Baseline Structural Assessment: Mechanism for Mitigating Potential Conflicts Due to Blast Vibration

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Abstract

Explosive energy is adopted in hard rock mining to disintegrate rocks and consolidated formations to desirable sizes for appropriate end use. The fragmentation process may result in undesirable vibrations that can impact on structures within the vicinity of the blast. Ground vibrations and airblast resulting from blasting have been found to induce or expand existing cracks and alter the integrity of building and engineering structures. Inadequate study of pre-mining conditions of structures within surrounding environments of mining activities that utilize blasting for fragmenting rocks have led to a series of conflicts between nearby affected communities and mine operators; consequently, affecting production, corporate image and worker morale. To mitigate potential conflicts due to blast vibrations, it is necessary to conduct baseline structural assessment to ascertain the integrity of building structures within the vicinity of mining operations. This paper demonstrates the significance of baseline structural assessment around proposed mining sites. A significant number (> 50%) of existing building structures within the study area were observed to have developed multiple cracks.

Keywords: Structural assessment, blasting, vibration, fragmentation, structural integrity

1 Introduction

Blasting involves the use of explosive energy to fragment in situ rock in mining operations. When an explosive detonates, 20-30% of energy released breaks and displaces the rock, while a greater percentage produces undesirable outcomes such as ground vibrations, airblast/air overpressure, flyrock and noise (Ebrahim *et al.*, 2012; Hajihassani *et al.*, 2014; Monjezi *et al.*, 2012; Onder *et al.*, 2007, Elevli and Arpaz, 2010). Ground vibration and airblast impact on nearby human settlements. High blast-induced vibrations can pose undesirable effects on structural integrity, and can also cause annoyance (Singh and Singh, 2005; Ozer *et al.*, 2008; Khandelwal and Singh, 2007; Hajihassani *et al.*, 2014).

Damage to structures within the vicinity of mining operations is often attributed to blasting activities, leading to protests and conflicts between receptor communities and mine operators. In Sri Lanka, for example, many complaints were raised on rock blasting activities during the Hambantota harbour project (Gad *et al.*, 2005). Mining companies operating in Ghana have also witnessed dissatisfactions, complaints and protests against their activities by several communities. Some of these protests that have occurred involved: Adamus Resources Nzema Mine and Anwia/Teleku-Bokazo communities; Ghana Manganese Company Limited and Tarkwa Banso community; Golden Star Resources Bogoso/Prestea Limited and Odumasi/Bogoso communities, and Anglogold Ashanti Iduapriem Limited and Teberebie community. Structural deformation or damage may be natural as a result of ageing, or due to other causes (such as building practices and lack of maintenance), that are unrelated to mining. Thus, pre-mining assessment of structural integrity of buildings in close proximity to mining operations becomes inevitable. This would help mitigate conflicts that may be attributed to blasting activities.

In mining communities in Ghana, the most common sign that informs owners/occupants of buildings about a change in structural integrity is the existence of visible cracks. Baseline structural assessments therefore must involve monitoring of structures to observe presence of crack development. In such studies, structures can be mapped and characterized using their location, size, age, structure type, building material type, roofing type, crack detection and measurements, and photographic and video records (Bansah *et al.*, 2014).

Thus, this study reports pre-mining conditions of structures within proposed mining sites in the Western Region of Ghana. It also highlights the significance of conducting baseline assessments of building structures located in close proximity to mining operations.

1.1 Community Perception of BlastInduced Vibrations

Mining communities are sometimes skeptical in welcoming mining projects despite economic and social benefits that may arise, because local population perceive such projects to generate undesirable effects. Such perceptions consequently affect relationship between mine operator and host community (Bagson, 2012; Akabzaa & Darimani, 2001). Even though blast-induced vibrations are inevitable in mining operations, community response to these vibrations is often subjective/psychological since two individuals may react differently to the same vibration event based on where they find themselves (in a structure), their state of mind and personality (Kuzu and Gulcu, 2009; Lubej *et al.*, 2000).

According to Grothe & Reinders (2007), blastinduced vibration often felt by residents around mining areas is perceived to be the most dangerous aspect of mining operations. As a result, people residing in close proximity to blasting operations may become infuriated and adopt radical means to halt mining operations, especially when blast nuisance persists for a longer time.

1.2 Mitigating Blast-Induced Vibrations

Blast-induced vibrations can cause damage to structures (Bansah *et al.*, 2014; Stojadinovic *et al.*, 2011; Dindarloo, 2005). Hence, it is imperative for mining companies to take appropriate steps to mitigate such vibration effects, and minimize local community fears. These control measures should not only aim at keeping levels of blast-induced vibrations within allowable regulatory limits. The measures should also ensure protection of local community against blast damage or nuisance and mitigate community complaints and protests.

Methods of controlling blast vibrations have been discussed by several researchers (Hoshino *et al.*, 2000; Siskind, 2000; Chen and Huang, 2001; Tripathy and Gupta, 2002; Adhikari *et al.*, 2004). The methods include bottom initiation, decrease in number of blast holes per delay, use of delay between blast holes and deck loading. Generally, many parameters, controllable such as distance from blast source, explosive quantity and properties, geometrical blast parameters, operational factors, initiation point and sequence, delays used, firing method and uncontrollable such as rock properties, local geology, surface topography influence blast-induced vibrations (Mohamed, 2010; Xia *et al.*, 2005; Kuzu, 2008; Hudaverdi, 2012; Dhekne, 2015). Thus, altering controllable parameters can consequently lessen blast vibrations, while uncontrollable parameters can be managed by adopting appropriate blast designs. Aldas and Ecevitoglu (2008) employed suitable time-delays among blast-hole groupings leading to a 12.5% reduction in blast- induced vibrations.

Nicholson (2005) also suggested that in order to mitigate blast-induced vibrations, blast engineers should be cognisant of the following:

- Good control of drilling to minimize deviations;
- Ensuring maximum relief to commensurate with other factors so that there will be free movement of rocks with normal powder factor; and
- Documenting conditions of the formation, *i.e.* ground water, fractured zones and open seams.

Notwithstanding these mitigation measures, most countries have formulated regulations and guidelines that are used to ensure that all vibration levels are kept within a specific limit. The United States Bureau of Mines (USBM) has documented aspects of vibration generation, propagation and impacts on structures. Many standard criteria for blast-induced vibration have been derived from the USBM. Ground vibration limits are typically linked to peak particle velocity (PPV) and “authorities accepted 50 mm/s as safe limit for mining and construction blasting” (Nicholson, 2005).

Crawford and Ward (1965) have indicated that these levels were very conservative and that most houses were able to withstand ground vibrations of approximately 137 mm/s (5.4 in/s) to 508 mm/s (20 in/s) before experiencing minor damage. In Ghana, however, the Minerals and Mining (Explosives) Regulations (LI 2177) requires maximum PPV and airblast levels in residential areas at 2 mm/s and 117 dBL respectively due to the generally weak nature of buildings within communities where mining occurs.

Community sensitisation and awareness on blasting operations and effects can also be adopted by mine operators to erase perceptions and ease fears to foster serene and friendly operating environment.

2 Resources and Methods Used

To demonstrate the significance of baseline structural assessments in mining projects, a case study of communities within proposed mining locations in the Bogoso/Prestea/Huni-Valley District of Western Region of Ghana is reported. The project is located 4 km south of Prestea township and on Latitude 5°24'N and Longitude 2°09'W.

Communities studied included Bondaye and Prestea Nankaba with other satellite settlements (Fig. 1). The topography of the area is dominated by a range of low rolling hills rising about 30 -100 m above surrounding lowlands and valleys. The area is greatly disturbed by illegal small scale mining operations. Proposed cluster of pits to be mined by Golden Star Resources include Beta South, Bondaye and Tuapim pits. The deposit is expected to be mined using open pit mining method with about 60% of material being free digging. The deeper competent zones are however proposed to be exploited by drilling and blasting.

Community consultative meetings were held with chiefs, elders and residents to explain the purpose and need for the study. The meetings were also conducted to solicit support and cooperation of local population in the data collection process. Structural assessment was conducted by taking coordinates of structures, determining structural material, documenting structure type, measuring structure size, detecting cracks, taking photographs and characterising other structural attributes of building structures.

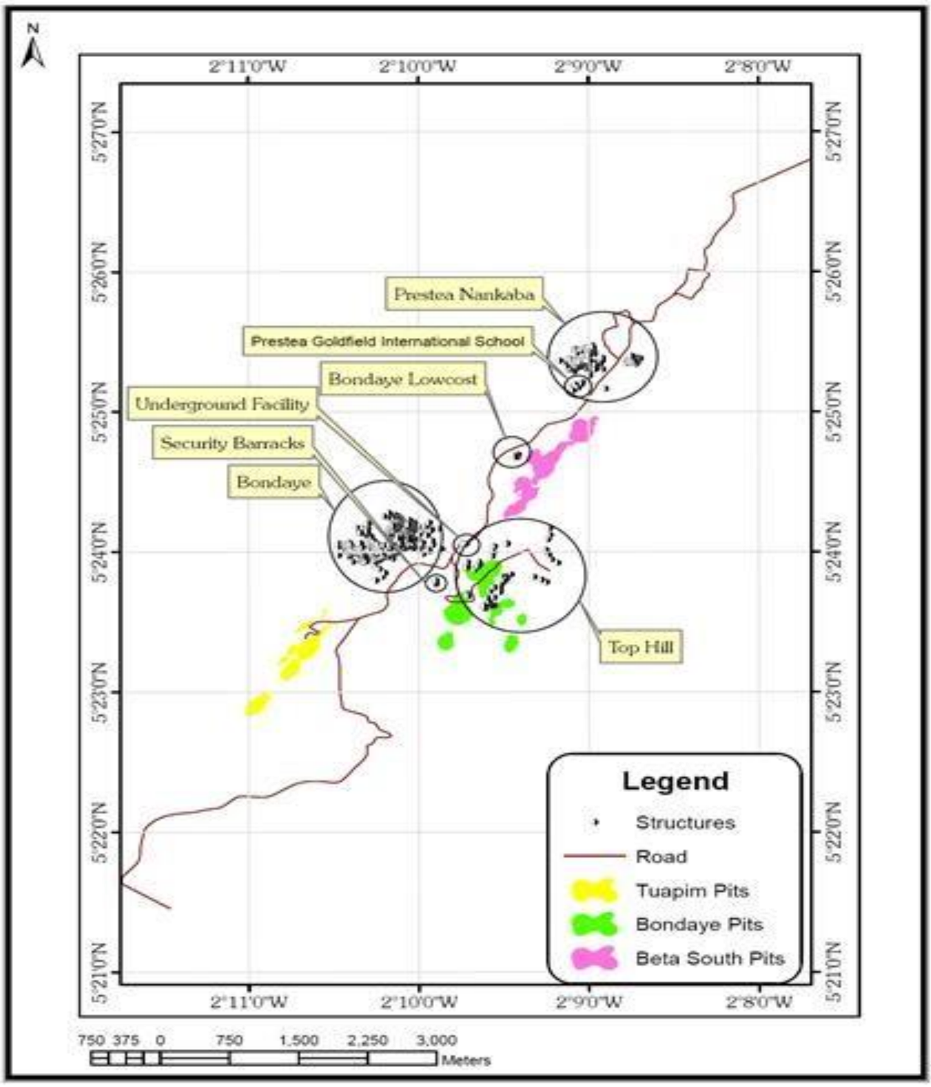

Fig. 1 Study Area

3 Results and Discussions

Over 800 structures were surveyed in the communities. However, 430 building structures randomly selected from the database are presented in this paper. The typical structures in the settlements include compressed block building, wattle and daub, wattle and daub either rendered or partly rendered with cement mortar, and sun-dried brick structure rendered with cement mortar. Figs. 2 to 7 are example building structures in the study area.

Fig. 2 53-Year Old Compressed Block Structure (*Structure has no cracks*)

Fig. 3 20-Year Old Wattle and Daub (*with multiple desiccation cracks*)

Fig. 4 32-Year Wattle and Daub Building partly rendered with Clay (*Structure has multiple cracks and no foundation*)

Fig. 5 21-Year Wattle and Daub Structure partly rendered with Cement Mortar (*Structure shows multiple desiccation cracks*)

Fig. 6 47-Year Sun-Dried Brick Structure rendered with Cement Mortar (*Structure has multiple cracks and no foundation*)

Fig. 7 19-Year Old Wattle and Daub rendered with Cement Mortar (Structure has no cracks)

The structures at Bondaye and Top Hill are mainly compressed block building constructed by the erstwhile State Gold Mining Corporation (SGMC). They are typically more than 50 years old and have undisturbed foundations. Even though these structures are poorly maintained and expected to deteriorate due to ageing, less than 20% of the 217 structures had developed hair-like cracks. A significant number (>50) of community-owned compressed block buildings at Bondaye recorded multiple cracks although they are younger (<30 years) than the SGMC buildings.

Furthermore, greater than 70% of wattle and daub structures rendered or partly rendered with clay or cement mortar, and owned by local population had developed multiple cracks. The structures are typically poorly constructed and maintained. The development of cracks in these structures could be attributed to differential settlement or hydrocompaction since the structures have no or poorly constructed foundations. Even though the wattle and daub and its modifications form about 15% of total number of structures studied, they show a significant number of structural deformations at younger ages than the compressed block buildings. Cracks found in "purely" constructed wattle and daub could also be attributed to desiccation effects typically associated with clay materials.

Together, 53% of 430 structures in the study area are inundated with multiple cracks. These findings are consistent with what is observed by Bansah *et al.* (2014) in similar studies conducted at Awunakrom in the Western Region of Ghana, where they found pre-existing cracks in many of the structures owned by local people in the community. It must be noted however, that the number of structures that have cracks in this present study would vary, if all the structures within the settlements are considered. Nonetheless, observations made in the study can be of significant use in blast impact prediction modelling and quality control and assurance. Additionally, community consultative meetings that would draw attention of community members to the pre-mining conditions of the buildings can help mitigate potential concerns and perceptions by the community.

Table 2 Construction Material Type

Material Type	(%) of Structures
Sun-dried brick structure	1.10
Compressed block building	83.67
Wattle and daub	5.31
Wattle and daub rendered with cement mortar	6.71
Wattle and daub partly rendered with cement mortar	3.21

Table 3 Age of Structures

Age (Years)	(%) of Structures
<10	18.95
10-19	10.37
20 – 29	14.18
30 – 39	25.90
40 – 49	4.49
≥50	26.11

4. Conclusions

This paper studied the pre-mining conditions of building structures within catchment communities of proposed mining operations. More than 50% of structures within the settlements were found to be inundated with multiple cracks. The deformations in the structures were attributed to ageing, poor construction and maintenance, and other factors such as differential settlement, hydrocompaction or desiccation effect. The results provide useful information for blast impact prediction modelling and blast quality control and assurance to mitigate potential environmental damage and complaints.

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