Blast Impact Prediction Studies at Ghana Manganese Company (GMC) Limited, Nsuta, Ghana*

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Abstract

Ghana Manganese Company (GMC) Limited has its mining operations currently concentrated in the Pit C area, and the company intends to re-develop the northern extension known as Pit C North, close to Tarkwa-Banso community. Mining of the pits involve both free digging and drilling and blasting of the overburden and the fresh competent rocks respectively. To conduct safe blasting operations in the Pit C North, studies were undertaken to assess the environmental impacts of blast associated with ground vibration, air blast and fly rock at 400 m from the pit periphery. It is however envisaged that settlements within 400 m from the pit periphery should be resettled by the Company. Various models were used to predict the blast impact in terms of ground vibration, air blast and fly rock distance. The ground vibration at 400 m from the pit periphery predicted with the USBM model is 0.67 mm/s but predicted with Gustaffson's model is 1.15 mm/s. Both predicted ground vibration values are below the Ghanaian's regulatory threshold of 2 mm/s. Similarly, at 400 m from the pit periphery, the predicted maximum air blast based on current drill and blast design parameters of the Mine is 52.17 dB (L). This predicted air blast value is lower than Ghanaian's regulatory threshold of 117 dB (L). The estimated maximum fly rock throw from Pit C North using the current drill and blast design parameters is 194 m. By adhering to best blasting practices and current drill and blast design parameters for Pit C North, impacts of ground vibration, air blast and fly rock on the neighbouring Tarkwa-Banso community are within the acceptable regulatory requirement for residential areas.

Keywords: Blast impact, Environment, Prediction, Regulatory threshold

1 Introduction

In designing blasts for mining ore deposits it is necessary that due attention is given not only to operational factors but also to important environmental factors. The blast must ensure optimum results for the prevailing conditions, while at the same time ensuring minimal effects on the environment. In cases where blasts must be conducted close to human settlements, impacts of interest would be the effects of fly rock, ground vibration, air blast and noise. Fly rock is usually a potential cause of death, serious injury and property damage, while ground vibration and air blast are potential causes of property damage and human annoyance. Noise is an environmental nuisance. Ghana Manganese Company (GMC) Limited, located at Nsuta in the Tarkwa Nsuaem Municipality (TNM) in the Western Region of Ghana has concession that extends over an area of 175 km^2 with an active mining footprint of about 13.51 km^2. The mine wishes to develop the northern extensions of its Pit C. The nearest settlement to Pit C North is the Tarkwa-Banso community. It is envisaged that settlements within 400 m from the pit periphery should be resettled by the Company.

The Ghanaian Minerals and Mining (Explosives) Regulations, 2012 (L.I. 2177) sub section 176 (1) (a) states that "the minimum safety distance between a blast and a person near the blast site is five hundred meters;" and sub section (2) states that "the minimum safety distance for civil works may with permission of the Chief Inspector be decreased if persons will not be endangered by the decrease". Sub section (199) of this regulation specifies that the blast vibration and air overpressure limits should not exceed 2 mm/s and 117 dB (L) respectively.

This paper is the outcome of a study that seeks to predict the level of blast impacts at 400 m from the periphery of Pit C North, and to establish whether the levels are within safe limits. The major blast impacts identified and considered for this study includes fly rock, ground vibration and air blast, and these have been predicted at the 400 m buffer from the periphery of Pit C North.

1.1 The Study Area

The GMC Mine is located at Nsuta-Wassa, in the TNM of the Western Region of Ghana. The Mine is about 304 km drive from Accra and about 63 km drive from the regional capital, Takoradi. It shares boundary with Tarkwa Banso and Nsuta, both suburbs of Tarkwa. Tarkwa Banso is of much importance in this study due to its close proximity to the operational sites of GMC. The population of Tarkwa Banso is estimated around 706 with majority of its inhabitants being farmers (GMC-EIS, 2012). The location of GMC site is shown in Fig. 1.

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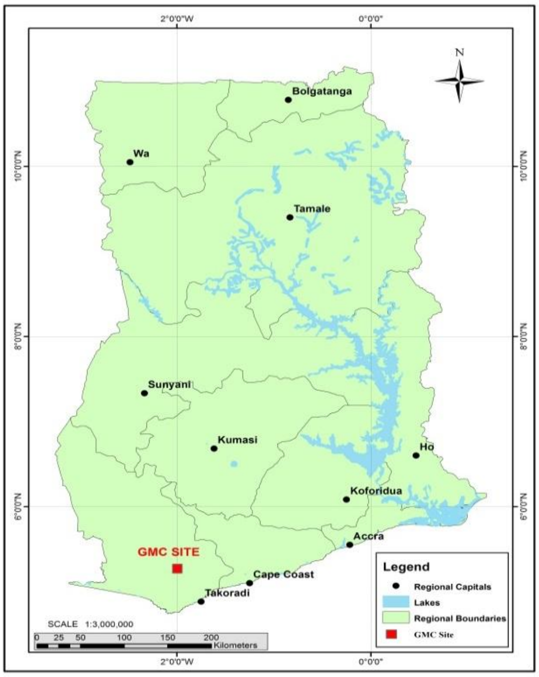

Fig. 1 Map Showing GMC Mine Site

The Mine is situated in the tropical evergreen forest in the Western Region of Ghana. Rainfall is almost throughout the year with the maximum occurring in the month of June. There is no complete dry season since the supposed dry season periods (December to February) have considerably intermittent high rains (Amegbey and Afum, 2014). Temperatures vary between 18 ^{0}C on cold nights to 35 ^{0}C on hot days. Apart from the mining activities, the local people cultivate crops such as cassava, maize, yam, cocoyam, plantain, in mined out areas on small scale (Kesse, 1985).

The GMC ore types are made up mainly of oxides and carbonates with the carbonate underlying the oxides on its concessions. Years of exploitation have however, depleted the oxides, leaving the carbonate. The deposit occurs within the Birimian rocks that form part of the Eburnean province of the Man Shield in the southern segment of the West African Craton and is sandwiched between the Birimian metasedimentary rocks. The host-rocks are the top of the fine grained metasedimentary rocks with isoclinals folds locally showing overthrust faults (Kesse, 1976). The layout of Pit C North in relation to the Tarkwa Banso community is shown in Fig. 2.

1.2 Mining at GMC

The Pit C North will be mined by conventional open pit mining methods utilising drill rigs, excavators, loaders and haul trucks in a fleet. Ore will be hauled using 100 tonne trucks and stockpiled near the carbonate crushing plant for processing. For the drilling operation, surface mounted drill-rigs (Atlas Copco ROC L8 and Atlas Copco CD ROC F9) would be used to make drill holes in the rock mass for the eventual loading with explosives for the fragmentation. The drill and blast parameters employed at Pit C North are given in Table 1.

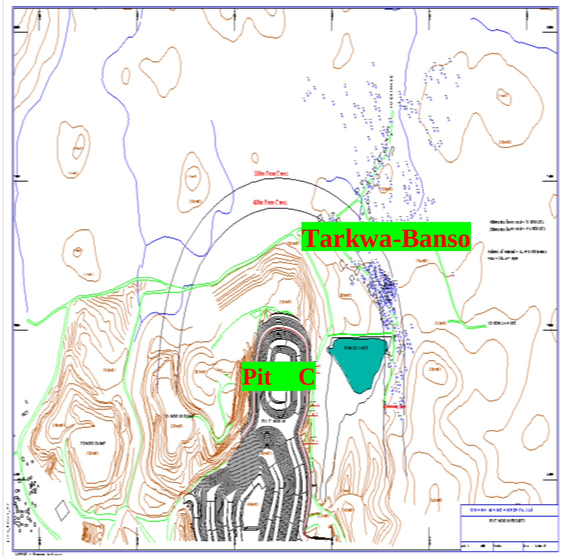

Fig. 2 Pit C North Project Layout

Table 1 Drill and Blast Parameters Used at Pit C North

PARAMETERS	DIMENSIONS
Hole Diameter, mm	115.0
Bench Height, m	10.0
Blast Hole Depth, m	11.0
Subdrill, m	1.0
Burden, m	3.5 (ore), 5.0 (waste)
Spacing, m	4.0 (ore), 5.0 (waste)
Hole Inclination (^{o})	80
Drilling Pattern, m x m	3.5 x 4.0 (ore), 5.0 x 5.0 (waste)
Bottom Charge / Hole, kg (Pentolite)	0.25
Column Charge / Hole, kg (Emulsion)	95 to 100
Total Charge / Hole, kg (Cooperation charge)	95.25 to 100.25
No. holes / blast	80 to 200
Specific Charge, kg/m^3	0.50
Stemming Height, m	3
Stemming Material and Size, mm	Crushed stones – 15 to 20

2 Materials and Methods Used

2.1 Historic Blast Performance

Historic blast vibration and air blast data obtained for a period of 35 months (211 blasts), from February 2010 to December 2012 for blasting operations at Pit C of GMC were assessed. The historic blast performance for all the monitored ground vibration results were lower than the Ghanaian Minerals and Mining (Explosive) Regulations, L.I. 2177, allowable PPV limit of 2 mm/s, while 12.5 % of air blast results monitored had values greater than the guideline level of 117 dB (L). Using data obtained from blasts monitoring at Pit C, Amegbey (2010) determined the Rock Transmission Factor (RTF) for the pit. The RTF results obtained with the Gustaffson and United States Bureau of Mines (USBM) models are presented in Table 2.

Table 2 RTF for GMC

Parameter	Mean Value	Model Used
K	10.30	Gustaffson
k	17.82	USBM
b	-0.888	

Source: Amegbey (2010)

2.2 Blast Impacts Prediction

The main undesirable impacts from open pit blasting are fly rock, ground vibration and air blast or air overpressure. The levels of these impacts can be estimated and compared with prevailing standards to determine the environmental suitability of the current drill and blast design parameters using appropriate models and field experience. For this study, the blast impacts predictions at 400 m from the periphery of Pit C North were considered.

2.2.1 Fly Rock Prediction

When fragmented rock resulting from the detonation of explosive charges is transported over a greater distance than anticipated the throw is called fly rock. The maximum fly rock distance, for a specific charge > 0.2 kg/m^3, may be estimated from the Equation 1 (Lundborg, 1981):

$$L_{max} = 143 \text{ x } d \text{ x } (q - 0.2), \text{ m} \quad (1)$$

where L_{max} = Maximum Throw (m); d = Hole Diameter (ins); and q = Specific Charge (kg/m^3).

The boulder size, Ø is also estimated by

$$Ø = 0.1 \text{ x } d^{2/3} \quad (2)$$

where Ø = Boulder Diameter (cm); and d = Hole Diameter (ins).

2.2.2 Ground Vibration Prediction

Ground vibrations are generated when some of the explosion energy released into the ground generates vibration waves within the rock. Several formulae are available in literature for determining the vibration level (PPV) for a given site condition. For the GMC site conditions, Amegbey (2009) proposed the use of Equations 3 and 4 after Gustaffson and the USBM respectively. With the RTF values for Pit C North determined from earlier studies (Table 2), PPV levels at various distances from the blast and for various cooperating charges have beendetermined according to Gustaffson and USBM models respectively given as:

$$PPV = K\sqrt{\frac{W}{D^{1.5}}} \quad (3)$$

$$PPV = k\left(\frac{D}{\sqrt{W}}\right)^{b} \quad (4)$$

where PPV = Peak Particle Velocity, mm/s; W = Cooperating Charge, kg; D = Distance, m; and K, k, b = Rock Transmission Factors (RTF).

2.2.3 Air Blast Prediction

In conducting blasting operations, one negative by-product is the generation of air blast or air overpressure. Unlike ground vibration, air blast seldom causes damage to structures; however, the resulting noise usually causes a lot of discomfort and annoyance to neighbours giving rise to complaints. Generally, properly designed and executed blasts should have minimal air blast, and this helps to improve the overall efficiency of blasts. The air blasts or air overpressures at the blast sites may be predicted using either Equation 5 (Ollofson, 1990; and Persson *et al.*, 1994) or Equation 6 (Holmberg and Persson, 1978). However, to convert the Air Blast or Air Overpressure from mbar to dB (L) units, the relationship in Equation 7 was used.

$$P = 0.7 \times \frac{W^{1/3}}{D} \quad (5)$$

$$P = k \times 0.7 \times \frac{W^{1/3}}{D} \quad (6)$$

$$dB\ (L) = 20 \log \frac{P}{Po} \quad (7)$$

where P = Air Overpressure or Air Blast, mbar; Po = Reference pressure of 0.00002 unitless; W = Cooperating Charge, kg; D = Distance, m; and k = 0.75 for Emulsion Explosives.

3 Results and Discussion

3.1 Fly rock

Using Equation 1, the maximum fly rock distance was determined for varying blast hole diameters and specific charges. The results are presented in Fig. 3. Substituting appropriate values from Tables 1 and 2 into Equation 1, the maximum fly rock distance for blasting in Pit C North is estimated as

194 m. This distance is less than the 400 m buffer, an indication that, adoption and a careful execution of the current blast design parameters for blasting at Pit C North would not pose fly rock problems in the Tarkwa-Banso community.

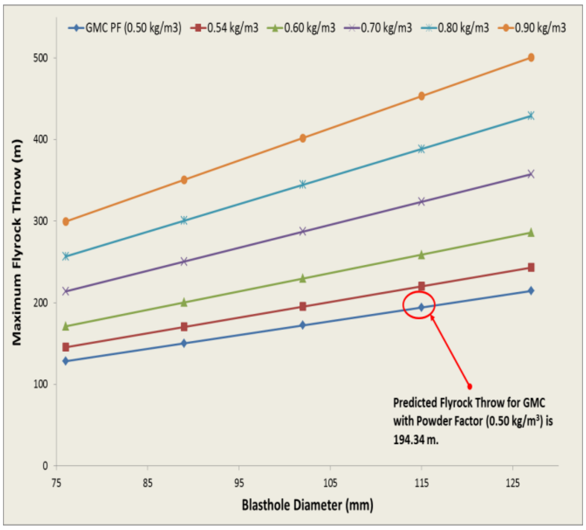

Fig. 3 Fly Rock Distances for varying Blasthole Diameters and Specific Charges

3.2 Ground Vibration

The two models (Equations 3 and 4) for PPV prediction are shown in Figs. 4 and 5. The predicted PPV values at 400 m from the pit periphery and for a cooperating charge of 100 kg are 1.15 m/s and 0.67 m/s for Gustaffson and USBM models respectively. Both values are below the regulatory threshold of 2 mm/s.

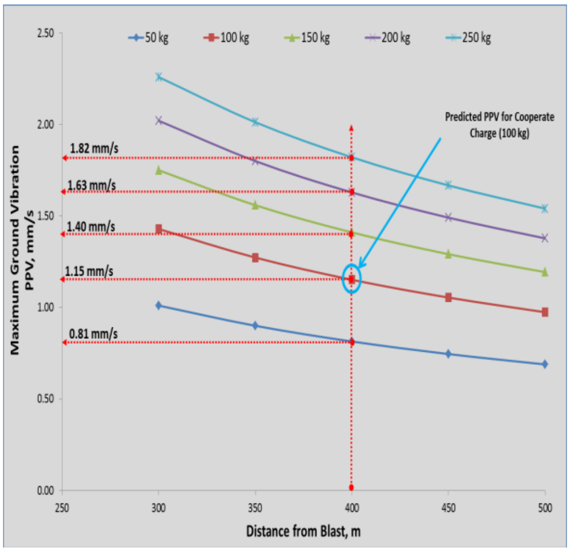

Fig. 4 Gustaffson's Model for PPV Prediction at Pit C North

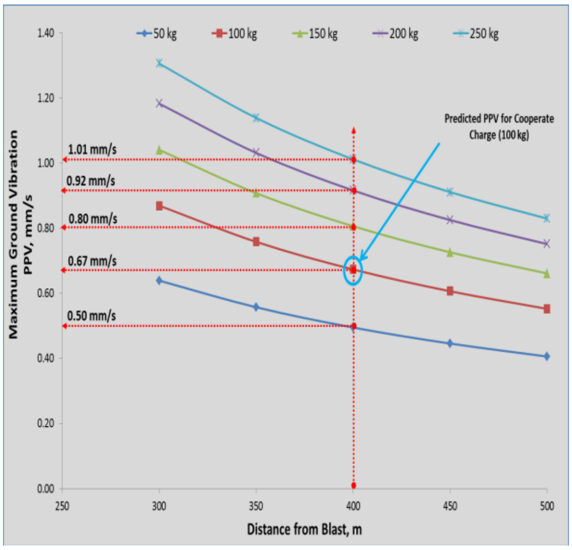

Fig. 5 USBM's Model for PPV Predictions at Pit C North

3.3 Air Blast

Using the relationships in Equations 5 to 7, for emulsion explosive with k = 0.75, the air blast levels at varying distances from a blast with cooperate charge of 100 kg as used in Pit C North of GMC was determined and shown in Fig. 6. The maximum predicted air blast at 400 m from blasting in Pit C North based on the proposed drill and blast design parameters is 52.17 dB (L) for the model according to Ollofson (1990) and Persson *et al.* (1994). The model according to Holmberg and Persson, (1978) yielded a smaller value of 49.7 dB (L). The maximum predicted value is lower than the allowable regulatory limit of 117 dB (L).

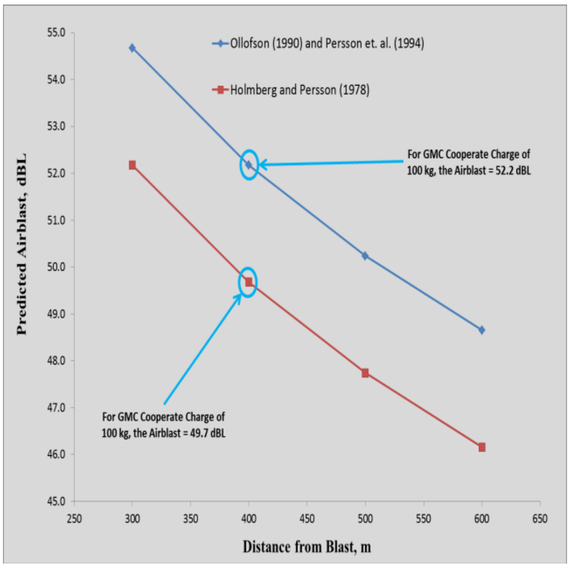

Fig. 6 Air blast Prediction Models at Pit C North

4 Conclusions and Recommendations

GMC is committed to adopting blasting practices that take into account measures to minimise impacts and protect the neighbouring communities beyond the pit periphery.

The predictive assessments were based on the blasting practices proposed by GMC, and the various models for blast impacts in terms of fly rocks, ground vibrations and air blasts. Results obtained demonstrated compliance with regulatory requirements as follows:

(i) When blasthole diameters of 115 mm are used and specific charge is maintained at 0.50 kg/m^3 the maximum fly rock distance predicted is 194 m. This distance is less than the 400 m buffer considered per the study.

(ii) At 400 m from the periphery of Pit C North and a maximum cooperating charge of 100 kg, the predicted PPV is 0.67 mm/s using the USBM model and 1.15 mm/s using the Gustaffson's model. Both values are below the allowable regulatory threshold of 2 mm/s.

(iii) Based on the current drill and blast design parameters, the maximum predicted air blast values at 400 m from the Pit C North periphery is 52.17 dB(L), and this is lower than the regulatory threshold value of 117 dB(L).

To be able to achieve the predicted results, it is highly recommended that best blasting practices including cleaning of boulders from bench floors, ensuring toe free benches and meticulously adhering to appropriate drill and blast geometric parameters should be adopted during all blasting operations at Pit C North.

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