Technical Note

Evaluating Force Distributions within Virtual Uncemented Mine Backfill Using Discrete Element Method

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Abstract: This paper investigates the distribution of intergranular forces within uncemented mine backfills using the discrete element method (DEM) and compares it with the existing analytical method. The virtual backfilling is modeled via the DEM to simulate the underground mining stopes backfilling with uncemented granular materials. Normal and shear forces of all particle contacts within the model backfill are tracked and analyzed with particular attention to the effect of sidewall friction. The DEM evaluates normal force chains and reveals a concentration of high forces within the model backfill. The DEM shows profiles of forces that are distinctly different from those obtained from analytical solutions. Quantitative analyses of the spatial distribution of forces, number of contact points, and changes in the orientation of forces are presented. The DEM demonstrates its capacity as a good tool for looking closely into the backfill on a particle scale. It highlights potential force distribution and concentration within a backfill and shows the limitations of analytical solutions, which helps engineers in the mining industry to better understand the possible mechanisms within backfill. **DOI: 10.1061/(ASCE)GM.1943-5622.0000850.** *© 2016 American Society of Civil Engineers.*

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Introduction

Mine backfilling is a process of filling an underground mined-out void (stope) using waste rock or tailings as the backfill material. It improves the general stability conditions while reducing the accumulation of tailings aboveground (Li 2014; Sivakugan et al. 2005). This paper focuses on the uncemented backfill under a fully drained condition. It is directly relevant to hydraulic fill that usually consists of classified tailings (uniform particle size) with a free-draining barricade. However, the analysis can also be extended to uncemented rockfill and aggregate fill. Hydraulic fill is widely used throughout Australia and has been considered the conventional mine fill (Sivakugan et al. 2005). On the other hand, rockfill has been used in mine stope backfilling for more than 95 years (Hustrulid and Bullock 2001) and the uncemented type is still used in current underground mine operations, e.g., a mine in Queensland Australia and Eagle Mine in Michigan (Eagle Nickel-Copper Mine, Michigan, United States of America 2015).

Understanding the distribution of intergranular forces, especially within hydraulic fills, is important because the resultant force on the barricade structures needs to be estimated with accuracy to reduce the risk of failure and subsequent debris flows into adjacent underground workings. For the design purposes, the horizontal force acting on the barricade is generally overestimated by the overburden. The total vertical force ($F_{v,\max}$) and total horizontal force ($F_{h,\max}$) of the overburden can be calculated as

$$F_{v,\max} = \sigma_v A = \gamma z A \tag{1}$$

$$F_{h,\max} = K\sigma_v A \tag{2}$$

where σ_v = total overburden stress; A = averaged cross-sectional area of the stope; γ = bulk unit weight of the backfill (kilonewtons per cubic meter); z = depth of the backfill (meters); and K = coefficient of lateral earth pressure (constant). Eq. (1) was first suggested by Fenner (1938).

The overburden theory described previously may not provide a realistic solution, especially for a narrow and tall stope. It does not take into account the force transfer toward the vertical walls, known as arching, which most often occurs in the field of mine backfilling. Janssen (1895) proposed a theory that takes into account the arching effect. Later verifications of Janssen's theory (Nedderman 1992; Ovarlez et al. 2003; Sivakugan et al. 2014; Vanel and Clément 1999; Vanel et al. 2000) showed that the concept of arching is still valid (Ebrahimi et al. 2010). In the application to hydraulic fills, Pirapakaran and Sivakugan (2007) provided reviews on the current state-of-the-art analytical solution with a particular reference to arching, which includes Marston (1930), Terzaghi (1943), Aubertin et al. (2003), and numerical modeling using *FLAC*.

This paper investigates intergranular forces within backfill using a more realistic approach [i.e., discrete element method (DEM)] than the conventional method (i.e., FEM) reported in the past. It highlights potential force distribution and concentration within a backfill and also shows the limitations of analytical solutions. Hence, it aims at giving practicing engineers in the mining industry a better understanding of possible mechanisms within the backfill.

The objective of this paper is to perform three-dimensional (3D) computational simulation of model backfill using discrete element modeling (DEM) to provide information on the spatial distribution of forces, force chains, and their orientation within a stope with particular focus on evaluating the effects of wall friction.

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