International Journal of Rock Mechanics and Mining Sciences 107 (2018) 48–54

Contents lists available at ScienceDirect

International Journal of
Rock Mechanics and Mining Sciences

journal homepage: www.elsevier.com/locate/ijrmms

Dynamic model validation using blast vibration monitoring in mine backfill

Muhammad Zaka Emad[a,*], Hani Mitri[b], Cecile Kelly[c]

[a] Department of Mining Engineering, University of Engineering & Technology, Lahore, Punjab 54890, Pakistan
[b] Department of Mining & Materials Engineering, McGill University, Montreal, Quebec, Canada
[c] Birchtree Mine, Vale Manitoba Operations, Thompson, Manitoba, Canada

ARTICLE INFO

Keywords:
Underground mining
Blast-induced vibrations
Numerical modelling
Calibration
FLAC3D

ABSTRACT

Sublevel stoping mining methods with delayed backfill are employed for mining steeply dipping ore deposits at deeper horizons. Cemented rockfill (CRF) is used as a backfilling material for open stopes formed during mining. In primary-secondary mining sequence, blast vibrations are induced in CRF during the extraction of adjacent stopes. Higher magnitude of blast vibrations may destabilize CRF causing failure and dilution of precious ore. This paper presents a methodology for calibrating a FLAC3D numerical model, encompassing mine backfill with blast-induced vibration data recorded from field instrumentation. Two FLAC3D models are prepared, one for simulating the blasting process and the other is prepared for backfill stability analysis. The first model resulted in load vectors to be applied to backfill and rock interface. The second model showed that the backfill fails under the blast vibrations induced by the adjacent production stope. The results of the back analysis of fill failure are presented and discussed. The methodology may serve as numerical model calibration procedure for mine backfill.

1. Introduction

Canadian hard rock mines have adopted sublevel stoping method with delayed backfill or its variations such as vertical block mining (VBM) for extraction of steeply dipping ore bodies.[1] In VBM, the ore-body is divided into rectangular prism blocks or stopes; which are mined-out while following pyramidal sequence. Stope production is carried out in three blast rounds or lifts as shown in Fig. 1. Each lift is blasted and mucked until sufficient room is available for the anticipated material from proceeding blast. Backfill is required to fill up the empty stopes. Cemented rockfill or consolidated rockfill (CRF) is a type of backfill, made by mixing cement slurry with rock aggregates from either development waste or quarry.[2,3]

Generally, CRF is designed with either limit equilibrium methods[4] or simple numerical models, which is rare. Static limit equilibrium methods are used to estimate the required uniaxial compressive strength of the backfill material and are based on gravity loading only.[4] However many authors believe that blast loading may influence the stability of CRF, in addition to the static loading.[2,4–9] An effective CRF design should accommodate static loading due to gravity and dynamic loading from blast-induced vibrations.[2,3,8–10] It is reported that blast vibrations from stopes adjacent to mined ones are perhaps one of the major causes of CRF failure.[2,8,9,11–14] Yu and Counter[2] and Yu[4] proposed that a safety factor of 2.5 can help CRF to withstand blast loading. Recently,[7] the effect of different simulated blast loads is examined through numerical modelling study. In that study a stable CRF stope under static load fails when dynamic load is applied.

In order for dynamic modelling to be used as a reliable tool for the design of CRF material, it must be first calibrated with field measurements of blast-induced vibrations. This paper presents a stepwise methodology for numerical model calibration using the results of a field investigation into the effect of blast-induced vibrations on CRF failure at an underground mining operation. A FLAC3D dynamic numerical model is constructed for a typical layout of a primary-secondary stoping system, encompassing a previously mined and backfilled primary stope.

2. Case study

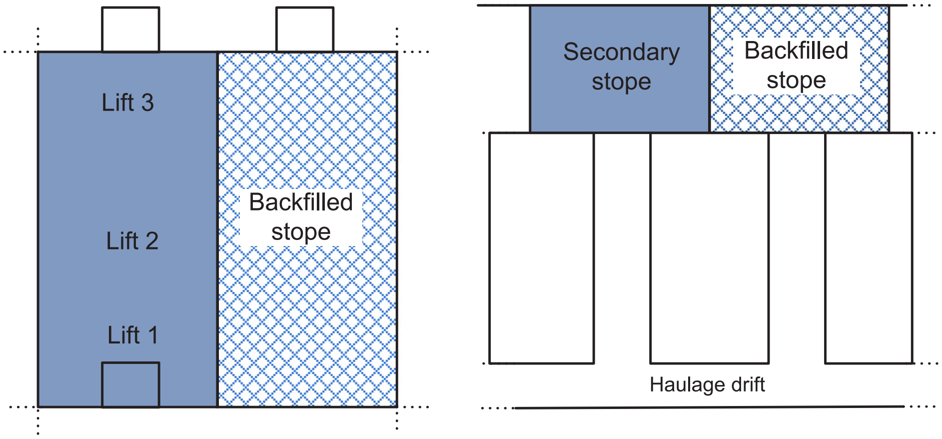
The case study mine utilize VBM for extraction of a tabular steeply dipping ore-body with a thickness of 8–30 m. Length of ore-body is 1450 m along strike (N45E) and dip is 85 West. The ore-body is divided into different zones as per geological settings. The zone studied is located at a depth of 839 m. The geology of the ore-body can be generally described as a brecciated-ultramafic rock in a sulphide matrix. The geology department of mine terms this rock as peridotite. Footwall rock comprise of biotite, plagioclase, pyrrhotite and quartz. The hangingwall rock is schist in major portion of ore-zone under study.

The massive ore-body is mined out with VBM in transverse retreat

---

[*] Corresponding author.
E-mail addresses: zaka@uet.edu.pk (M.Z. Emad), Hani.mitri@mcgill.ca (H. Mitri), Cecile.kelly@vale.com (C. Kelly).

https://doi.org/10.1016/j.ijrmms.2018.04.047
Received 16 January 2017; Received in revised form 25 April 2018; Accepted 29 April 2018
1365-1609/ © 2018 Elsevier Ltd. All rights reserved.



a) b)

Fig. 1. Stope extraction sequence in vertical block mining system: a) longitudinal section; b) plan view.

Table 1
Rock mass properties for different geological units at the case study mine.[10,11]

Material	σ_t (MPa)	σ_c (MPa)	E (GPa)	ϕ (°)	c (°)	υ (MPa)
Ore	0.45	22.36	37.8	43	12.70	0.3
Footwall	0.3	13.6	35.8	44	6.25	0.29
Hanging-wall	1.12	47.53	56.85	45	19.38	0.25
Cemented Rockfill	0.03	3	2.5	37	1.1	0.35

Table 2
In-situ stress magnitude at level 2750 (839 m).[16]

	σ_1	σ_2	σ_3
Herget and Miles (MPa)	31.8	26.7	15
Orientation	Perpendicular to ore body	Parallel to ore body	Vertical
Computed using FLAC3D (MPa)	31.75	26.8	14.98
Boundary stresses (MPa)	13.39	11.67	8.62

primary-secondary panels from hanging wall to footwall. The ore-body is divided into sublevel with intervals of approximately 30 m. A stope is mined from top sill and mucked from bottom. Fig. 1 shows extraction of a typical stope in three blasts. CRF is placed in empty stope through top sill drive using a load-haul-dump machine. Stope adjacent to CRF is blasted no earlier than 28 days to ensure curing of CRF. Likewise, VBM is employed for the extraction of secondary stopes. The rock mass properties obtained from the mine are shown in Table 1.[8,9] The mechanical properties of CRF are taken from the CRF testing conducted by.[3] The in-situ stress values at the mining level 2750 (839 m depth) are shown in Table 2.[15]

3. Monitoring blast-induced vibrations on-site

In-situ blast vibration monitoring experiment is conducted to monitor blast vibrations in the CRF from adjacent production stope. Fig. 2 shows the schematic of the blast vibration monitoring experiment. The details of blast vibration monitoring experiment are published by.[16]

During the experiment two geophones are mounted; one of them inside a drill-hole in CRF, and the second is mounted on the surface of the backfill using a bolt that is cement-grouted. The detonation sequences employed for the three blast lifts are shown in Fig. 3. Total explosive charge for Blast 1, 2 and 3 is 1216.9 kg, 2476.86 kg and 3175.6 kg. The total powder factor for Blast-1, 2 and 3 is 1.1 kg/ton, 0.87 kg/ton and 0.59 kg/ton. The charge per delay ranged from 31.5 kg to 106 kg for Blast 1, 81.1 to 180.81 kg for Blast 2 and 68.18 to 180.9 kg for Blast 3.

Fig. 4 show the results of monitoring blast vibrations in backfill. The maximum vibration magnitudes recorded in CRF are 33 mm/s at 0.32 s, 86 mm/s at 0.33 s, and 425 mm/s at 1.52 s, for the blasts 1, 2 and 3 respectively.

4. Numerical models

Two FLAC3D[18] models are developed for model calibration (Fig. 5). The first model is "backfill model" used for simulating mining sequence. The second model is "equivalent cavity model", used to derive the velocities (or blast vibrations) to be applied in the backfill model. The equivalent cavity method is employed by[19–23] for simulating blast-induced vibrations. The primary and adjacent secondary stopes are modeled with finer mesh to reduce the computation time. The stope is 18 m long, 12 m wide and has a height of 34 m. CRF and rock interface is created through ten centimeters thick zones surrounding primary stope. A small gap of 1 m on top of the backfill is also modeled to prevent stress load transfer from strata above the backfill.

Model boundaries are placed at a distance of 285 m from the stope. The model boundaries are transformed to viscous boundaries during the dynamic analysis. The geo-materials are assumed to be homogeneous-isotropic for this analysis. After setting boundary conditions and material properties, the model is solved for equilibrium using linear-elastic constitutive model.

Linear-elastic constitutive model is employed to solve the model for initial equilibrium. The numerical model is solved with elasto-plastic Mohr-Coulomb material model. Once equilibrium is established the stope mining and backfilling sequence is simulated with gravity loading. At this point, the numerical model is ready to receive vibration data as input parameter on face of CRF. The equivalent cavity method is used for simulating the effects of blast-vibrations on CRF stope.

The radius of equivalent cavity is considered within three to nine times the diameter of blast hole.[20] The equivalent cavity model is also generated using FLAC3D code.[18] The diameter of blast-hole is 10 cm. One quarter of the blast hole is simulated as 30 cm diameter equivalent cavity. The model boundaries are placed 25 m away from the cavity with the depth of the model to be 35 m. The mesh is graded and mesh sensitivity analysis is performed. The material is modeled as linear-elastic and material properties for ore are taken from Table 1. The length of blast hole charged with explosive is constructed with finer zones, as shown in Fig. 5.

Download English Version:

https://daneshyari.com/en/article/7206155

Download Persian Version:

https://daneshyari.com/article/7206155

Daneshyari.com