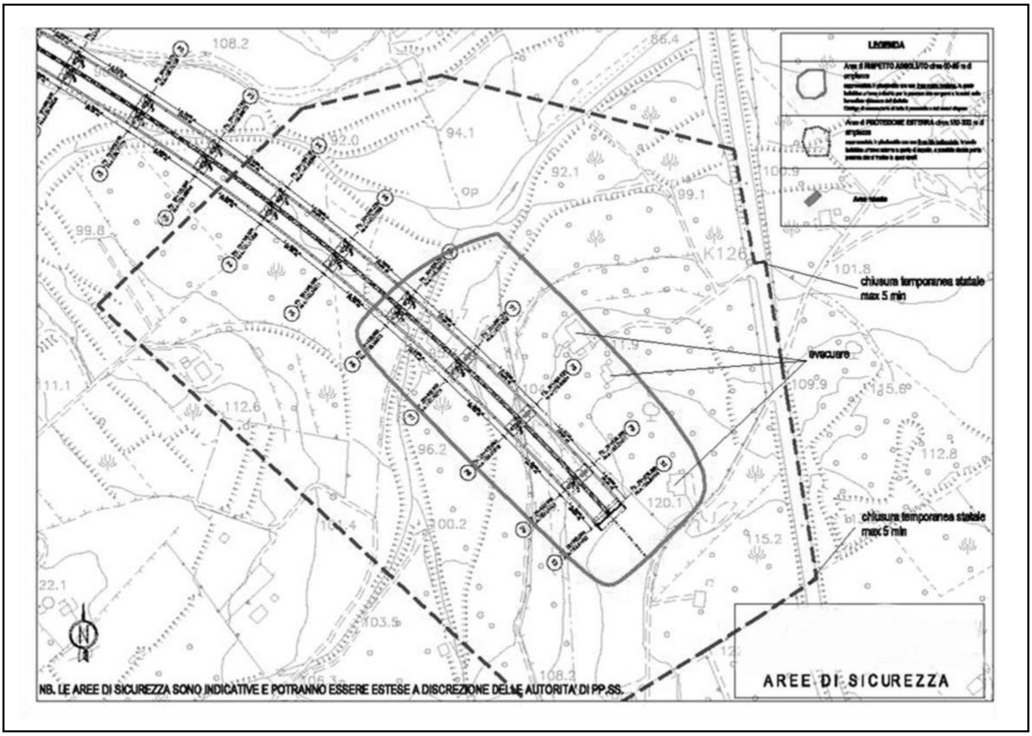


Figure 14. Correct assessment of safety distances and areas.

of the detonation is required, the most important parameters are the detonation rate and the density.

## 4. CONCLUSIONS

To sum up all previous considerations, the right way for a proper and effective risks analysis in sensitive activities like the use of high explosives for blasting demolition in urban areas and active industrial sites, might proceed along the following steps:

- to identify the structures and plants really to be protected;
- to characterize carefully the materials objects of the action of high explosives by on-site tests and studies;
- to be aware of the main characteristic features of the high explosives to be used;
- to calculate theoretically the expected airblast/acoustic values;
- to expect, only if necessary, to equip passive protections made of steel mesh and textile.

The main output of this way to proceed might be the right calculation of safety distances and areas (Figure 14), that is to say important values that are very often wrongly over-estimated.

## REFERENCES

Meyer, R., Köhler, J. & Homburg, A. 2002. Explosives. Wiley-VCH (ed.): 42, 83-84, 90, 161, 300.