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EXPLOSIVE CONSUMPTION REDUCTION BY INTRODUCING HOLLOW PLASTIC TUBES IN EXPLOSIVE COLUMN

Vineeth Balakrishnan and Manoj Pradhan
Mining Engineering Department, National Institute of Technology, Raipur, India
E-Mail: discovervineeth@gmail.com

ABSTRACT

There is a huge demand for explosive in India and it will increase further as the mining activities are on a rise. India consumed around 1211427 metric tons of ammonium nitrate based explosive in 2016-17. The emulsion explosive is an ammonium nitrate based explosive which is dominating the commercial explosive market. It mainly consists of an oxidizer and a fuel. Since the fuel used is generally any hydrocarbon, explosives generate huge quantity of fumes some of which are toxic in nature. Further, these fumes contribute to environmental pollution by polluting the air, water, and soil. This paper suggests an innovative method of using hollow plastic tubes with explosive which can reduce the total fumes generated due to blasting by reducing the total explosive consumption.

Keywords: emulsion explosive, rock blasting, hollow plastic tubes, blast generated fumes.

INTRODUCTION

Mining engineering practices of rock blasting are well established. Explosives are charged in blast holes suitably located, and then detonated using initiating devices. An explosive is any device or material which can produce a sudden outburst of gas, applying a high impulsive loading to the surrounding medium [1]. There are many types of explosives such as mechanical, electrical, nuclear and chemical. For mining, chemical explosives are the most used.

The development of explosives has a long history. The black powder or gunpowder, nitro-glycerine, and dynamite are the explosives of the previous generation. ANFO and slurry are also introduced but due to superior detonation characteristics the site mixed emulsion (SME) is dominating the modern market of bulk explosives.

From the chemical point of view, an emulsion explosive is a two-phased system in which a dispersed (inner) phase is distributed in continuous (outer) phase. These are hence called water in oil type, in which the aqueous phase is composed of inorganic oxidizing salts dissolved in water, and the oil phase of a liquid which is immiscible with water that is hydrocarbons. For adequate sensitization of emulsion explosive, either explosive sensitizers such as TNT, PETN are used or gas bubbles are used. These gas bubbles when adiabatically compressed produces hot spot phenomenon, favouring initiation as well as the detonation of the emulsion explosive. These gas bubbles are generally introduced by using chemical foaming agents such as sodium nitrate or using glass micro balloons [2].

India has consumed about 1211427 metric tons of AN based explosive in the year 2016-17 [3]. This quantity will further increase as the current trend is planning of large opencast mines and expanding already existing mines to an annual production of around 50 million metric tons or more. In case of coal mines, generally, the coal produced is consumed in pithead thermal power plant which also emits a lot of fumes. Hence these localities where both large coal mines and large thermal power plants co-exist are becoming clusters of pollution. These areas are facing grave environmental challenges and need some innovative solutions.

The blasting operation produces both non-toxic and toxic gases. The detonation products of explosive consist of water (H_2O), carbon dioxide (CO_2), nitrogen (N_2), carbon monoxide (CO) and oxides of nitrogen (NO_X). The toxic gases are mainly carbon monoxide (CO) and oxides of nitrogen (NO_X). These gases have many other serious impacts on the environment which forces us to think towards the possible methods of mitigation of the sources of pollution. As mining industry is backbone of the economy of any country, rather than being critical of mining activities, innovative problem-solving methods should be developed which can change the scenario. One such innovative idea of using hollow plastic tubesin explosive column for blasting is suggested in this paper. This method can reduce the explosive consumption which in turn will decrease the production of fumes in blasting and make the process more sustainable.

CHEMISTRY OF EXPLOSIVES

For any commercial explosive, there are generally two reactants, a fuel (generally hydrocarbon) and an oxidizer (generally aqueous solution of ammonium nitrate) that react to form the products. The simplest picture of how the decomposition reaction occurs is to imagine that in a zone where an explosive is detonating, the reactant molecule is completely broken down into its individual component atoms [4].

$$C_cH_hN_nO_o \rightarrow cC + hH + nN + oO$$

These atoms then recombine to form the ultimate products of the reaction. The typical products formed are H_2O, CO_2, N_2, NO_2, NO and CO.

In case of ammonium nitrate based explosives the decomposition reaction of oxygen balanced system is:

$$3NH_4NO_3 + CH_2 \rightarrow 3N_2 + 7\,H_2O + CO_2$$

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It must be noted that, if there is exactly enough oxygen to burn all the carbon then only carbon dioxide is formed. But this is not the case with every explosive. Some explosives have more than enough oxygen to burn all the carbon to CO_2. These explosives are called over oxidized or fuel lean. Most explosives compounds do not have enough oxygen to burn all the carbon to CO_2; they are called under oxidized or fuel rich. In all cases the products formed can be estimated by applying following rule; first, all nitrogen forms N_2, then all the hydrogen is burned to H_2O. Any oxygen left after H_2O formation burns carbon to CO. Any oxygen left after CO formation burns CO to CO_2. Any oxygen left after CO_2 formation forms O_2. Traces of NO_X (mixed oxides of nitrogen) are always formed. This set of rules is called the simple product hierarchy for CHNO explosives [4].

Ammonium Nitrate explosive containing a stoichiometric mix of fuel and oxidizer minimizes the production of NO_X and CO. If the fuel is excess, explosive detonation will form more CO. If the fuel is not enough, explosive detonation will generate an increased quantity of NO_X. The explosive charged in the blast hole may flow into cracks and cavities around the borehole where it will not detonate properly as the width of the cracks are less than the critical diameter of the explosive. This incomplete detonation leads to excess generation toxic gases.

The estimation of carbon dioxide emissions from blasting can be done based on the oxygen balanced condition of explosive in which about 0.06 kg diesel (about 6% diesel by weight) is used to prepare 1 kg of explosive; explosive used is oxygen balance and complete combustion of fuel take place during blasting. The combustion reaction for diesel is:

$$C_{12}H_{23} + 71\, O_2 \rightarrow 48\, CO_2 + 46\, H_2O$$

The above reaction revels that 3.16 kg of CO_2 is emitted in combustion of 1 kg of diesel or detonation of 1 kg of explosive will emit 0.19 kg of CO_2[5].

While the CO_2 emissions from blasting can be estimated by using an oxygen balance condition, it is almost impossible to estimate quantities of CO and NO_X generated by the blasting as they are different for different blast environment.

IMPACT OF BLASTING FUMES ON ENVIRONMENT

A snapshot of a typical blast generating a large cloud of fumes is shown in Figure-1. Explosives are primary air pollutant. As discussed above, during blasting huge quantity of gases like CO_2, CO, NO_Xetc. are emitted in the environment. Though CO_2 is not a toxic gas, but is amain pollutant that is warming our earth. Gases like CO and NO_X are highly toxic. The quantity of fumes produced in blasting depends on the formulation, confinement and age of explosive. A brief discussion on the various gasses product generated during blasting is presented below.

Carbon dioxide: Carbon dioxide is a colourless, odourless, nontoxic gas having a density of around 1.98 kg/m^3. It is a greenhouse gas mainly responsible for climate change. Global warming is a major concerned for environmentalist today. Detonation of one kg of explosive produces about 0.19 kg of CO_2. This implies that every year about 230171130 kg of CO_2 is emitted in India by burning of explosive.

Carbon monoxide: Carbon monoxide is also a colourless, odourless gas but it is highly toxic in nature. It is slightly denser than air having a density of around 1.15 kg/m^3.It reacts with the haemoglobin and forms carboxyhemoglobin which fills the space in haemoglobin that normally carries oxygen and makes it ineffective for delivering oxygen to bodily tissues [6].

The CO gas which remains in ground after blasting can be released at once during the loading operation. It can also migrate hundreds of meters along the ground and get collected in some confined spaces. Such cases are being reported in many parts of the world where such confined spaces typically being homes of the persons living nearby and poisoning people living there. National ambient air quality standards of Indiaprescribe a maximum limit of CO in Industrial, residential, rural and other areas as 2 mg/m^3 for 8-hour time weighted average and 4 mg/m^{3}for 1-hour time weighted average [7].

Nitrogen dioxide: Nitrogen dioxide is a reddish-brown gas above 21.2 °C with a pungent, acrid odour, becomes a yellowish-brown liquid below 21.2 °C, and converts to the colourless di-nitrogen tetroxide (N_2O_4) below - 11.2 °C. Gaseous NO_2 diffuses into the epithelial lining fluid (ELF) of the respiratory epithelium and dissolves, and chemically reacts with antioxidant and lipid molecules in the ELF; The health effects of NO_2 includes bronchoconstriction, inflammation, reduced immune response, and may have effects on the heart.

Nitrogen oxides when released into the atmosphere after the detonation of explosive; combines with water droplets in rain to form acid rain. Acid rain can cause great damage to human, animals and crops. Moreover, toxic chemicals present in the air can force wildlife species to move to new place and change their habitat. National ambient air quality standards of India prescribes a maximum limit of CO in Industrial, residential, rural and other areas as40 μg/m^3 for annual time weighted average and 80 μg/m^3 for 1-hour time weighted average[7].

With depletion of shallow deposit, the mines are becoming deeper and deeper, requiring more explosive to break the rock. The demand of the minerals is also growing. Both these factorsindicate that explosive consumption will increase manifolds in the years to come causing more damage to the environment. There are techniques to break the rock without blasting, but these techniques have their own limitations, and still there is no alternative to blasting. The only way to save our environment from this ill effect of blasting is to reduce the explosive consumption by adopting efficient blasting techniques,which consumes less explosive and provide satisfying blast results.

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Figure-1. Snapshot of typical blast with huge quantity of fume generation.

ATTEMPTS MADE FOR EXPLOSIVE CONSUMPTION REDUCTION

In the conventional blast practice, cylindrical blast holes are drilled in the rock mass to be fragmented, and explosive is poured into it up to a certain height. The remaining portion of the blast hole is filled tightly by drill cuttings to confine the explosive within the blast hole. The quantity of explosive required depends on explosive characteristics and nature of the rock mass to be fragmented. The height up to which explosive is filled in the blast hole is called column height and remaining height which is filled with drill cutting called stemming height. Many a times, in soft rock (which require less explosive), same quantity of explosive is filled in the blast holes, as in case of hard rock (requiring more explosive). This is done to build up the column; otherwise coarse fragments are generated from the stemming region.

Attempts have been made by blasting researchers to reduce explosive consumption by inserting air/solid deck [8] or by inserting discarded water bottles [9] in between the explosive column. Both these techniques were found effective in reducing explosive consumption without compromising with the blast results.

Decking is mainly of two types namely solid decking and air decking. The deck technique was originally developed by Melnikov and Marchenko. In this method a deck of drill cuttings (solid deck) or wooden spacers (air deck) are provided in between the explosive column for reducing the explosive consumption. The deck blasting method suffers from the disadvantages that the method is time consuming and labour intensive; the charging need to be stopped for inserting deck. The method also requires dual initiation. Moreover, this method makes the column inconsistent resulting in generation of coarser fragments from the decking region.

Use of discarded water bottles in between the explosive column is recent method and is being used in many mines in India. In this method used water bottles are inserted into the explosive column at regular interval manually during charging of blast holes. Though this method does not require dual initiation, but like decking this method is also time consuming and labour intensive. The continuous availability of used bottles is also a major challenge for the mine operators, as no system exists for proper collection of discarded bottles. The bottles are collected from various dirty places and garbage and thus can be unhygienic for the blasting crew.

In this paper a technique of explosive consumption reduction using hollow plastic tubes is discussed and some trial blasts conducted in a limestone mine are reported.

Using hollow plastic tubes in explosive column

In this method, hollow plastic tubes are placed into the blast hole along with explosive in such a way that the hollow tube occupies space in between the explosive column. These plastic tubes have 83 mm diameter. The length of the tube can be fixed according to local geology. For these experiments, each tubes used were having a length of around 540 mm and weight of around 18 g. Four to five tubes were used in each blast hole.

The study was conducted at Century cements limestone mine, Baikunth in Chhattisgarh state of India.The quarry produces the cement grade limestone which is fed to the cement plant. This depositbelongs to the sediments of Chhattisgarh basin, which are horizontal, thick-bedded and classified as stromatolitic limestone of Raipur Group. The density of limestone varied from 2100-2500 kg/m^3. The deposit is overlain by a thin layer of hard laterite and clay.

The deposit is worked in two pits, namely Block ‘B’ and ‘MF2’. In each of the pit, besides the overburden bench there are three benches of varying height. The height of benches varies from 6.0-9.5 m.Conventional drilling and blasting method is used for excavation. The holes were drilled by pneumatically operated drills having a diameter of 115 mm in staggered pattern. The boulders which cannot be handled by excavator were further fragmented either by secondary blasting or by rock breaker. The burden and spacing were 3.0 - 4.0 m and 5.0 - 6.0 m respectively. The conventional practice of the mine was to charge the holes with site mixed emulsions (SME) of matrix density between 1300 kg/m^3 and VOD 4500 to 5000 m/s(Figure-2(a)). Shock tubes with cartridge booster were used to initiate the explosive.By following these conventional practices the actual powder factor of the mine were near6.0t/ kg. The mine considers fragments of size more than 1 m as boulders and the optimum size range was 0.1-0.8 m.

The trial blasts were conducted on second bench of Block ‘MF2’ of the mine.The faces were so selected that they have a uniform geometry. In all the experiments, hollow plastic tubes were inserted in the explosive column while charging (Figure-2 (b)). The hole depth, spacing, burden were9.0 m, 5.0 m and 4.0 m respectively. 17 ms hole to hole delay, 42 ms row to row delay, and 250 ms down the hole delay were used in all the blasts. The first, second and third blasts had 38 holes, 56 holes and 30 holes respectively.

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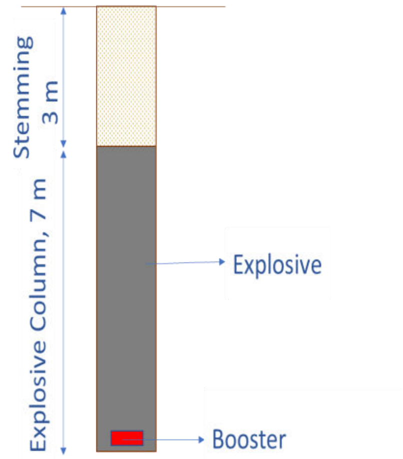
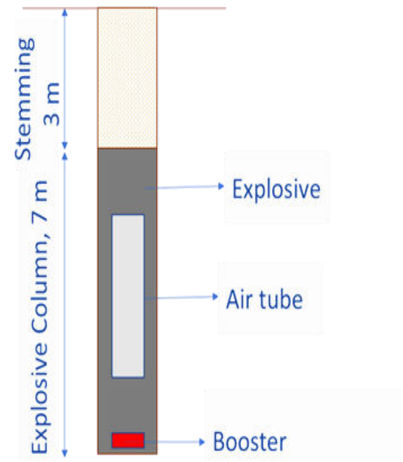


(a)



(b)

Figure-2.(a) Cross section of blast hole when charged with explosive only; (b) Cross section of blast hole when charged with hollow plastic tubes in between the explosive column.

RESULTS AND DISCUSSIONS

The sole objective of the blasting is to break the rock into desired fragmentation. The fragmentation is that one parameter which is significantly used to judge the blast results. The visual inspection immediately after the blastsrevealed satisfying results of fragmentation for all the three trial blasts. The pictures taken immediately before and after the blast are shown in Figure-3 and Figure-4 respectively.

Figure-3. Snapshot showing one of the face where trial blast is conducted.

Figure-4. Snapshots showing fragmentation achieved.

Detailed fragmentation analysis was performed using Wipfrag software. This software is used for digital image analysis of blasted fragments for finding size distribution.For this analysis scaled photographs of the muck pile were taken after each blast to cover whole material. To get the idea of material inside the muck pile scaled photographs were taken after every 20-25% loading of muck. A collection of 18-25 scaled photographs were used to generate the size distribution graph.

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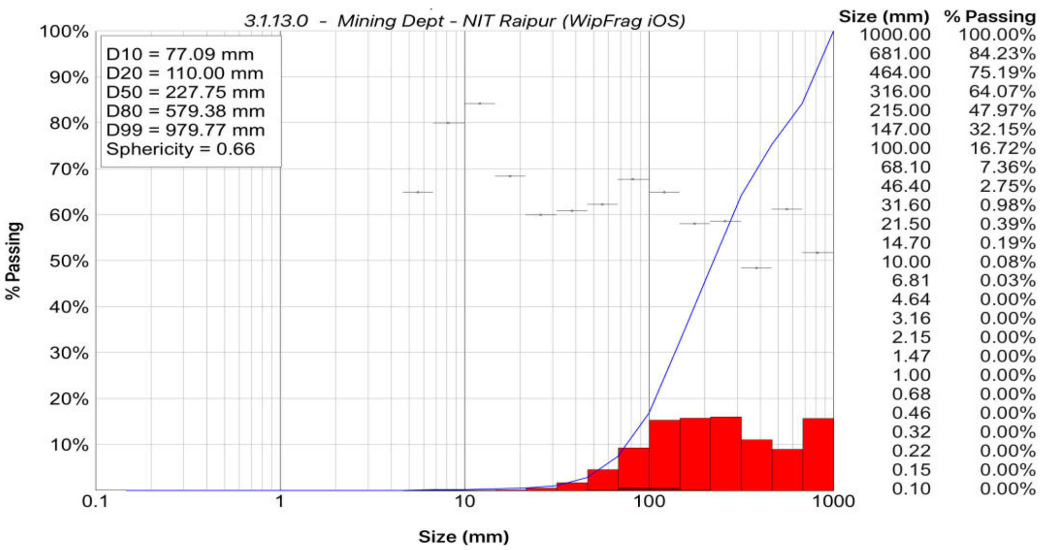

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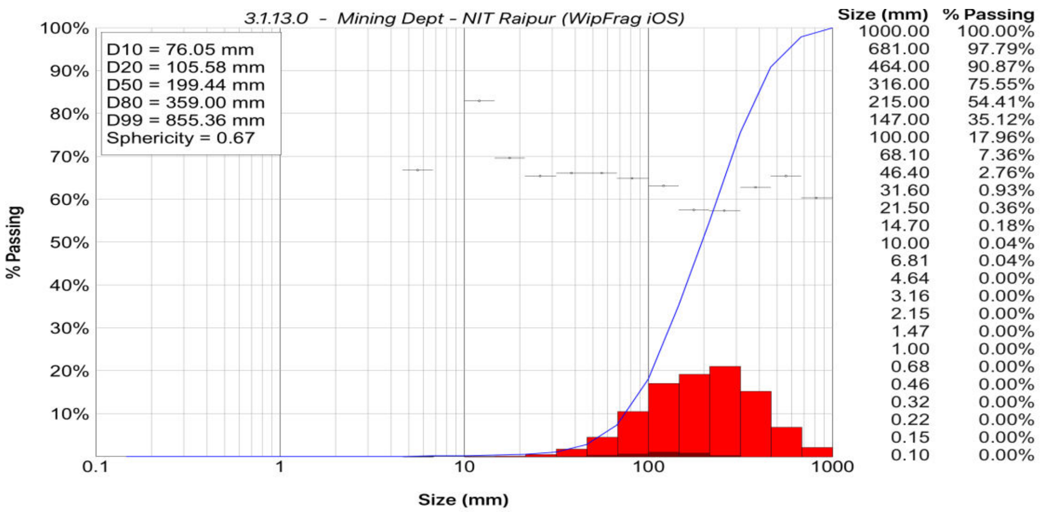

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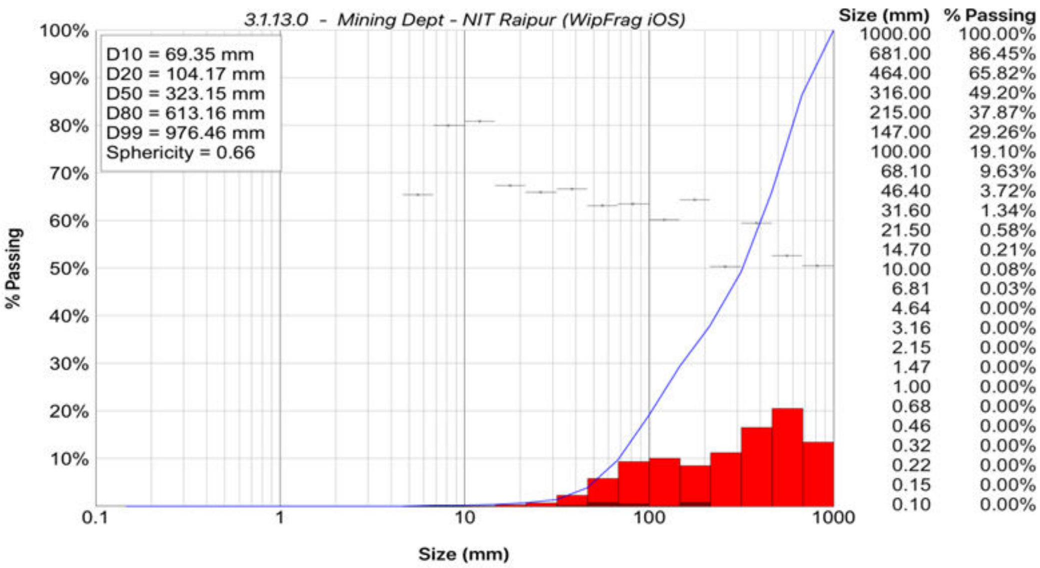

(c)

Figure-5.a, b and c are showing the fragmentation achieved for first, second and third trials respectively.

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Figure-5(a, b&c) shows fragmentation analysis of the muck pile for first, second and third trial respectively. For the first blast 20% particles were below 110 mm, 50% particles were below 228 mm, 80% particles were below 580 mm and 99% particles were below 980 mm. For the second blast 20% particles were below 106 mm, 50% particles were below 200 mm, 80% particles were below 359 mm and 99% particles were below 856 mm. For the third blast 20% particles were below 105 mm, 50% particles were below 324 mm, 80% particles were below 614 mm and 99% particles were below 977 mm. The fragmentations achieved in all the three blasts were found to be satisfying for the mines.

The following table summarizes the blast results for both the trials.

Table-1. Comparison of blast results for both the trial blasts.

	First trial	Second trial	Third trial
Total explosive consumption, (kg)	1910	2788	1542
Fragmentation	Good	Good	Good
Powder factor (t/kg)	6.63	6.71	6.68

The powder factor is a term used to define the quantity of rock blasted per kilogram of the explosive. It is used to compare the explosive consumption for different blasts. For estimation of actual powder factor number of dumper trips required to shift the material blasted were counted. These dumpers loaded with the material are weighed at the top of the pit. The more is the powder factor the more is the rock blasted. In both the blast, the powder factor of the trial blasts charged with hollow plastic tubeswas found to be 11 %more than the portion where conventional blasting was used.

Blasting is considered asan environment damaging activity. The most important environmental impacts of blasting areemissionof carbon dioxide and noxious gases, and generation of ground vibration. The quantity of carbon dioxide and noxious gases generated from a blast depends on the total quantity of explosive blasted. Since the proposed technique is found to be effective in reducing explosive consumption by 11 %, blasting with hollow plastic tubes will reduce emission of CO_2 and noxious gases by the same percentage.

CONCLUSIONS

The use of hollow plastic tubes in blasting not only offers a significant saving of about 11% of explosive without hampering the performance of blast but also gives a decent fragmentation acceptable to the mine. This method can reduce the emission of $CO_2$and other noxious gases in the environment; which is due to explosive consumption reduction. Moreover the better fragmentation achieved will also reduce the consumption of diesel by the dumpers.

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