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Use of Discarded Water Bottles in Blasting- An Innovative Enviro-Friendly Technique

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***Abstract*---** The increased bottled water consumption has become a serious environmental threat in India. The bottled water industry has being growing at a CAGR of 15 % for the last 3 years and is currently valued to INR 60 billion. The industry is expected to grow at a CAGR of 22 % in the next 5 years. The bottles used for packaging the water are mostly made up of a plastic known as Polyethelene Terephthalate (PET) which is derived from crude oil. After consuming water, the plastic bottles are discarded. Though, the PET used to manufacture bottles is recyclable, only about 50 % of the discarded plastic water bottles are recycled and the remaining are dumped indiscriminately onto bare lands and water bodies or incinerated. Buried water bottles degrade the land as it takes more than 1000 years for PET to decompose. Incineration of PET also emits harmful gasses and the solid residue contains heavy metals.

India is a mineral rich country. Every year about 0.78 MMT explosive is used to mine the minerals. Air deck blasting, in which an air deck is inserted in between the explosive column, is an accepted technique used all over the world to reduce explosive consumption and to improve blast results. Many devices like plastic spacers, wooden spacers, chemically activated air bags etc are being used to provide air deck. Discarded water bottles were recently tried to provide air deck in blasting in some mines in India. The results were very encouraging. The total explosive cost was reduced by 7-16 % with better fragmentation, less fly rock and reduced ground vibration. The carbon dioxide emission was also reduced by 5-11%. The paper presents case studies of four mines where discarded water bottles were used to provide air decking.

***Keywords*---**Air deck blasting, Carbon dioxide emission, Discarded water bottles, PET.

I. Introduction

RAPID urbanization, increase in tourism, growing population and awareness about drinking water lead to the exponential growth of bottled water industry in India. The bottled water industry has been growing at a CAGR of 15 % for the last 3 years and is currently valued to INR 60 billion. The industry is expected to grow at a CAGR of 22 % in the next 5 years [1].

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Total consumption of PET in bottle segment in India in the year 2012-13 was 0.6 MMT, 21 % of which was consumed by packaged water industry. The consumption is estimated to touch 1.25 MMT by 2016-17 [2].

Sector wise PET consumption in India in 2012-13 and sector wise consumption of bottle grade PET are presented in Fig. 1 and Fig.2 respectively. After consuming the water, the plastic bottles are discarded. The bottles used for packaging the water are mostly made up of a plastic known as Polyethelene Terephthalate (PET) because it does not contaminate the contents and is light weight. Polyethylene Terephthalate is a polymer resin that is part of the polyester family and is derived from crude oil. PET can be easily recycled into many new products. It can be made into peolyster filament yarns for manufacture of shirts, jackets etc, pillow fills, floor carpets, mats, automobile components such as bumpers and door panels etc.

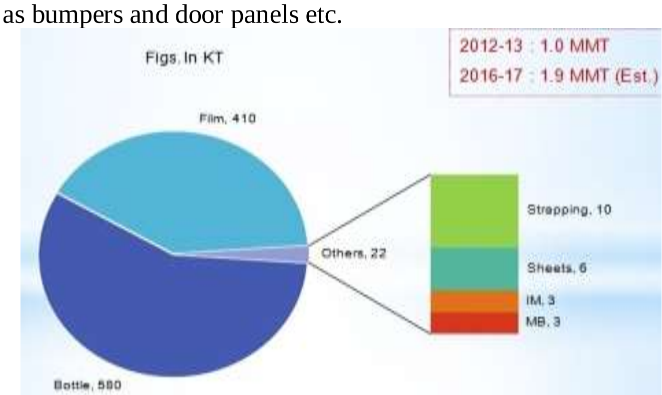

Fig. 1 Sector wise consumption of PET in India in 2012-13 [2]

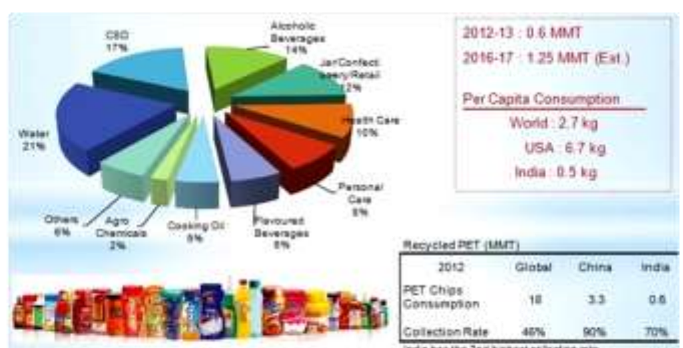

Fig. 2 Sector wise consumption of bottle grade PET in India in 2012-13 [2]

India has the second highest collection rate of PET bottles after China. About 70 % of the PET consumed in bottle segment is recycled (Fig 2). The average recycling rate of bottle grade PET (all segments of bottle) is pretty high in India than the global average of 46 %, but the recycling rate of discarded water bottle is quite low because of poor collection rate. It is estimated that less than 50 % of the plastic water bottles discarded are recycled in India and the remaining is dumped indiscriminately onto bare land and water bodies or is incinerated. PETs don't biodegrade they photo degrade, which means they break down into smaller fragments over time. Those fragments absorb toxins that pollute waterways, contaminate soil, and sicken animals. It takes more than 1000 years for PET to decompose. It is estimated that 10 billion PET bottles consumes about 0.8361 km^2 of landfill space (Fig. 3). Moreover incineration of PET produces toxic by-products such as chlorine gas and ash containing heavy metals.

Fig. 3 Plastic scrap dumped indiscriminately onto bare lands.

India is a mineral rich country. Every year, 0.78 MMT of explosive is used to mine the minerals [3]. ANFO, slurry and emulsion explosives are being used in India in commercial blasting. Among these explosives, bulk emulsion explosive is dominating the market because of their excellent detonation characteristics, good water resistance, swift charging rate and exceptionally good safety characteristics. The only demerit of emulsion explosive is its high density (high RBS). Because of high RBS, when emulsion explosives are used in soft to medium hard and easy to blast rock, more explosive is consumed. Air deck blasting is used around the world in surface blasting to reduce the explosive consumption. In air deck blasting, an air pocket is inserted in between the explosive column. The air deck decreases the explosive column density and distributes the explosive energy uniformly. Thus, air decking reduces the explosive consumption, improves rock fragmentation and controls ground vibration. Many devices like plastic spacers, wooden spacers, chemically activated air bags are being used to provide air deck. Discarded water bottles were recently tried to provide air deck in blasting in some mines. Four case studies of different mines, where discarded water bottles were used to provide air decking, are presented in this paper.

II. Case Studies

Four case studies have been cited in this paper. One of them pertains to a lime stone mine, the other one is about a copper mine and the remaining two case studies have been taken from iron ore mines Discarded water bottles made of only PET were used in all the case studies as these bottles were found suitable to be used to provide air decking in between explosive column. The PET offers a high degree of impact resistance and tensile strength. It also provides a very good chemical resistance and can be used up to maximum temperature of 93º C. The water bottles used in first case study is of 500ml. In the other two case studies, 1 liter plastic bottles are used. In the fourth case study, 1 liter bottles are used as air decking in column charge and few bottles of 2 liter capacity were placed above the explosive column in stemming region to stabilize the stemming. The detailed specifications were shown in Table I.

TABLE I
DETAILS OF THE DISCARDED PLASTIC BOTTLES USED IN DIFFERENT CASE STUDIES.

	Capacity, ml	Length, mm	Max Diameter, mm	Weight with cap, g
Case study 1	500	205	66	17
Case study 2	1000	270	79	26
Case study 3	1000	270	79	26
Case study 4	1000 2000	270 338	79 83	26 38

Each mine conducted a number of trial blast with different number of water bottles inserted in between the explosive column, to optimize the number of water bottles to be placed in the blast hole. The established blast practices with accepted blast results are presented in the case studies. The bottles were dropped into the blast hole during charging of explosive at regular interval so that they will uniformly distributed throughout the explosive column as shown in Fig. 4 and Fig. 5. The case studies are described below.

Fig. 4 Photograph showing placing of water bottles in a blast hole

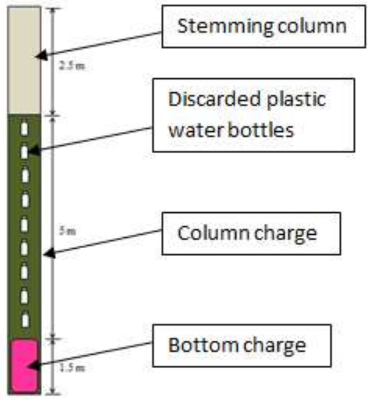

Fig. 5 Cross section of the blast holes showing plastic bottles inserted in between the explosive column.

A. Case Study 1

This case study is of captive lime stone mine of a cement plant. The quarry produces the cement grade limestone which is fed to the plant. The limestone deposits of this mine belong to the sediments of Chhattisgarh basin, which are horizontal, thick bedded and classified as stromatolitic limestone of Raipur group. The overburden consists of hard laterite and clay with an average thickness of 1.5 m. underlying this; the limestone and shale are structurally disturbed by the vertical and horizontal fissures and joints.

The average height of the bench is 9.0 m. The holes diameter is 100 mm. Bulk emulsion explosive (SME) with density of about 1.15 g/cc was used as column charge and cartridge booster about 11.0 kg/hole was used as base charge. About 57.0 kg of explosive was being charged in 9.0 m high benches. The VOD of the explosive was 4100 ±500 m/s. Shock tubes were used for initiation.

A number of trial blasts with different number of discarded water bottles of 500 ml capacity were carried out. It was found that as many as 9 nos of water bottles can be safely used in 9.0 m high medium hard benches without compromising with the blast result and thus 4.95 kg of explosive/hole was saved. When 9 bottles were inserted, the holes were charged with only 52.0 kg of explosive. No notable difference in fragmentation was noticed Fig. 6. However, blast induced ground vibration and fly rock was recorded to be significantly reduced [4].

Fig. 6 Rock fragmentations in lime stone mine when discarded plastic bottles are used

B. Case Study 2

The second case study is of a mechanized iron ore mine. The overburden mainly comprises of cherety and jaspery quartzite at eastern flank and the rest is of laterite and lateritic morum. The thickness of the overburden varies from 2.2 M to 10.5 M. The principal rock in the area is quartzitic sandstone, shale and chery quartzite. The rocks show a general strike NNE-SSW direction with a westerly dip. The iron ore found in the area can be classified as hard ore, lateritic ore, friable flaky and powdery ore and blue dust. In addition to the above, shaly powdery ore of brownish red color is also found in patches.

The mining was done by mechanized open cast method using shovel-dumper combination. The bench height of 9.0 m was maintained. Blast holes having diameter of 150 mm was used for blasting the ore. Bulk emulsion explosive having velocity of detonation 4200 ±500 m/s and density 1.10 g/cc was used to break the ore. 250 g cast booster was used to initiate the explosive in combination with shock tube. Each hole of about 10.0 m depth was being charged with 115-120 kg of explosive.

A number of trial blasts with different number of discarded water bottles of 1 liter capacity were carried out. It was found that as many as 22 nos of water bottles can be safely used in 9.0 m high medium hard benches without compromising with the blast result and thus 20.0 kg of explosive/hole was saved. When 22 bottles were inserted, the holes were charged with only 95.0 kg of explosive. The fragmentation was reported to be improved. Fly rock and ground vibration were also found to be reduced [5].

C. Case Study 3

The third case study is of a fully mechanized iron ore mine worked using shovel-dumper combination. Ore is processed (crushed & screened) to get finished product- lump& fine. The iron ore found in the area can be classified as steel grey hematite, blue grey hematite, laminated ore, lateritic/ limonitic ore, flaky ore/ blue dust, BHQ, shale. The top most parts of the deposit are represented by a number of ridges of enriched ore developed over non-enriched iron formations like shale and banded hematite quartzite.

The average height of the bench was 11.0 m. The holes diameter was 259 mm. Bulk emulsion explosive (SME) with density of about 1.10 g/cc was used as column charge and cast booster as base charge. About 247.0 kg of explosive was being charged in 11.0 m high benches. The VOD of the explosive was about 4200 ±500 m/s. Shock tubes were used for initiation.

A number of trial blasts were conducted using plastic bottles of 1liter capacity. As much as 20 nos plastic bottles were used in 11.0 m high benches. When the water bottles were used in the blast holes, the holes were charged with only 227.0 kg of explosive. Thus, there was a net saving of about 20.0 kg of explosive per hole. The fragmentation was found to be improved. The fly rocks and ground vibration were also reduced.

D. Case Study 4

This case study is of a mechanized copper mine located in central India. The mining of copper ore is being done using shovel dumper combination. Chalcopyrite is the main primary copper ore which is associated with secondary and oxidized minerals. The quartz reef is the main host of sulphide mineralization. Beside the main mineralization in quartz reef considerable amount of sulphide mineralization also occurs in the silicified altered granite rock. The major ore minerals which occur in quartz reef and granitoids are chalcopyrite, pyrite, sphalerite, chalcocite, borite, malachite, azurite, cuprite, native copper.

The mine was developed by forming 12 m high benches. The blast hole diameter being used was 150 mm. High energy site mixed slurry (SMS) was used to break the rock. The rated VoD of the explosive was 3800 ±500 m/s. The density of the explosive in the watery hole was kept up to 1.1 g/cc and for dry hole was lowered up to 0.96 g/cc. In hard rock, sub grade drilling up to one meter was done. The 13 m deep holes were charged with about 170.0 kg of explosive. Because of the nature of the strata, the mine was facing the problem of excessive fly rock. The experiments were carried out with discarded water bottles and it was found that up to 12 nos of bottles of 1 liter capacity can be placed in between the explosive column. Five to six bottles of 2 liter capacity were placed above the explosive column in stemming region to stabilize the stemming. When water bottles were used in the blast hole, the holes were charged with only 150 kg of explosive. Hence about 20 kg/hole of explosive was saved. Initiation was done by using DF cord relay combination and cartridge booster.

The fragmentation was found to be improved. The problem of fly rock and ground vibration was also reported to be reduced significantly.

III. Economics And Environmental Impact

For calculation of financial gain, only the saving in explosive consumption has been considered. The indirect benefits due to improvement in productivity of shovel, dumpers and crusher etc due to improvement in fragmentation have not been taken into consideration. The cost of the explosive is taken as INR 40.00/kg and the cost of discarded water bottle of capacity 2 liters is taken as INR 3.00/bottle, capacity of 1 liter is taken as INR 2.00/bottle and that of capacity 500 milliliter is taken as INR 1.50/bottle. The savings in explosive cost due to use of discarded water bottles of all the four case studies are presented in Table II.

TABLE II
SAVINGS IN EXPLOSIVE COST DUE TO USE OF SCARDED PLASTIC BOTTLES AS AIR DECK

	Case study 1		Case study 2		Case study 3		Case study 4	
	Without bottles	With bottles	Without bottles	With bottles	Without bottles	With bottles	Without bottles	With bottles
Explosive type	SME	SME	SME	SME	SME	SME	SMS	SMS
Explosive quantity/hole, kg	57	52	115	95	247	227	170	150
Explosive cost/hole, INR	2280	2080	4600	3800	9880	9080	6800	6000
No of bottles placed/hole	__	9(.5 L)	__	22(1L)	__	20(1 L)	__	12(1 L) 5 (2 L)
Cost of bottles/hole, INR	__	13.5	__	44	__	40	__	35
Total cost, INR	2280	2093.5	4600	3844	9880	9120	6800	6035
Net saving/hole, INR	186.5		756		760		765	
Saving in %	8.18		16.40		7.6		11.25	
In hole VoD, m/s	4261.8		5400		5943.6		not recorded	
Fragmentation	no noticeable difference		improved		improved		improved	

The estimation of carbon dioxide emission is based on the assumption that about 0.06 kg diesels 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:

$$C_{12}H_{23} + 71\ O_2 \rightarrow 48\ CO_2 + 46\ H_2O \qquad (1)$$

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.

The combustion reaction of PET is:

$$C_{10}H_8\ O_4 + 10\ O_2 \rightarrow 10\ CO_2 + 4\ H_2O \qquad (2)$$

According to the above reaction, combustion of 1kg of PET emits about 2.291 kg of CO_2.

The environmental impact of blasting such as fly rocks and ground vibration were observed to be improved in all the case studies presented in the paper. There was also a significant reduction in carbon dioxide emission. The Table III summarizes some of the important environmental benefits of using discarded plastic bottles in blasting.

IV. Results And Discussion

Use of discarded water bottle in blasting was found to be very effective technique in reducing explosive consumption. It is found that the total explosive cost was reduced by 7-16% when discarded water bottles were used as air deck in between the explosive column. In three case studies cited in this paper, rock fragmentation was also found to be improved. Rock fragmentation plays a very vital role in controlling the cost of down streaming operations like loading, transportation and crushing. Thus, this technique can reduce the cost of mineral production significantly, not only due to saving in the explosive cost but also due to improvement in the productivity of the loaders, dumpers and crusher.

Blasting is considered to be environment damaging activity. The most important environmental impacts of blasting are emission CO_2 and oxides of nitrogen, noise, ground vibration and fly rock. In all the four case studies reported in this paper, a noticeable reduction in CO_2 emission was observed. The CO_2 emission was reduced by 5-11% due to the replacement of explosive by PET bottles. In three of the four case studies presented in this paper, rock fragmentation was also reported to be improved significantly. Rock fragmentation indirectly influences the emission of greenhouse gas. With improvement in rock fragmentation, the fill factor of loading and transportation machine improves and thus the productivity of these machines enhances. With increase in productivity, the fossil fuel consumption reduces; consequently the emission of greenhouse gasses reduces.

Blast induced ground vibration is another important impact of blasting on the environment. It not only causes the structural damage in the close vicinity of blasting site but also lowers the ground water table and influence the flora and fauna of the surrounding area. The blast induced ground vibration mainly depends on the maximum charge/delay. In all the four case studies cited in this paper, significant reduction in the ground vibration is reported. The reduction in the ground vibration occurred because of the reduction in explosive quantity poured in each blast hole.

The fly rock is the most hazardous effect of rock blasting which has the potential to cause death, serious bodily injury to men and damage to property, equipment etc. In three out of the four case studies presented in the paper, fly rock was reported to be reduced. Introduction of discarded water bottles in between the explosive column distribute the explosive energy uniformly and reduces the energy concentration. In case study 4, five bottles of 2 liter capacity were placed above the explosive column in stemming region to stabilize the stemming, the practice was found very effective in controlling the fly rock problem being faced by the mine.

V. Conclusion

Today, the whole world is concerned about greenhouse effect and global warming. The main cause of global warming is the excessive emission of greenhouse gases, mainly CO_2. In India every year about 0.15 MMT of CO_2 is emitted in the atmosphere by detonation of explosive. By using discarded water bottles in blasting, 5-11% CO_2 emission could be reduced. Moreover, the technique was found very effective in reducing explosive consumption and other environmental impacts of blasting like ground vibration and fly rock.

About 50 % of the water bottle ends in landfills and pollute the land. Hence by adopting this technique the precious land can be saved as it takes more than 1000 years for PET to decompose. This method can also improve the socio-economical condition of the poor people residing in the surrounding of the mine. The rag pickers can generate more income by collecting the discarded plastic bottles.

TABLE III
ENVIRONMENTAL IMPACT OF USING DISCARDED PLASTIC BOTTLES AS AIR DECK

	Case study 1		Case study 2		Case study 3		Case study 4	
	Without bottles	With bottles	Without bottles	With bottles	Without bottles	With bottles	Without bottles	With bottles
Explosive type	SME	SME	SME	SME	SME	SME	SMS	SMS
Explosive quantity/hole, kg	57	52	115	95	247	227	170	150
CO_2 produced/ hole by explosive, kg.	10.81	9.86	21.80	18.01	46.83	43.03	32.23	28.44
No of discarded water bottles/hole	__	9(.5L)	__	22(1L)	__	20(1L)	__	12 (1L) 5 (2L)
Mass of PET / bottle, g		17 (.5L)		26(1 L)	__	26 (1L)	__	26 (1L) 38 (2L)
Mass of PET/hole, g.	__	153	__	572	__	520	__	502
CO_2 emission/hole by PET	__	0.35	__	1.31	__	1.19	__	1.15
Total CO_2 emission/hole, kg	10.81	10.21	21.80	19.32	46.83	44.22	32.23	29.59
Net saving in CO_2 emission/hole, kg	0.6		2.48		2.61		2.64	
Saving in CO_2 emission in %	5.56		11.34		5.57		8.19	
Fly rock	no noticeable change		reduced		reduced		significantly reduced	
Ground vibration	reduced		reduced significantly		reduced significantly		reduced significantly	

REFERENCES

[1] http://www.valuenotes.biz/knowledge-center/short- industry-reports/packaged-bottled-water-market-india-2013-18/

[2] Report on Indian Plastic Industry2012-16 (http://www.plastindiafoundation.org/pi/psir.pdf)

[3] Annual Report (2013-2014) of Petroleum and Safety Organization (http://peso.gov.in/PDF/AR2013_14.pdf)

[4] Piyush Sinha et al (2013), "Reduction in Explosive Consumption Through Placement of Low Cost Non Explosive Air Gap" B. Tech. Dissertation, Submitted to National Institute of Technology, Raipur, India.

[5] Raman Sundar D B, Satpathy R R, Satyanaryanan G V, Pradhan G K & Pradhan M (2013), "Explosive Energy Distribution Through Placement of Low Explosive Air Gap –Case Study of an Indian Iron Ore Mine" 7th World Conference on Explosives & Blasting, Moscow, Sep15-17, pp 22-29.

[6] Pradhan G & Pradhan M, (2012), "Explosive Energy Distribution in an Explosive Column Through use of Non-explosive Material-case Studies of Some Indian Mines" 10th International Symp. on Rock Fragmentation by Blasting, FRAGBLAST 10, New Delhi, Nov 24-29 pp 81-89.

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