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TEKNIK PELEDAKAN

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Subjects

1. Use Forms of Explosives
2. Estimating Properties of Explosives
3. Explosive Selection Criteria
4. Blasting Accessories
5. Initiation and Priming Systems

Subjects

6. Nonelectric Initiators
7. Qualitative Description of a Shock Wave
8. Fracture Mechanism in Blasting of Rock
9. Rock and Rock Mass Properties and Their Influence on The Results of Blasting
10. Characterization of The Rock Masses for Blast Designing

Subjects

11. Real Effects in Explosives
12. Theories of Scaling
13. Blasthole Loading
14. Preliminary Blast Design Guidelines
15. Controllable Parameters of Blasting

Subjects

16. Bench Blasting
17. Drilling Patterns and Hole Sequencing
18. Initiation Sequence and Delay Timing
19. Explosives as a Source of Fragmentation Energy
20. Evaluation of Blast Results

Subjects

21. Blasting in Underground
22. Overbreak Control
23. Perimeter/Contour and Controlled Blasting
24. Environmental Effects of Blasting
25. Blasting Safety

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Explosive Selection Criteria

https://www.miningmagazine.com/supply-chain-management/news/1371861/riogel-causing-latam-blast

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Explosive Selection Criteria

1. Explosive cost
2. Charge diameter
3. Cost of drilling
4. Rock characteristics
5. Fragmentation difficulties
6. Volume of rock to be blasted
7. Atmospheric conditions

Explosive Selection Criteria

8. Presence of water
9. Fumes (adequacy of ventilation)
10. Propagating ground
11. Storage considerations
12. Sensitivity considerations
13. Explosive atmospheres

Introduction

One of the groups of parameters that can be controlled by the technicians in blastings is that of **the explosives**. **The selection of the type of explosive** forms an important part of the blast design and, consequently, the obtainable results.

Introduction

Explosive selection is dictated by economic considerations and field conditions. The blaster should select a product that will give **the lowest cost per unit of rock broken**, while assuring that **fragmentation and displacement of the rock are adequate** for the job at hand.

Explosive Cost

The cost of the explosive is obviously a very important selection criterion. To start with, one must choose the lowest cost explosive with which the work at hand can be carried out.

Explosive Cost

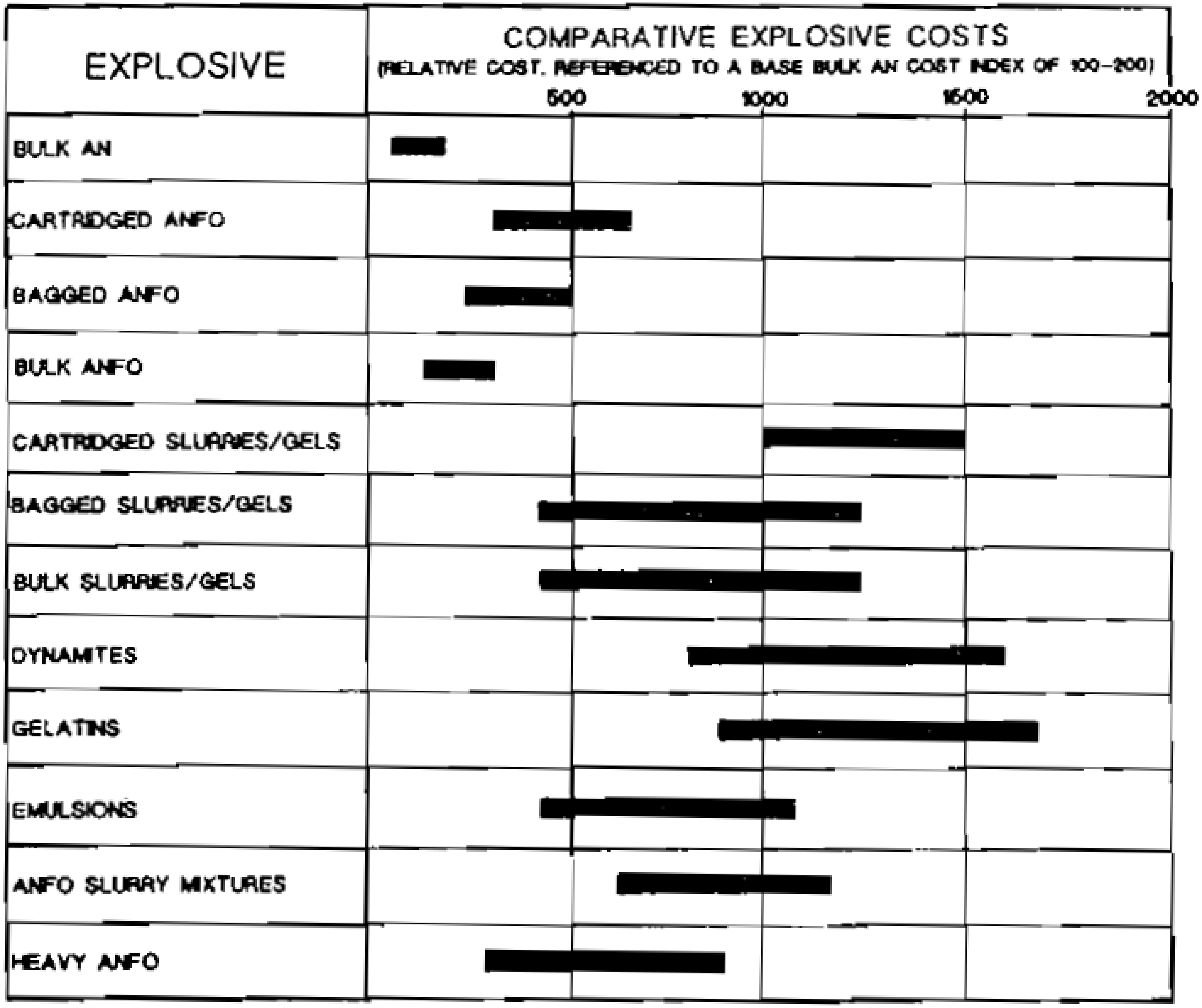
When speaking of cost, it would be *more correct* to do this by expressing it **per unit of available energy ($/kcal)** than by unit of weight ($/kg) because, the fact is that the results of the blastings depend upon the energy destined to fragmentation and swelling of the rock.

Explosive Cost

Therefore, from an economical point of view, the best explosive *is not always* the least expensive *but rather* the one that achieves the lower blasting costs.

Read more in Mining Engineering Handbook (SME), 2011, Ch. 4.9.4.

Explosive Cost



Explosive Cost

No other explosive product can compete with **ANFO** on the basis of cost per unit of energy. Both of the ingredients, ammonium nitrate and fuel oil, are relatively inexpensive, both participate fully in the detonation reaction, and the manufacturing process consists of simply mixing a solid and a liquid ingredient. The safety and ease of storage, handling, and bulk loading add to the attractive economics of ANFO.

Explosive Cost

Despite its excellent economics, ANFO is *not always* the best product for the job, because it has several shortcomings. ANFO has no water resistance, it has a low specific gravity, and under adverse field conditions it tends to detonate inefficiently.

Explosive Cost

By the pound, **slurry** costs range from slightly more than ANFO to about four times the cost of ANFO. The more expensive slurries are:

1) those designed to be used in small diameters; and
2) high-energy products containing large amounts of aluminium or other high-energy ingredients.

Explosive Cost

Dynamite cost ranges from four to six times that of ANFO, depending largely on the proportion of nitroglycerin or other explosive oil.

Charge Diameter

When explosives are used with detonation velocities that vary greatly with the diameter, which is the case of ANFO, the following precautions must be taken:

- ✓ With <u>blasthole under 50 mm diameter</u>, it is better to use slurries or cartridged dynamites, even though they are more costly.

Charge Diameter

- ✓ Between 50 and 100 mm, ANFO is adequate for bench blastings as a column charge and in inner charges increasing the density by 20% with pneumatic chargers and effective priming.
- ✓ Above 100 mm, there are no problems with ANFO, *although in hard rocks* it is better to design columns with selective charges and a good initiation system.

Charge Diameter

✓ In large diameters with different mixtures of bulk explosives (ANFO, slurries, emulsions and heavy ANFO) it is very economical to charge by mechanical means.

Charge Diameter

✓ Lastly, the gelatin and granular cartridged explosives are still used in small diameters, but in medium type calibers they are being substituted for cartridged slurries and emulsions.

Cost of Drilling

Under normal drilling conditions, the blaster should select the lowest cost explosive that will give adequate, dependable fragmentation. However, when drilling costs increase, typically in hard, dense rock, the cost of explosive and the cost of drilling should be optimized through controlled, in-the-mine experimentation with careful cost analysis.

Cost of Drilling

Where **dynamites** are used, gelatin dynamites will give *higher energy densities than* granular dynamites.

The energy density of **slurry** depends on its density and the proportion of high-energy ingredients, such as aluminium, used in its formulation. Because of the diverse varieties of slurries on the market, the individual manufacturer should be consulted for a recommendation on a high-energy slurry.

Cost of Drilling

The energy density of **ANFO** can be increased by the addition of finely divided aluminium. The economics of **ALANFO (aluminized ANFO)** improve where the rock is more difficult to drill and blast.

Rock Characteristics

The **geomechanic properties of the rock mass** to be blasted make up the most important group of parameters, not only for their direct influence upon the results of the blasts but for their interrelation with other design variables as well.

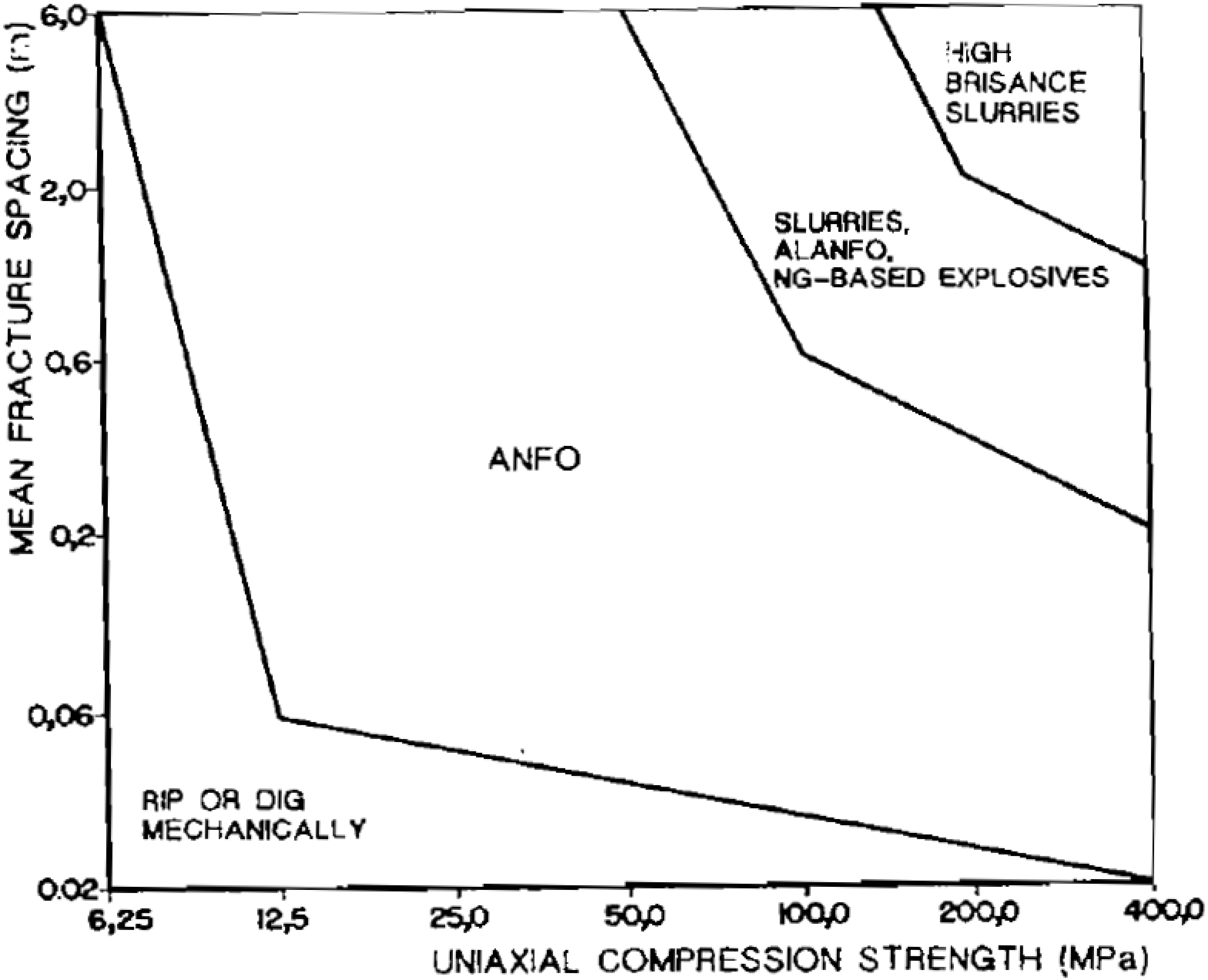
1. Resistant Massive Rocks

In these formations, there are <u>very few fissures and planes of weakness</u>, which requires that <u>the explosive create a larger number of new surfaces</u> based upon its Strain Energy (ET). The ideal explosives therefore are those **with high density and detonation velocity**: slurries, emulsions, and gelatin explosives.

2. Highly Fissured Rocks

Explosives with high ET have very little influence upon final fragmentation in these masses because when they start to develop radial cracks these are quickly interrupted when intersected by preexisting fissures. For this reason, explosives with **high Gas Energy** (EB), such as ANFO, are indicated.

Rock Characteristics (Brady and Brown, 1985)



3. Rocks that Form Blocks

In the masses with large spacing between discontinuities that form voluminous in-situ blocks, and in ground where large boulders exist within plastic matrixes, fragmentation is governed mainly by the geometry of the blast and, in lesser degree, by the properties of the explosive.

In these cases, explosives with **a balanced ET/EB relationship** are recommended, such as ALANFO and heavy ANFO.

4. Porous Rocks

Apart from selecting the proper explosives, which would be those with **low density and detonation velocity**, such as ANFO, the following measures should be taken to retain the gases within the blastholes for as long a period as possible:

- ✓ control the stemming material and height;
- ✓ properly sized burden;
- ✓ bottom priming;
- ✓ reduce blasthole pressure by decoupling the charges or adding inert materials.

Fragmentation Difficulties

Hard and dense rock may cause **expensive drilling and fragmentation difficulties** frequently. A high detonation velocity does help in fragmenting hard, massive rock. With **cartridged dynamites**, the detonation velocity increases as the nitroglycerin content increases, with **gelatin dynamites** having *higher velocities than their granular* counterparts.

Fragmentation Difficulties

Several varieties of **slurry**, and particularly **emulsions**, have high velocities. The individual manufacturer should be consulted for a recommendation on a high-velocity product. In general, **emulsions** exhibit *higher velocities than* **water gels**.

Fragmentation Difficulties

The detonation velocity of **ANFO** is highly dependent on its charge diameter and particle size. **In diameters of 9 in or greater**, ANFO's detonation velocity will normally *exceed 13,000 fps*, peaking *near 15,000 fps* **in a 15-in diameter**. These velocities compare favourably with velocities of most other explosive products.

Fragmentation Difficulties

In smaller diameters the detonation velocity falls off, *until at diameters below 2 in* the velocity is less than half the 15,000-fps maximum. In these small diameters, the velocity *may be increased* to nearly 10,000 fps by high velocity pneumatic loading, which pulverizes the ANFO and gives it a higher loading density.

Fragmentation Difficulties

In many operations with expensive drilling and difficult fragmentation, it may be advantageous for the blaster to compromise and use a dense, high-velocity explosive **in the lower position of the borehole** and **ANFO as a top load**.

Volume of Rock to be Blasted

The volume of the excavation and the work schedule give the amount of explosive necessary for the breakage operation.

In large operations, the quantity of explosive may be such as to consider its use in **bulk form**, as it makes mechanized charging possible from the transport units themselves, reducing labor costs and making better use of the volume of rock drilled.

Atmospheric Conditions

Low atmospheric temperatures have strong influence on the explosives which contain NG as they tend to freeze at temperatures under 8°C. To solve this problem, substances such as nitroglycol are used to lower the freezing point to below -20°C.

High temperatures also give problems, making the handling of explosives dangerous.

Atmospheric Conditions

With the development of **slurries**, these risks have almost disappeared, although *in cold weather* the cartridges *become less cap sensitive and more initiation energy is needed*. If a **slurry** is to be used in <u>cold weather</u> the manufacturer should be asked about <u>the temperature limitation</u> on the product.

Atmospheric Conditions

For many years, **dynamites** have employed low-freezing explosive oils which permits their use in the lowest temperatures.

ANFO is not affected by low temperatures when properly primed, but *in hot atmospheres* it is necessary to control the evaporation of liquid fuel.

Atmospheric Conditions

The effect of temperature is *alleviated* if explosives are stored in a heated magazine or if they are in the borehole long enough to achieve the ambient borehole temperature. Except in permafrost or in extremely cold weather, borehole temperatures are seldom low enough to render slurries insensitive.

Presence of Water

ANFO has no water resistance. When **ANFO** is in an atmosphere with *more than 10% humidity*, an alteration is produced that stops detonation.

Presence of Water

- ✓ If there is not much water present, **pulverized ANFO is placed in waterproof plastic containers**, reaching densities of 1.1 g/cm^3.
- ✓ If there is more water present and the former procedure is not feasible, the blasthole can be **dewatered** by using a down-the-hole submersible pump and then **placing a waterproof liner in the hole**, loading the **bulk ANFO** inside the liner before the water seeps in again. **Heavy ANFO** has opened new perspectives for lowering blasting costs.

Presence of Water

- ✓ If the flow of water makes dewatering impossible, explosives such as **bulk watergels** and **emulsions** can be used, pumping or pouring them, or **gelatin explosives** and **cartridged slurries**.

Presence of Water

Furthermore, the ANFO will quickly become desensitized *if the borehole liner is ruptured*. The appearance of orange-brown nitrogen oxide fumes upon detonation is a sign of water deterioration, and an indication that a *more water-resistant* product or *better external protection* should be used.

Presence of Water

Slurries are gelled and cross-linked to provide a barrier against water intrusion, and as a result, exhibit excellent water resistance. When **dynamites** are used in wet holes, gelatinous varieties are preferred. Although some *granular dynamites* have fair water resistance, the slightly higher cost of gelatins is more than justified by their increased reliability in wet blastholes.

Environmental Problems

The main problems that affect areas near the blastings are vibrations and air blast.

From the explosive point of view, those with high strain energy give higher vibration levels. Thus, when feasible, it is better to use ANFO instead of slurries.

Environmental Problems

As to air blast, it is recommended that the explosive has a balanced strain energy/bubble energy relationship and, above all, that the geometric design of the blasting be controlled.

Fumes

Although many explosives are prepared so that their oxygen balance gives maximum energy and minimum toxic detonation gases, the formation of harmful fumes with a certain nitrous gas and CO content is inevitable.

Fumes

In underground operations, the fumes enter as a selection criterion and it must be pointed out that it is more a problem of poor ventilation rather than of the explosive itself.

Fumes

The presence of plastic containers, inadequate charge diameters or inefficient initiations can bring about a large volume of fumes.

Cap sensitive slurries generally give gases with good properties, whereas with bulk slurries certain precautions must be taken, as well as with ANFO which produces a high concentration of nitrous gases.

The gelatin explosives are usually good, but not so those dynamites with a high AN content.

Propagating Ground

Propagation is the transfer or movement of a detonation from one point to another. Although propagation normally occurs within an explosive column, *it may occur* between adjacent blastholes through the ground.

Propagating Ground

In ditch blasting, a very sensitive straight **nitroglycerin dynamite** is sometime used to purposely accomplish propagation through the ground. This saves the cost of putting a detonator into each blasthole. Propagation ditch blasting works best in soft, water-saturated ground.

Propagating Ground

In all other types of blasting, propagation between holes is undesirable because it negates the effect of delays. **Propagation between holes** will result in poor fragmentation, failure of a round to pull properly, and excessive ground vibrations, airblast, and flyrock.

Propagating Ground

In underground blasting, the entire round may fail to pull. The problem is most serious when using <u>small blastholes</u> loaded with dynamite. <u>Small blastholes</u> require small burdens and spacings, <u>increasing the chance of hole-to-hole propagation</u>, particularly when sensitive explosives are used.

Propagating Ground

When propagation is suspected, owing to poor fragmentation, violent shots, or high levels of ground vibrations, the **use of a less sensitive product** usually solves the problem.

Straight nitroglycerin dynamite is the most sensitive commercial explosive available, followed by other granular dynamites, gelatin dynamites, cap-sensitive slurries, and blasting agents, in decreasing order sensitivity.

Propagating Ground

A different problem can occur when ANFO or slurry blasting agents are used at close spacings in soft ground. The shock from an adjacent charge may dead press a blasting agent column and cause it to misfire.

Storage Considerations

Federal requirements for magazine construction are less stringent for blasting agents than for high explosives. Magazines for the storage of **high explosives** must be well ventilated and must be resistant to bullets, fire, weather, and theft; whereas **a blasting agent** magazine need only be theft resistant.

Storage Considerations

The operator can *advantageously* use **two-component explosives.** Two-component explosives are sold as separate ingredients, neither of which is explosive. The two components are mixed at the jobsite as needed, and the mixture is considered a high explosive. Persons who mix two-component explosives are often required to have a manufacturer's license.

Storage Considerations

Federal regulations do not require ingredients of two-component explosives to be stored in magazines nor is there a minimum distance requirement for separation of the ingredients from each other or from explosive products. Even though, **two-component explosives** should be protected from theft.

Storage Considerations

The use of **two-component explosives** eliminates the need for frequent trips to a magazine. *However, when large amounts of explosives are used*, the higher cost and the time-consuming process of explosive mixing begin to outweigh the savings in traveltime.

Sensitivity Considerations

Sensitivity considerations address questions of the safety and the dependability of an explosive. More sensitive explosives such as **dynamites** are somewhat more vulnerable to accidental initiation by impact or spark *than* **blasting agents**. **Slurries and nitrostarch-based explosives** are generally *less sensitive to impact than* **nitroglycerin-based dynamites**.

Sensitivity Considerations

However, more sensitive explosives, all conditions being equal, are less likely to misfire in the blasthole.

Safety Conditions

A balance between sensitivity and safety is not always easy to achieve. Gelatin explosives have high sensitivity but if explosive left-overs are found in the muck pile for some reason and heavy machinery is used, detonation could occur with the consequent danger for operators.

Safety Conditions

This problem has been solved with the use of **slurries and emulsions** that are insensitive to being struck, friction or subsonic stimulation, but have an adequate degree of sensitivity for initiation.

Explosive Atmospheres

Excavations carried out in gassy atmospheres, such as in coal mines as well as in other metal mines or civil engineering, could cause great catastrophies if secondary blast occur. For this reason, in such projects it is most necessary to undertake the task of studying the atmosphere and environment near the blasting so as to decide whether to use permissible explosives and/or inhibitors in the stemming material.

Supply Problems

Another final factor to take into account is **the available supply** in function with the location of the work and the proximity of explosives and their accessories.

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