BULK EMULSION EXPLOSIVE - A CASE STUDY

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ABSTRACT

This paper deals with results from two case studies in Sweden where Bulk Emulsion Explosives have been used.

A comparison is made with other types of explosives regarding costs for drilling and blasting.

By using Bulk Emulsion Explosive it was possible to achieve a better breakage performance. In a copper mine this resulted in a decreased powder factor and thereby less cost for the explosive. In a limestone quarry an expansion of the drilling pattern lowered the drilling cost and the change-over to Bulk Explosive made handling and storage more adventageous.

The studies are made for a surface copper mine using large diameter (251-310 mm) drill holes and a limestone quarry using small diameter drill holes (95 mm).

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1. INTRODUCTION

Rational large scale mining and excavation have forced the development of mining equipment and consequently also explosive products including manufacturing, distribution ar handling.

The safety and working environment has become most significant parameters when the overall mining operation is evaluated. This has to a great extent influenced the produ development towards less sensitive explosives.

Today most of the commercial explosives in the world an used in large diameter drillholes. The explosive is then handled as bulk explosives.

ANFO is since more than 25 years the most common bulk explosive as it is cheap, easy and safe to handle. ANFO is unfortunately not water resistant and despite a lot of efforts has been made to add ingredients m order to increase the water resistance, this has only succeeded to a marginal degree.

The overall cost for the excavation including loading, hauling, crushing etc. must be minimized. By changing the explosive usually all operations are affected. More powerful explosive in the drillholes gives for example finer fragmentation and a faster flow of rock through the loading-hauling-crushing operation.

After many years of experience in huge operations with large hole diameters up to 12 1/4" Nitro Nobel now also has systems available for small diameter blastholes (down to 64 mm).

Most of the Swedish quarries work with drilling equipment for 64 up to 125 mm drillholes. By use of bulk emulsion systems it has become possible to double the number of drillholes per round despite charging time has been reduced. Better fragmentation has resulted in decreased costs for secondary blasting.

2. DESCRIPTION OF THE BULK EMULSION SYSTEM

EMULITE® is an emulsion explosive. It consists of small droplets of ammonium nitrate solution, tightly packed in a mixture of oil and wax. Looked at through a microscope, its structure resembles that of a honeycomb. The thickness of the oil and wax membranes separating the droplets is less than one tenthousandth of a millimetre. This involves an extremely large contact area between the fuel-oil and wax and the oxidizer-ammonium nitrate. As a result very rapid and complete explosive combustion is obtained. The oil and wax membrane also protects every droplet of ammonium nitrate and makes the explosive highly water resistant.

By adding "hot spots" in the form of small hollow glass spheres (microspheres) or air bubbles the sensitivity of the emulsion can be varied. The hot spots, which are only one tenth of a millimetre m diameter, act as density gradients in the explosive and effectively transfer shock wave energy to heat and enhance the rapid explosive combustion of the emulsion.

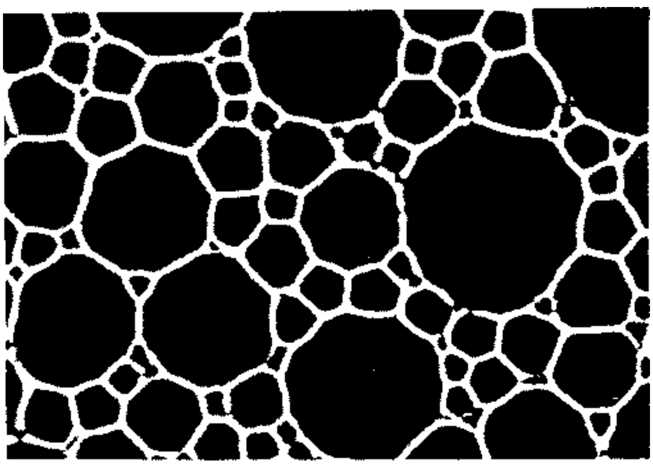


Figure 1. Structure of an emulsion seen through a microscope.

EMULITE contains no raw materials classified as explosives and becomes itself an explosive only in the final stage of production.

EMULITE is extremely insensitive to accidental initiation through friction, fire or other mechanical stimuli. It is therefore extremely safe to manufacture and handle than any other commercial explosive.

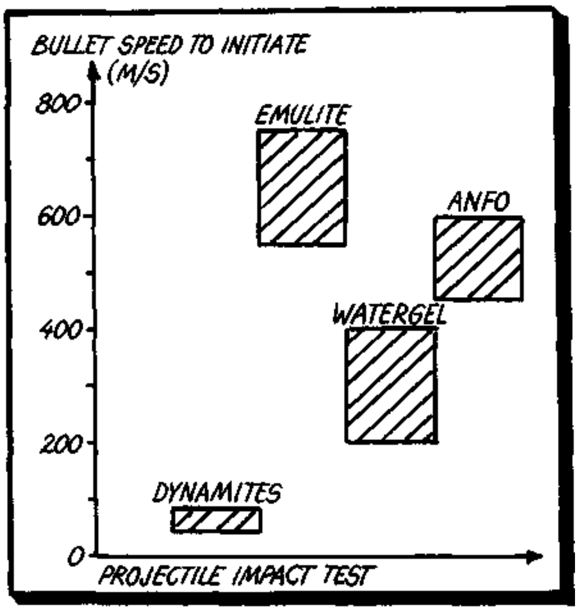


Figure 2. Sensitivity for some commercial explosives in the projectile impact test.

2.1 Bulk Manufacturing Systems

Production of EMULITE can be either centralized or decentralized depending on for instance consumption volumes, regulations etc.

Centralized production comprises besides manufacturing of tailor-made explosives, also a possibility to produce a non-explosive emulsion matrix, which can be sensitized on site by chemical gassing or by microspheres.

Since production of EMULITE is very safe, the manufacturing unit can be located close to worksite. No explosive needs to be stored as loading of the truck is integrated with production of the explosive. This implies storing and transport of non-explosive raw materials only.

Manufacturing units are available with production capacities from 1,200 tonnes per annum. They are built up by container moduls adaptable for a wide variety of applications.

2.2 Bulk Pump Trucks

Nitro Nobel has designed two basic types of bulk truck bodies for transport and charging of emulsion explosives.

The EMULITE Pump Truck body is suitable for straight EMULITE or plant-mixed EMULAN®. The EMULITE Multi Truck body is designed for:

- Pumping of straight EMULITE;
- Mixing and pumping of EMULAN;
- Mixing and augering of EMULAN and ANFO.

Both types can pump explosive into even water-filled drillholes.

Pumping starts with the charging hose at the bottom of the hole and the water, if any, is displaced.

The bodies are available with different load capacities to fit demands of explosive per shift etc.

EMULAN is a bulk explosive produced by mixing PRILLIT (ANFO) with an emulsion. The addition of emulsion will give a more powerful explosive than PRILLIT itself with higher bulk strength and improved water resistance. The proportions of emulsion and ANFO can be varied to produce a range of products to meet different blasting conditions. A mixture of 75 per cent EMULITE and 25 per cent PRILLIT is named EMULAN 7500, a mixture of 40/60 EMULITE/PRILLIT is named EMULAN 4000 etc.

Generally the following is valid for EMULAN:

a) EMULAN with up to 40 per cent EMULITE matrix can be augered into dry holes. Poor water .resistance.
b) EMULAN 4000-6000 can be augered into wet holes but dewatering is necessary before loading. Average to good water resistance.
c) EMULAN with more than 60 per cent EMULITE matrix is pumpable and can be loaded into waterfilled holes. Excellent water resistance.

Velocity of detonation measurements have been used to control the water resistance of EMULAN 7500. VODrmeasure-ments in the hole diameter 9 7/8" shows that the VOD is stable 5,300 - 5,500 m/s, even when the explosive has slept for one month in wet holes.

3. AITIK COPPER MINE

At the Aitik open pit mine north of the Arctic Circle, Boliden Mineral AB is mining about 12 million tonnes of low grade copper ore per year. The average copper content is only 0.38 per cent.

In 1966 development work began and in 1968 production could start. New large scale techniques and equipment for open pit operation had made it realistic to benefit from mining low grade copper ore.

The bedrock is predominantly represented by biotite gneiss and sericite schist and the main mineralization of economic interest is disseminated chalcopyrite. Gold and silver (0.3 respectively 4 g per tonne of ore) are extracted from the copper concentrate.

3.2 Drilling and Blasting

Generally

Since the start up of the mine, hole diameters of 9 7/8" have been used.

18 m vertical holes are drilled in the 15 m high bench in a 7.5 x 9.5 m^2 pattern for the stock blasts. An unloaded hole length of 4 m is left after the hole has been loaded.

In 1969 Nitro Nobel built a plant 25 km outside Aitik for manufacturing of bulk explosives. A high strength, high density (1.45 - 1.5 g/cm^3) aluminized TNT-based water-gel named Reolit was produced with minor modifications up to 1983. Emulsion explosives were then tested and in 1987 EMULITE 1050 had replaced the TNT-slurries.

EMULITE 1050 is a booster-sensitive, on-site sensitized emulsion with 5 per cent aluminium.

As from June 1987 tests with EMULAN 7500 started and the results were so encouraging that today the mine is using EMULAN in preference of EMULITE 1050.

EMULAN 7500 consists of a mixture of 75 per cent EMULITE 1000 and 25 per cent PRILLIT (ANFO). The EMULAN 7500 has been sleeping in wet holes at Aitik up to 5 weeks without any malfunction. 95 per cent of all boreholes in the mine are waterfilled.

3.3 Loading

Today a bulk truck with a load capacity of 14 tons is used for transportation and loading.

Both EMULITE and EMULAN are sensitized by adding gassing agents at the same time as the explosive is pumped into the borehole.

The distance from the plant to the mine is 25 km. One load takes 2.5 - J hrs to complete. Load cells on the truck make it possible to predetermine the amount of explosive loaded into each hole.

Before loading and during the loading operation the density is checked. Normally a density of around 1.15 g/cm will grant that the density in the hole bottom does not exceed 1.3 g/cm .

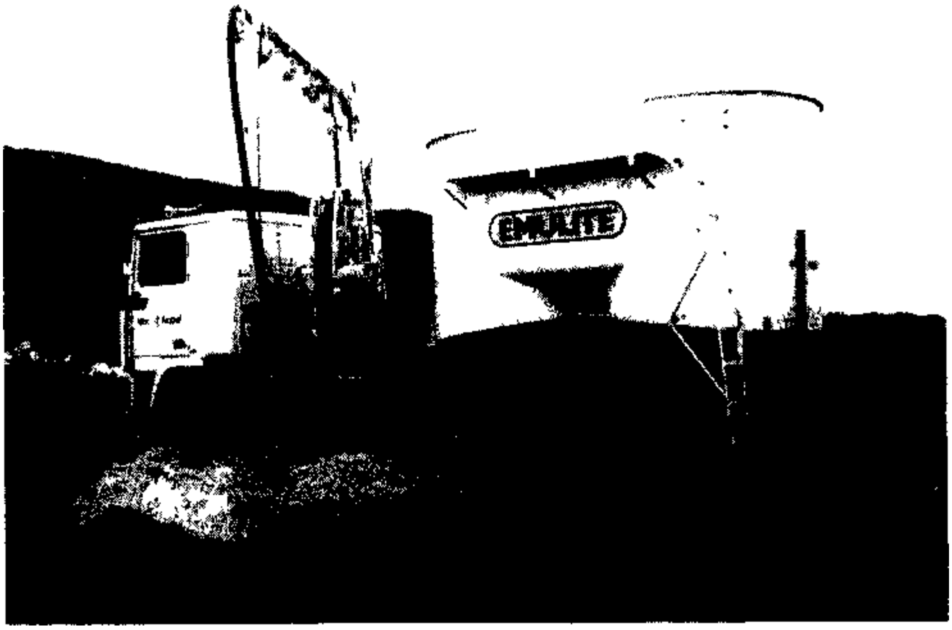


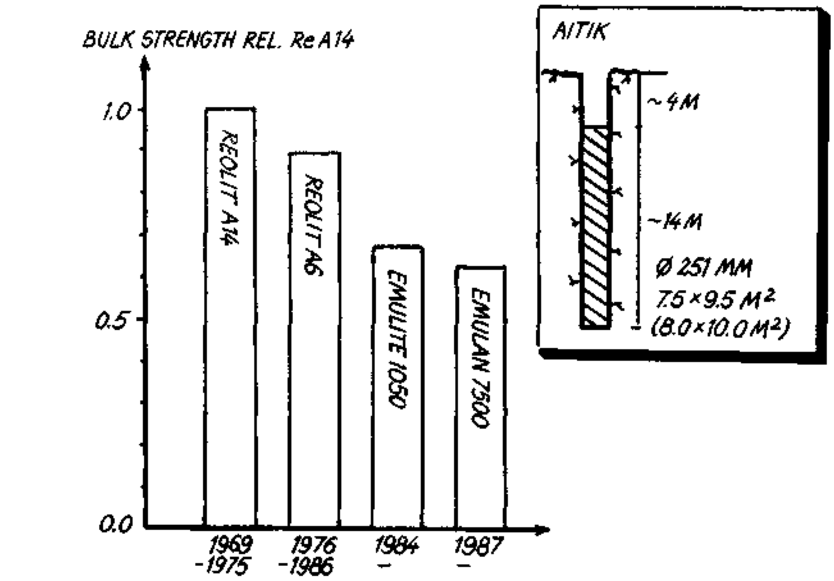
Figure 3. Bulk loading of EMULITE in the Aitik Mine.

3.4 Blasting Results

In the Aitik mine, the hole pattern was originally 8 x 10 m^2 when the high energy TNT-slurry Reolit A14 with a density 1.5 g/cm^3 was used. Powder factor was kept as high as 1.1 kg/m^3.

Later on the drillpattern was reduced to 7.5 x 9.5 m^2 and still today this burden and spacing are utilized.

Figure 3 shows the strength and type of explosives at Aıtık. It ıs remarkable to note how the bulk strength diamatıcally lias been reduced during the years.



DENSITY(ß/CM*)	1.5	1A5	1.25	1.2
EmoeiOHENERGY (MJ/KG)	52	4-5	3.6	33

Figure 4. Bulk strength relative Reolit A14.

The theoretically calculated explosion energy has been reduced from 5.2 to 3.3 MJ/kg and the density has decreased from 1.5 to 1.2 g/cm .

Today the specific charge is 0.89 kg/m and the mine claims that the fragmentation and heave for EMULAN 7500 is as good as when the TNT-slurry was used!

The mine is always following up each blast by surveying the broken quantity and the toe breakage.

4. GOTLAND

4.1 Small diameter holes. Limestone

At Gotland, an island located southeast of Sweden the rock type can be described as horisontally bedded limestone.

Two big quarries, Nordkalk and Cémenta, on the northern part excavate 5 million tonnes per year for cement industry and steel production.

Normally sedimentary limestone rock requires an explosive with a low VOD and high volume of gas. In order to evaluate how efficient EMULAN with a high VOD works in this specific type of rock a sequence of rounds were blasted at Nordkalk, with a stepwise expanded drilling pattern.

With 20 metres bench height and 95 mm holediameter a drilling pattern of 2.7 x 6 m was employed when dynamite and ANFO were used.

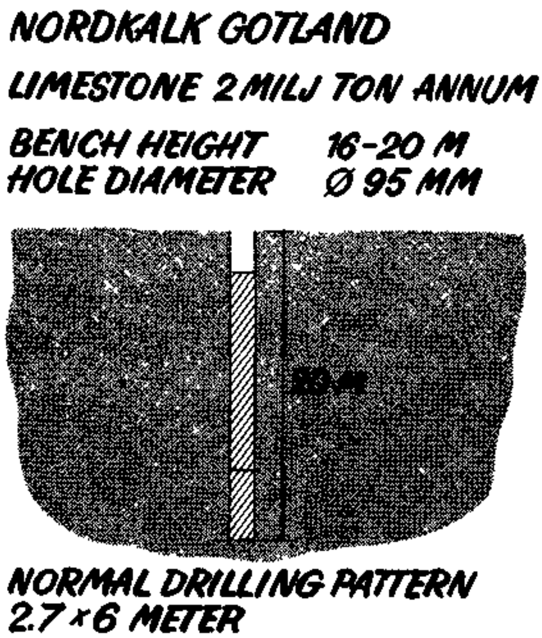


Figure 5. Blasting geometry at Nordkalk.

DYNAMEX M® is used as a bottom charge and ANFO as a column charge. Normally 50 kgs of DYNAMEX is enough to reach above the water level and allow ANFO in the dry column part.

For the first round with EMULAN a drilling pattern of $2.5 \times 6\ m^2$ was used. Stemming was about 2 m. The blasting result was very good but the fragmentation was too fine to be acceptable. The high density of EMULAN together with this narrow drillpattern resulted in a very high powder factor.

The drilling pattern was later expanded to $3.2 \times 6.4\ m^2$ but still fragmentation was too fine.

Finally a pattern of $3.7 \times 7.2\ m^2$ was reached giving a normal blasting result in comparison with DYNAMEX and ANFO.

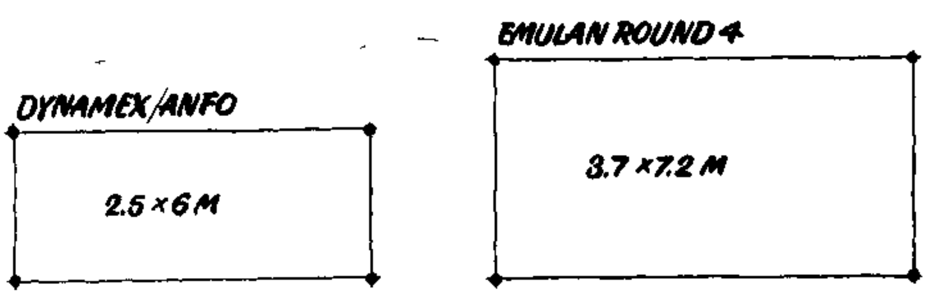


Figure 6. Original and final drillpattern after change of explosive.

This resulted in a reduction from 0.067 to 0.038 drilled metres per m^3, a decreased powder factor from 0.37 to 0.31 kg/m and a reduction of the cost for blasting and drilling.

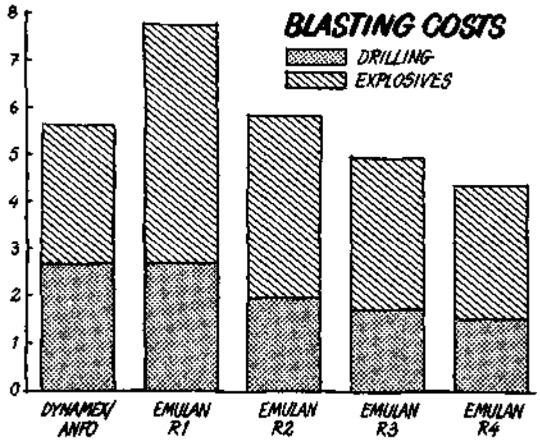


Figure 7. Total blasting cost for different explosive combination.

4.2 Distribution and loading

The bulk product distributed to Gotland was a non-explosive emulsion matrix which can be shipped with the regular ferry. The sensitizer (microspheres) was added when the matrix was pumped into the pump truck. The amount of EMULITE corresponded to the daily comsumption of the quarries meaning that no explosive needed to be stored on worksite.

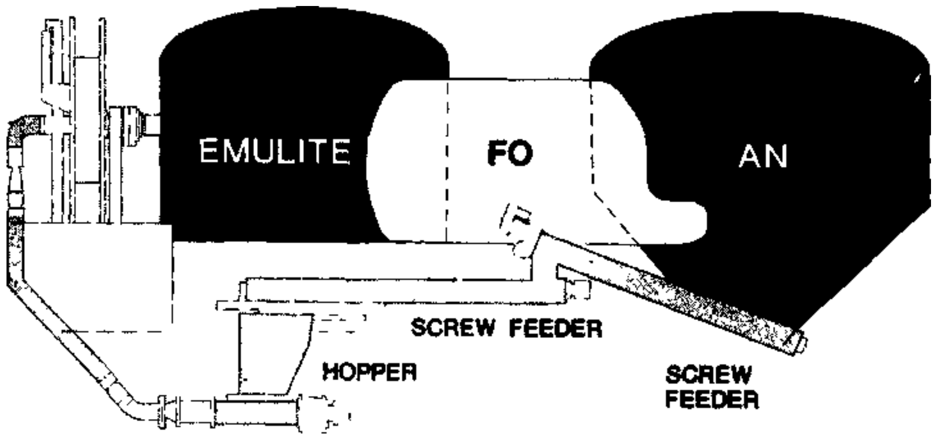


Figure 8. Schematic layout of EMULITE/EMULAN bulk truck.

Mixing of EMULAN is carried out in two augers on the truck. In the first auger PRILLIT is mixed and in the second auger PRILLIT and EMULITE are mixed, forming EMULAN.

4. DISCUSSION

The excellent results achieved with the new generation explosives, EMULITE and EMULAN can only be explained by the fact that the efficiency of combustion is superior for the emulsion explosives.

Usually commercial explosives have a very pronounced diameter dependent VOD, which indicates a non-ideal detonation with decreased efficiency at the early expansion phase. Qualitatively this means that the total energy delivered by the explosive decreases when the diameter is decreased.

The ratio between ideal VOD and real life in situ measured VOD indicates the degree of non-ideality for various hole diameter.

Because of the extremely intimate contact between fuel and oxidizer in emulsions, most of the released chemical energy is immediately transferred to expansion work assisting the breakage performance.

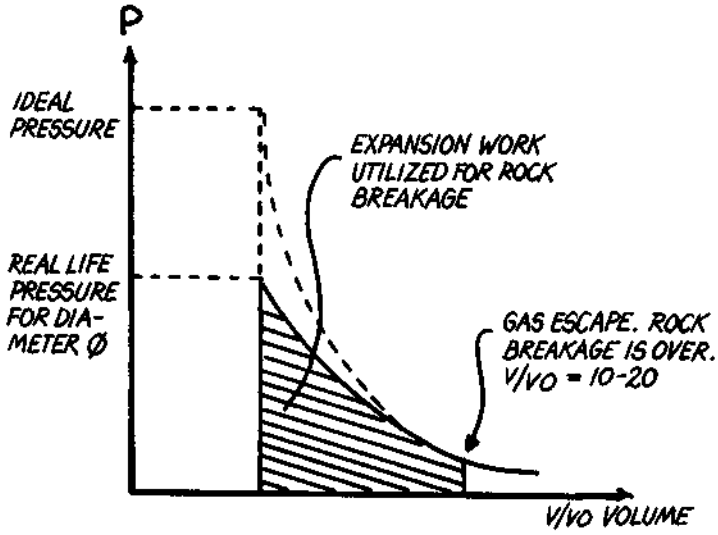


Figure 9. Schematic description of ideal and non^ideal behaviour.

5. CONCLUSION

The ideal behaviour of emulsion explosives, as explained above has been verified through long-term production blasting in various applications all over the world.

Experience shows that working conditions for the blasting crew becomes significantly better when explosive can be pumped directly into the hole instead of carrying it by hand.

Low raw material costs in combination with good water resistance, excellent blasting performance, safe manufacturing and handling definitely help the practical blaster to minimize the overall production costs in the mine.

EMULITE in bulk seems to be a rational alternative for large consumers of explosives, such as quarries and open pit mines. It is also an interesting alternative for contractors working with large excavation projects.