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Analysis of Effect of Aluminized CANFO on Fragmentation and Economics of Quarry Blast

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ABSTRACT

Reducing the explosive cost for drilling and blasting operations conducted at limestone quarries is a major concern for every mine operator. In Pakistan, to reduce explosive cost, Calcium Ammonium Nitrate with Fuel Oil (CANFO) is commonly used in explosive column charge in place of Ammonium nitrate fuel oil (ANFO). However, fragmentation of the blast has to be compromised over cost reduction. Hence it is desired to enhance the performance of CANFO. In this study, Aluminum (AL) is added into Calcium Ammonium Nitrate (CAN) to analyze its effect on fragmentation and economics of blast at a limestone quarry. Experimental shots were held using rectangular drilling pattern (current practice), using CANFO and ALCANFO in separate shots, while all other blast design factors were kept constant. Post blast analysis for all shots was done in terms of fragmentation and cost. The shots using ALCANFO proved to be better fragmentation wise, and also assured a saving of 1.6% in drilling and blasting costs.

1. Introduction

Explosive cost (almost 15%) is the second major part in the total production cost of quarry operations after fuel cost. In order to minimize the total production cost at a quarry, it is therefore necessary to reduce the explosive cost by optimizing its effectiveness. The optimization of explosive performance not only reduces the explosive cost, but it also helps in reducing the loading and transportation cost by helping to achieve suitable fragmentation.

In most of the cement quarries of Pakistan, combination of explosives consisting of dynamite, water gel and ANFO is used. In this combination, Ammonium Nitrate Fuel Oil (ANFO) constitutes 80-85%. However now a days in Pakistan, the trend is to replace ANFO with CANFO (Calcium Ammonium Nitrate with Fuel Oil) due to the cheap cost and abundant availability of the later.

However, CANFO is a low density product with a low energy per meter of column length. This low energy results in poor fragmentation, thus increasing the overall production cost. It is therefore needed to raise the level of energy for CANFO. In this study, an attempt is made to improve the blasting performance of CANFO by adding aluminum into it. The addition of aluminum in CANFO was considered, based on the fact that the density and available energy of ANFO is recorded to increase with aluminum addition, but no such study has been conducted using CANFO. The amount of added aluminum was determined from an oxygen balanced relation established between reacting ingredients.

The experimental shots were fired using CANFO and aluminized CANFO in separate shots and results were compared in terms of fragmentation and cost of explosives. All the experimental work was conducted at D.G. cement factory, Chakwal Pakistan where almost 3.6 Mt/year of limestone is produced

2. Literature Review

Basic components of mining explosives depend upon oxidants and flammables. The detonation parameters depend upon the structure of the mixture, while the explosive reaction in detonation zone depends upon the oxidants and fuel being used.

ANFO consists of fuel oil and porous ammonium nitrate granules having an average size of 1 mm. These ammonium nitrate granules can absorb FLEX 401 oil, up to a wt. % of 9.5. Ammonium nitrate decomposes to produce oxygen for the reaction of flammable component. In ALANFO, in addition to oil, aluminum powder also acts as fuel.

Flaked aluminum was added in ANFO in different quantities by weight (Table 1) and was found that addition of aluminum increases the workability of ANFO and improves the blast results. In another study it was

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found that aluminized ANFO has superior detonation parameters as compared to ordinary ANFO, and in terms of thermo chemical properties its efficiency is found to be directly proportional to the concentration of aluminum. The maximum performance from aluminized ANFO is assured only when oxygen balance approaches to zero. It was concluded from this study that adding aluminum to ANFO resulted in better performance in three ways: detonation products became less toxic, secondly its workability is increased and lastly blast wave performance is enhanced.

Aquarium test was used to investigate the role of aluminum addition to ANFO and it was found that aluminum not only increase the total energy of the explosive but also initial shock pressure imparted to the surrounding medium was affected by aluminum content.

On the other hand in one of the studies, it was claimed that addition of aluminum has no effect on the strength of ANFO and whatever benefit is obtained by addition of aluminum can be attributed to the increase in density of ANFO. It was anticipated that similar results as ALANFO can be obtained from the use of high density ANFO, where high density has no effect on work per unit mass but only increases the loading density.

At sari kaya tepee lime stone quarry (Turkey), use of ALANFO not only allowed the expansion of drill pattern but also resulted in better performance than conventionally used ANFO.

Table 1: Elements of aluminized ANFO

Element [wt.%]	Explosive		
	ANFO-Al-Type1	ANFO-Al-Type2	ANFO-Al-Type3
Ammonium Nitrate(V) (Porous)	91.85	88.71	85.23
Aluminum	3.64	7.27	12.12
OilFLEX401	4.51	4.02	2.65

He reported a saving of 28% in drilling and blasting cost by using ALANFO. A decrease in overall mining cost is predicted by using ALANFO due to its higher density.

Buczkowski suggested that incase of ALANFO, oil adsorption in porous ammonium nitrate shouldn't be a lot ,as aluminum powder is already present for the same purpose as fuel oil. He also recommended the use of atomized aluminum powder as a source of aluminum in ALANFO as it possesses lesser quantity of aluminum oxide produces almost no dust and is lower in cost than flake powder. It should also be noted that aluminum should be pure as much as possible, as inert substances in impure aluminum can result in decrease of detonation velocity and other energetic characteristics of ANFO as it absorbs heat from the reaction zone.

3. Research Methodology

3.1. Rock Properties

This study was conducted at a limestone quarry near Khairpur village in Pakistan. This limestone quarry produces 3.6 Mt/year of lime stone intended to be used for cement production. The lime stone has a compressive strength of 220 kg/cm^2, tensile strength of 45.0 kg/cm^2 and has a density of 2·5 Metric ton/ m^2.The look of the deposit is massive

3.2. Experimental Program

Bench 2 and 3 were selected for test blasts. A series of conventional and modified blasts were conducted at these two benches, using CANFO and aluminized CANFO respectively. All nonel initiation system was used, i.e. nonel was used both down the hole and at surface. An in-hole delay of 25 m sec was used in each hole; while a10 meter instantaneous nonel was used for surface connections. In all test blasts, drill cuttings were used as the stemming material. The properties of other explosives used during the test blasts are given in Table 2

Table 2: Explosive properties

Explosive	Velocity of detonation (m/sec)	Density (g/cm^3)
Wabox 80% (dynamite)	5000	1.5
Blaster (water gel)	4300	1.2

3.2.1 Preparation of aluminized CANFO

Percentage weighted quantities (Table3) of aluminum; calcium ammonium nitrate and fuel oil were derived from oxygen balanced equation (below) of reacting ingredient.

$$2Al + 5\,Ca\,(NO_3)_2\,NH_4NO_3\;10\,H_2O + 9CH_2 \longrightarrow 5CaO + 9CO_2 + Al_2O_3 + 69H_2O + 10N_2$$

Table 3: Weight % quantity of ingredients in ALCANFO

CAN%	AL%	Fuel Oil%
92.2	5.5	2.3

3.2.2. Test blasts at bench # 2

Total of two shots were fired at bench#2, one using CANFO (conventional) and one using ALCANFO (modified). Each shot consisted of eight holes. During the blasting of shots all blast design parameters were kept constant except that in modified blast ALCANFO was used in place of CANFO.

For both conventional and modified blast at Bench #2, other blast design parameters were kept same which are given in Table 4.

Proper mixing was ensured visually using accurate composition of CAN with fuel oil at site. CANFO, fuel oil and aluminum were mixed together using hand shovel on concrete surface. Table 5 shows the actual quantities and weight % of CANFO and ALCANFO used for blasting purposes at bench 2 & bench 3.

3.2.2.1 Blast design

Table 4: Blast design parameters at bench # 2

Parameters	Values
Bench height	9m
Hole Diameter	110mm
Hole depth	8m
Burden	3.5m
Spacing	4.5m
Hole inclination	85 (degree)
Sub drilling	1m
Stemming	1.5m

3.2.2.2. Firing pattern

Firing pattern of the blast holes were also kept same in both conventional and modified blast and is shown in Fig. 1.

3.2.2.3. Charging sequence during modified and conventional blasting

During conventional and modified blasting, the explosive was loaded as shown in Fig. 2 and 3.

3.2.3. Test blasts at bench # 3

Two shots were conducted at bench#3, same as bench #2.One of the shots was done using CANFO (conventional blast), and the other using ALCANFO.

3.2.3.1 Blast design

All blast design parameters were kept constant for conventional and modified shots at bench # 3 as given in Table 6.

Table 5: Quantity of CANFO and ALCANFO used in bench # 2 & 3

Quantity/hole	Conventional	Modified Blast	Conventional	Modified Blast
CAN%	94	92.2	94	92.2
CAN weight(kg)	33.8	33.2	30.1	29.5
Fuel oil%	6%	5.5	6	5.5
Fuel oil Weight(kg)	2.2	2	1.9	1.8
AL%	0	2.3	0	2.3
AL weight (kg)	0	0.8	0	0.7
Total weight CANFO(kg)	36	–	32	–
Total Weight (ALCANFO)	–	36	–	32

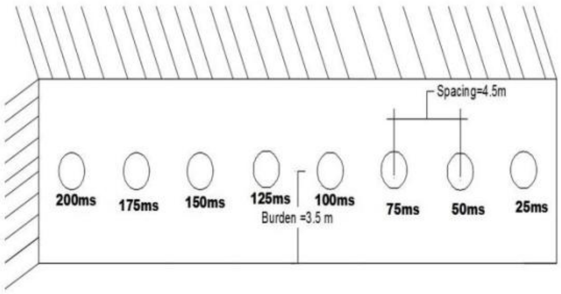

Fig. 1: Firing pattern of conventional & modified blasts at bench # 2

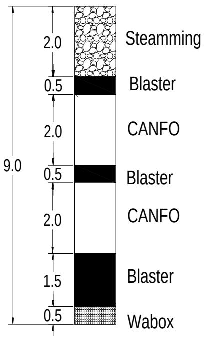

Fig. 2: Charging sequences, conventional blasting at bench # 2

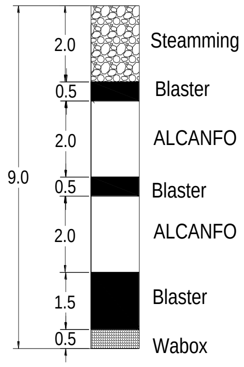

Fig. 3: Charging sequence, modified blasting at bench # 2

Table 6: Blast design parameters at bench # 3

Parameters	Values
Bench height	8.5m
Hole diameter	110mm
Hole depth	8m
Burden	3.5m
Spacing	4.5m
Hole inclination	85^0
Sub drilling	1m
Stemming	1.5m

3.2.3.2. Firing pattern

In each shot at bench #3, five holes were fired. The firing sequence of each shot was kept constant as shown in Fig. 4.

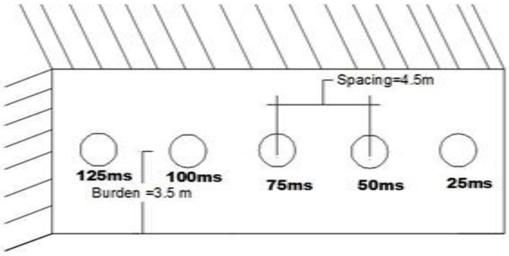

Fig. 4: Firing pattern of holes at bench # 3

3.2.3.3. Charging sequence during conventional and modified blasting

The charging sequence of the conventional and modified shots at bench#3 is shown in Figs. 5 and 6, respectively.

4. Results and Discussions

4.1 Fragmentation Analysis of Blast Results

After each shot, the muck pile was examined for the presence of any misfires & boulders. All boulders were put at aside and were counted. Fragmentation performance of each shot was determined according to the number of boulders. Any fragment having a dimension larger than 1.5 m was designated as boulder as per crusher limitations, and was subjected to secondary drilling and blasting.

By observing the loading and crushing efficiencies, it was found that on average, fragmentation performance of modified blast was better than the conventional blasts, and no boulders were produced as well in modified blast.

4.1.1 Fragmentation analysis at bench#2

Conventional shot at bench#2 produced an average of seven boulders, while no boulders were produced from the modified shot in which ALCANFO was used as column charge. The results of fragmentation analysis at bench#2 are given in Table 7.

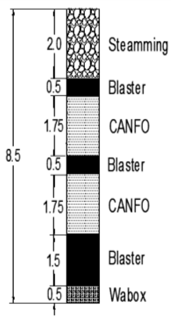

Fig: 5: Charging sequence of conventional blast at bench # 3

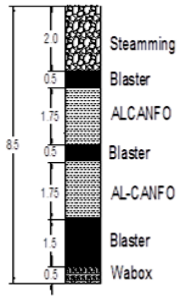

Fig. 6: Charging sequence of modified blast at bench # 3

4.1.2. Fragmentation analysis at bench # 3

At bench # 3, the performance of modified shot was also found better than the conventional shot and is shown in Table 8.

Table 7: Fragmentation analysis at bench#2

Bench # 2	Primary Blast tons /shot	Boulders tons/shot	%age of boulders /shot
Conventional (CANFO)	2721.6	56.7	2.08
Modified (ALCANFO)	2721.6	0	0

Table 8: Fragmentation analysis at bench # 3

Bench#3	Primary blast tons /shot	Boulders tons/shot	%age of boulders /shot
Conventional (CANFO)	1594	40.5	2.5
Modified (ALCANFO)	1594	0	0

4.2 Cost Analysis of Blast Results

4.2.1 Cost analysis of shots at bench # 2

The cost of primary blast using only CANFO was apparently less than the ALCANFO, but it resulted in coarser fragmentation which needed secondary blasting. The addition of AL powder into CAN added to explosive cost, but the improvement in fragmentation nullified any need of secondary blast. Hence the increase in cost was well compensated by reduction in secondary drilling and blasting costs. The detail of cost analysis is given in Table 9.

Table 9: Cost comparison of shots at bench # 2

Bench#2	Primary blast (PK Rs)	Secondary blast (PK Rs)	Total cost (PK Rs)
Conventional (CANFO)	18.41	2.16	20.57
Modified (ALCANFO)	20.24	0	20.24

The graphical representation of cost comparison between conventional and modified blast at bench # 2 is shown in Fig. 7.

4.2.2. Cost analysis of shots at bench # 3

Modified blast at Bench#3 resulted in better fragmentation than conventional shot and therefore proved to be cheaper overall (Table10).

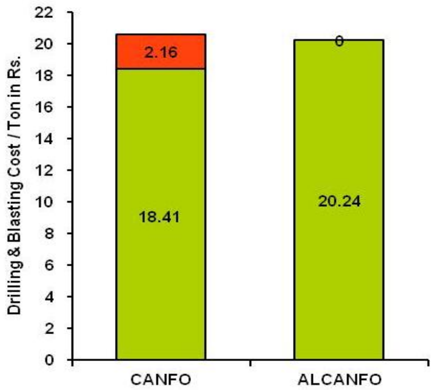

Fig. 7: Economics of conventional and modified blast at bench # 2

Table 10: Cost comparison of shots at bench # 3

Bench#3	Primary b last (PK Rs)	Secondary blast (PK Rs)	Total Cost (PK Rs)
Conventional (CANFO)	19.19	2.06	21.25
Modified (ALCANFO)	20.93	0	20.93

This cost comparison at bench#3 is also expressed in graphical form as shown in Fig. 8.

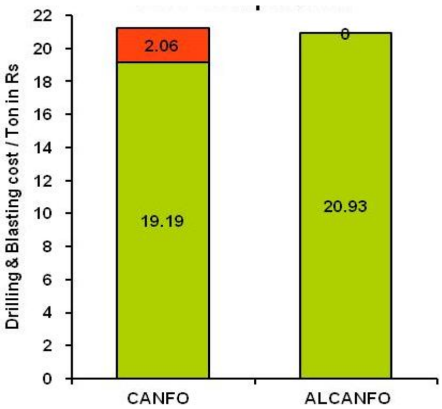

Fig. 8: Economics of conventional and modified blast at bench # 3

It is believed that the improved fragmentation would also reduce the loading, hauling and crushing costs. The improved fragmentation intends to increase burden and spacing of a blast hole, which result in further cost reduction.

5. Conclusions

Field tests at the Sakesar lime stone quarry in Pakistan have shown that the fragmentation of blasted material improved by the use of ALCANFO. The overall drilling and blasting cost reduced to almost 1.6 %. Although the saving was small, but elimination of need of secondary blast and improved material handling operations highly recommend the use of ALCANFO i n place of CANFO.

It is also suggested to carry out a study to analysis the effect of fragmentation by varying the currently applied spacing and burden using ALCANFO. It will help to check the possibility of further cost reduction.

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