

Research Article

Predicting the Impact of Rock Blasting on Building Structures at Awunakrom in the Ahanta West District of Ghana

¹K.J. Bansah, ²E. Assan and ¹G. Galecki

¹Mining and Nuclear Engineering Department, Missouri University Science and Technology, Rolla-Missouri, USA

²Safety and Environmental Research Consultancy Limited, Tarkwa, Ghana

Abstract: Blasting is an important process after drilling is completed in hard rock mining. It involves placing explosives in drill holes and detonating them to cause explosion. The energy released during this process fragments the rocks into sizes for desired end use. The detonation of these explosives may produce undesirable effects such as ground vibration which is capable of causing damage to building structures. It is therefore, necessary to conduct blast impact studies to determine potential impact of blast induced ground vibration prior to mining and establish remediation techniques. Blast impact study was conducted at Awunakrom in the Ahanta West District of Ghana. Building structures within the study area were mapped and characterized. A blast impact prediction model was also generated. Blast induced vibrations that may propagate from the Father Brown pit of Golden Star Wassa Limited using various instantaneous charges were determined. It was found that bench blasting at the Father Brown pit has a potential of causing damage to building structures within the Awunakrom community if the maximum instantaneous charge adopted at the southernmost periphery of the pit exceeds 30 kg. It was therefore, recommended that all bench blast conducted at the southern periphery of the Father Brown pit should adopt a maximum instantaneous charge of 30 kg to avert any potential blast damage. However, variable instantaneous charges of more than 30 kg can be adopted as the blast location moves towards the northern periphery.

Keywords: Blasting, blast impact, ground vibration, mining, maximum instantaneous charge

INTRODUCTION

Mining activities invariably impact on the surrounding communities. Among these impacts is structural damage as a result of blast induced vibrations from rock fragmentation practices. In order to mitigate the impact of blasting on building structures within communities adjacent to mining operations, blast impact studies that assess the quality of the structures and predict potential ground vibration impacts become imperative. These studies are done to determine compliance with environmental quality standards and also, provide data for planning. This therefore, would encourage cooperation between the mine and its surrounding communities. Moreover, breach of environmental regulations which could hinder the smooth operations of the mine would be avoided.

Golden Star Wassa Limited (GSWL) is a surface mining company operating several pits including the Father Brown pit in the Western Region of Ghana. The Father Brown pit located at Awunakrom in the Ahanta West District (Fig. 1) of Ghana has been mined to its limit. However, exploration has indicated the presence of mineralized zone at the southern portion of the pit

closest to the Awunakrom community. The newly identified ore will be exploited by expanding the existing pit limits. The pit expansion project will move the pit limit further south towards the Awunakrom community, a condition that is likely to increase the potential of blast impact on building structures within the community. There is therefore, the need to conduct blast impact prediction studies to ascertain the level or degree of impact and establish remediation techniques prior to mining.

BRIEF INTRODUCTION TO BLASTING

Blasting involves the placement of explosives into drill holes and detonating them to cause an explosion thereby breaking the rock into fragments for the desired end use (Agbeno, 2011). Blasting could be categorized as either primary or secondary. Primary blasting is used to break in-situ rock into desired fragment sizes. In the event of boulders occurrence from primary blasting operations, secondary blasting is used to reduce their sizes. Also, controlled blasting is used to reduce over break and minimise fracturing of rocks at the boundary of an excavation (Richard, 1973).

Corresponding Author: K.J. Bansah, Mining and Nuclear Engineering Department, Missouri University Science and Technology, Rolla-Missouri, USA

This work is licensed under a Creative Commons Attribution 4.0 International License (URL: <http://creativecommons.org/licenses/by/4.0/>).

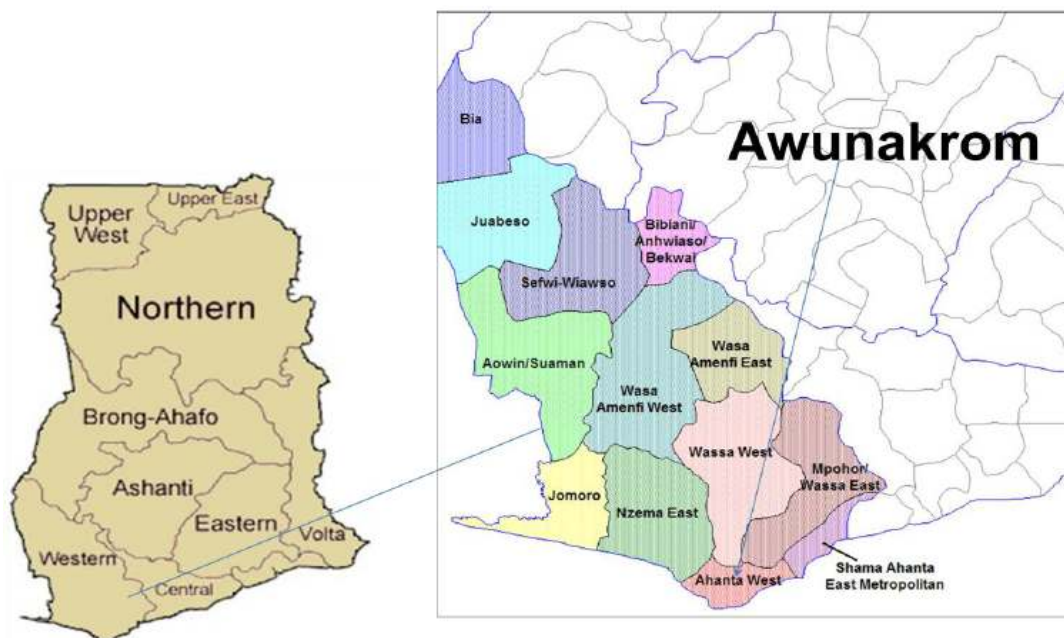


Fig. 1: Map of Ghana showing the Ahanta west district

According to Anon (2013a), two forms of energy are released when explosives react: shock energy and gas energy. The energy released have four major results (Anon, 2013b): rock fragmentation, rock displacement, ground vibration and Air blast. Rock fragmentation and displacement are usually desirable while ground vibration and air blast are undesirable and may impact on structures in the vicinity of the blast. In order to achieve optimum blast results, the blast should be designed to enhance efficient utilisation of blasting energy in the rock breaking process. This involves reducing cost through less explosive consumption, less wastage of explosive energy, less throw of blasted materials and a reduction of blast vibration to achieve greater safety and stability of structures around the blast area (Manmit and Chinmay, 2007).

The following summarizes some reasons for conducting blasting:

- Produce boulders for sea defence purposes
- Produce chippings for civil works
- Remove rocks which act as obstacles during road and other construction works
- Access underground (e.g., shaft sinking, tunnelling, raise boring and ramp construction)
- Loosen rock for excavation for further processing to obtain valuable minerals
- Overburden removal to access an ore body
- Developing surface and underground mines

METHODS

Given the sensitive nature of the studies, series of community consultative meetings were conducted. These meetings explained to chiefs, elders and

community members the purpose and need for such studies. Building structures within the community were mapped and characterised based on structural integrity. Crack width measurements of buildings with cracks were done to obtain baseline data. Existing blast monitoring data were also obtained from the mine for blast impact prediction modelling.

DATA COLLECTION AND RESULTS

Structural assessment: The Awunakrom community was zoned into Zone A, B and C (Fig. 2). Structures within these zones were coded and enumerated. The location, size, structural type, crack detection and measurements, photographs and other important characteristics of all building structures within Awunakrom were also collected. In all, 428 structures (Zone A = 241, Zone B = 131 and C = 56) including living rooms, kitchens, baths, toilet facilities, church buildings etc. were counted. A database which contains the characteristics of the building structures within the community was created (Fig. 3 for database interface). A video of all the structures within Awunakrom was also made.

The building structures were mainly wattle and daub with a few sun-dried brick and sandcrete structures. They are mostly roofed with corrugated roofing sheets with a few pre-fabricated and bamboo roofing. Most of these structures have developed various vertical or near vertical and horizontal cracks.

The basic building material in Ghanaian mining areas is earth or soil. The earth may either be used in raw form without treatment or be compressed to increase density and strength. Wattle and daub and Atakpame are examples of structures constructed with

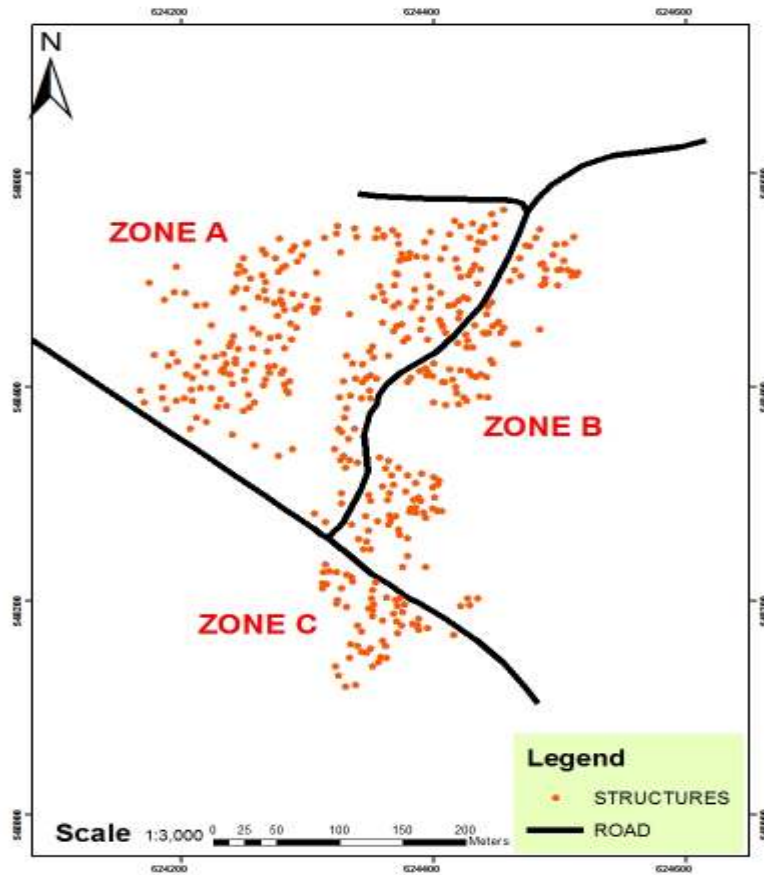


Fig. 2: Map of Awunakrom showing the zones

The figure shows a screenshot of a web-based database interface titled "STRUCTURAL ASSESSMENT AT AWUNAKROM". The interface is organized into several sections:

- Owner/Caretaker Personal Information:** Includes fields for Name Title (Mr), Surname (Akese), First name (Nana), and Other names (Kordjie). A timestamp "29/09/2012 13:01:28" is displayed. There is a "Picture:" label and a photo of a building.
- Structure Information:** Contains dropdown menus for Structure Use (Bedroom), Roof Type, and Structure Type (Building blocks). It also has input fields for Number of Rooms (2), Structure Age (4 years), Structure Size (12.63 m x 5.8 m), and GPS Coordinate (N: 548552, E: 624448).
- Crack Assessment Information:** Features a "Presence of Crack:" dropdown (No) and input fields for Vertical, Near Vertical, Horizontal, and Near Horizontal crack counts. There are also fields for Cracks (Total), Crack Dimensions, and For Multiple Cracks.
- Comments:** A text area containing the text "not occupied, under construction".

At the bottom of the interface, there is a "Crack Description:" text area and a set of navigation icons.

Fig. 3: Database interface

raw earth while compressed block, landcrete block and sandcrete block buildings are made from compacted earth material. These structures according to Amegbey *et al.* (2009) are affected by blasting in different ways depending on their strength which is a function of their construction methods, environmental factors, material quality and age of building and location of structure from the blast point. Figure 4 and 5 are photos of wattle and daub and compressed block structures.

Blast impact assessment and prediction: Blast impact study was conducted on building structures beyond a 318 m contour from the periphery of the Father Brown Pit. The total number of structures considered was 243. Structures (185 in number) within the 318 m limit were not considered as part of the studies since GSWL agreed with the occupiers on a relocation package due to the closeness of the structures to the pit. Figure 6 shows the 318 m contour.

Generally, it is accepted that the Peak Particle Velocity (PPV) assesses best the damage potential of vibration waves. According to the US Bureau of Mines, peak particle velocity could be predicted using the following scaled distance model (Dowding, 1996):

$$v = k \left[\frac{D}{Q^{1/2}} \right]^a \quad (1)$$

where,

v = Peak particle velocity (mm/s)

D = Monitoring distance (m)

Q = Maximum instantaneous explosive charge (kg)

“ k ” and “ a ” are called site specific parameters

Historical blast data from the Father Brown pit of GSWL was obtained. The scaled distance $D/Q^{1/2}$ was plotted against the peak particle velocity (ppv) as shown in Fig. 7. Comparing the equation of the line shown in Fig. 7 with equation (1), $k = 7652.06$ and $a = -2.043$. Accordingly, a model for predicting ppv's at Awunakrom established as in Eq. (2):

$$v = 7652 \left[\frac{D}{\sqrt{Q}} \right]^{-2.04} \pm 6\% \quad (2)$$

Vibration waves reaching structures beyond 318 m limit were predicted using the Father Brown pit as a source of propagation. From the historical blast data, the following instantaneous charges are possible: 41, 30, 25, 20, 15 and 12 kg, respectively. Using these instantaneous charges, ppv's at various distances were predicted and shown in Fig. 8.



Fig. 4: 12-year old wattle and daub partly rendered with cement mortar (In the construction of wattle and daub, the earth is used in raw form without treatment or additives for the walling: Arrowed yellow is the raw earth material and red arrow shows the cement mortar rendering)



Fig. 5: 5-year old compressed block building at Awunakrom (In this type of structure the earth material is stabilised by compaction to increase density and strength)

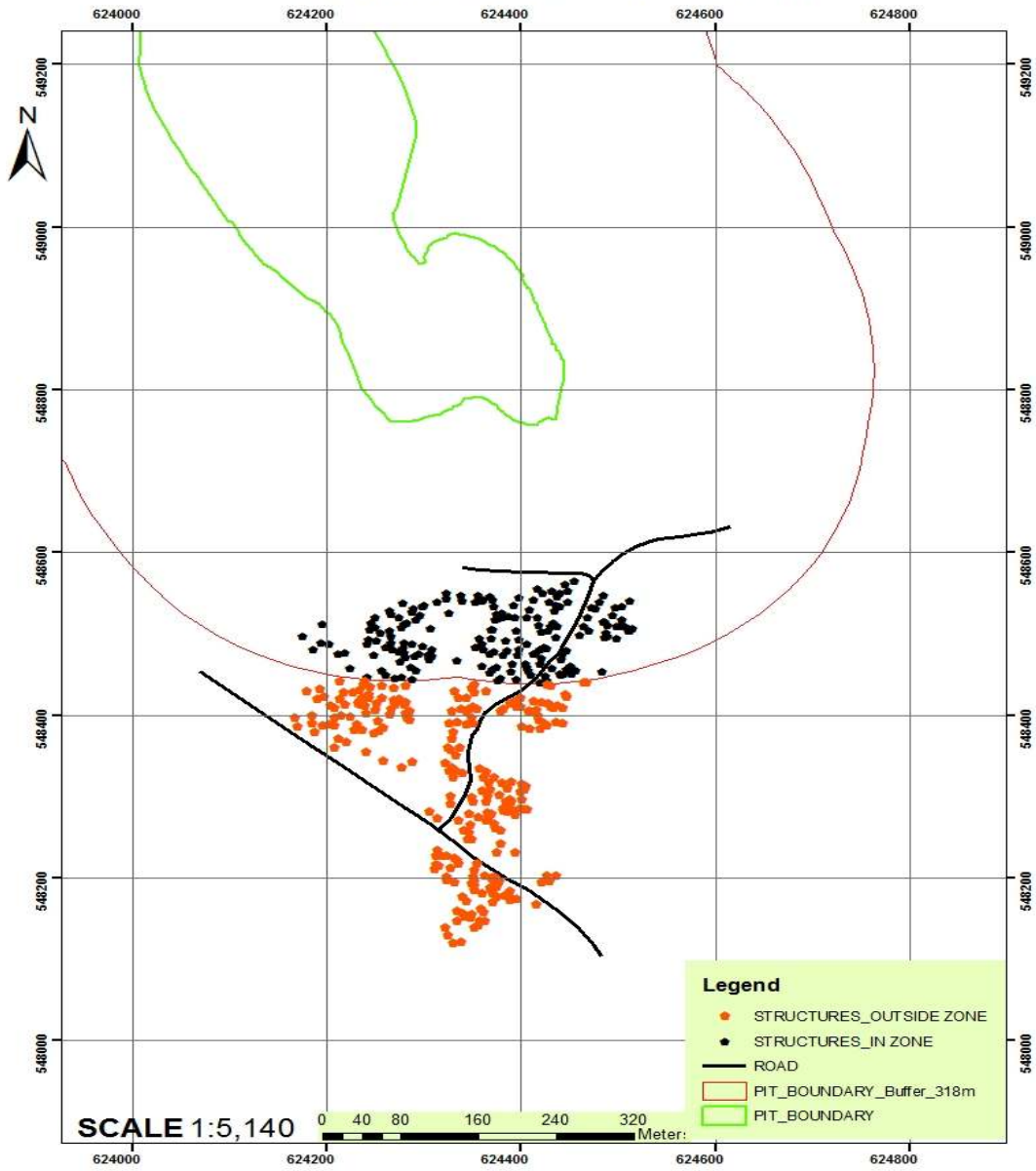


Fig. 6: Awunakrom 318 m buffer

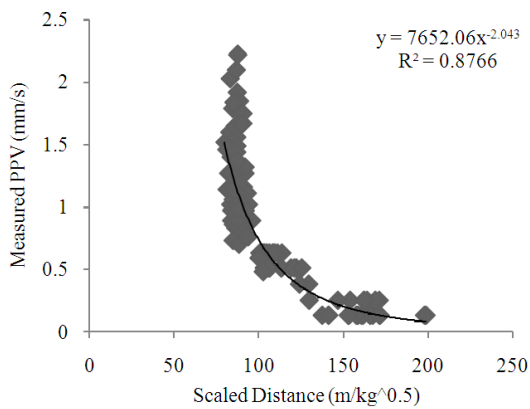


Fig. 7: Scaled distance vs PPV

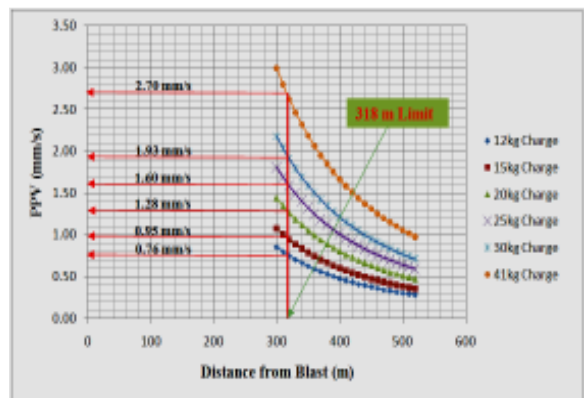


Fig. 8: Predicted PPV vs distance from Blast zone

Table 1: Predicted PPV at various instantaneous charges

Instantaneous Charge (kg)	PPV (mm/s) @ 318 m
41	2.70
30	1.93
25	1.60
20	1.28
15	0.95
12	0.76

The ppv arising out of a blast with the various instantaneous charges is summarised in Table 1.

DISCUSSION OF RESULTS

Amegbey *et al.* (2012) indicated that a ppv greater than 2 mm/s will initiate cracks in the weakest structures (wattle and daub). It then recommended a ppv threshold limit value of 2 mm/s for Ghanaian mining industry. This ppv of 2 mm/s has been adopted as a standard by the Ghanaian Government for use by all mining companies in Ghana. With instantaneous charge of 41 kg, the predicted ppv at 318 m is 2.7 mm/s. This ppv is higher compared to the recommended value of 2 mm/s. This suggests that buildings within the Awunakrom community will develop cracks if an instantaneous charge of 41 kg is adopted for blasting at the southern most periphery of the Father Brown Pit. However, this ppv reduces with distance and therefore farther structures will receive less than the permissible levels of vibration. It can also be deduced that, a maximum explosive charge of 30 kg should be adopted for all blast rounds at the southernmost periphery of the pit to avert any potential blast damage on structures, since it will produce a ppv lower than the permissible limit. It is also worthy to note that, as one moves further the northern extent of the pit higher than 41 kg of instantaneous charge can be adopted, but the limit such as not to impact on structures should be determined by Eq. (2) and the corresponding correction factor.

CONCLUSION

The primary objective of this study was to predict the impact of surface blasting on building structures beyond 318 m from the periphery of the Father Brown Pit of Golden Star Wassa Limited at Awunakrom in the Ahanta West District of the Western Region of Ghana.

All building structures within the Awunakrom settlement were mapped and characterised. It was found that most of the building structures were wattle and daub, described as the weakest structure in Ghana. Blast impact prediction indicates that blasting at the Father Brown pit has a potential of causing damage to building structures at Awunakrom if the instantaneous charge exceeds 30 kg at the southernmost pit periphery. It is therefore, recommended that a 30 kg maximum instantaneous charge be adopted for all blast rounds at the southernmost periphery of the Father Brown pit to avert any potential structural damage, though instantaneous charge of higher than 41 kg can be adopted at the northern extent of the pit.

REFERENCES

- Agbeno, S.K., 2011. Ground fragmentation. Unpublished B.Sc. Lecture Notes, University of Mines and Technology, Tarkwa, pp: 111.
- Amegbey, N., Dzibodzi-Adjimah, S.K. Agbeno and C. Akayuli, 2009. Blasting standards for Ghana. Proceedings of the Mining and Innovation Conference. University of Mines and Technology, Tarkwa, Ghana.
- Amegbey, N., S. Yormekpe-Agbeno and C.K. Akayuli, 2012. Blasting standards for the Ghanaian mining industry. Ghana Mining J., 13: 46-50.
- Anon, 2013a. Rock Blasting and the Community. Retrieved from: [www.rockblasting and the community](http://www.rockblastingandthecommunity.com). (Accessed on: March 14, 2013)
- Anon, 2013b. Explosives. Retrieved from: www.nps.gov. (Accessed on: March 14, 2013)
- Dowding, C.H., 1996. Construction Vibrations. Prentice Hall Inc., Englewood Cliffs, NJ, USA, pp: 604.
- Manmit, R. and K.P. Chinmay, 2007. Optimisation of blasting parameters in opencast mines. B. Tech. Thesis Report, National Institute of Technology, Rourkela, pp: 71.
- Richard, A.D., 1973. Explosives and Borehole Loading. In Jack, M.E. (Ed.), Chapter 11.7 of SME Mining Engineering Handbook. 1st Edn., Vol. 1, SME, Port City Press Inc.