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# A numerical evaluation of continuous backfilling in cemented paste backfilled stope through an application of wick drains

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ABSTRACT

Cemented paste backfill (CPB) is gaining popularity in many underground mines worldwide. Sufficient water is added into CPB to make a flowable material for pipe transportation. Barricades are built near the drawpoints to prevent in-rush of the fill slurry. To avoid barricade failures resulting from excessive backfill pressures, backfilling is typically performed with a plug pour followed by a final pour. The interval between the two pours should be shortened or removed to increase mining productivity and avoid pipe clogging. Recently, Li proposed to apply wick drains in backfilled stopes to promote drainage and consolidation. The preliminary simulations by considering an instantaneous filling indicated that the drainage of CPB can be significantly accelerated by using wick drains. Barricade was not considered. Here, some new numerical modellings are presented with more representative filling sequences, stope geometry, and different draining configurations. The results illustrate that the stope can be backfilled continuously by using wick drains.

## 1. Introduction

Underground mining involves creating voids (i.e. stopes) that could endanger ground stability when the stope dimensions are too large. This may impact the ore recovery and dilution rates, cause ground subsidence, and lead to serious safety issues. On the other hand, the mining practice produces a large amount of mine wastes including waste rock and tailings. Usually, the former is stacked in the form of waste rock piles while the latter is deposited at tailing impoundments. In both cases, the mine wastes are disposed on the ground surface and occupy a lot of land, and may cause instability and acid mine drainage [1–3]. To date, several methods have been developed to address these problems, among which stope backfilling is considered as the optimal method.

In general, mining backfill plays the role of ensuring stability of regional ground and local stopes, increasing ore recovery rate and minimizing ore dilution [4–11]. The surface disposal of mine wastes can be disposed by backfilling, which is regarded as an environmental friendly solution [1,2]. Mining backfill is typically classified as rockfill, hydraulic backfill and cemented paste backfill (CPB); each has some advantages and limitations [6].

In the past three decades, CPB has been developed and widely adopted in many underground mines in Canada, Australia, China, and elsewhere. Generally consisting of 70–85% (solid weight) of full tailings, CPB has many operational and environmental benefits [6,12]. However, sufficient amount of water is added into the backfill to make a flowable material for pipe transportation from surface backfill plant to underground voids (Fig. 1, left picture). Because of the flowability of backfill, barricades have to be built near the drawpoints to prevent the in-rush of backfill (Fig. 1, right picture).

Once placed in the stope, CPB's particles tend to settle down under self-weight, leading to establishment of excess pore-water pressure (PWP) [13–18]. The process of the dissipation of the excess PWP is a well-known phenomenon called self-weight consolidation or sedimentation [18–23]. Due to the development of the excess PWP and to avoid excessive backfill loads exerted on barricades, stope filling is typically divided into a plug pour and a final pour in practice, separated by an interval of several days [17,24,25]. For the sake of barricade stability, this interval is necessary, even obligatory in some cases. Alternatively, the rising rate (i.e. speed, influenced by the flow rate of backfill feeding and stope geometries) of the backfilling should be low enough [16]. On the other hand, from an economic point of view, this interval is undesirable because it slowdowns the production and occasions pipe clogging. Consequently, one seeks a fast and continuous backfilling by means of improved drainage and consolidation of backfill.

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**Fig. 1.** A stope being backfilled (left) with a barricade constructed near the drawpoint (right).

A number of works have been reported on improving the drainage of barricade by using different porous materials [26–28], but few works on improving the drainage of CPB. Until recently, Li proposed to use wick drains in backfilled stopes to improve drainage and consolidation [9,29]. The concept is straightforward. Without wick drains, the drainage of backfill typically occurs vertically in one dimension (upward and downward). Once wick drains are used, the drainage of backfill can occur in both horizontal and vertical directions, thereby improving the drainage of the backfill significantly. This has been confirmed by some preliminary numerical results obtained with GeoStudio 2007 [30]. However, the preliminary numerical models considered only one or two wick drains vertically placed in the backfilled stope, considering one layer instantaneous backfilling. The barricade was not taken into account. In this work, the conceptual introduction of wick drain in backfilled stope is briefly recalled. New numerical modelings using GeoStudio 2007 are presented with more representative filling sequences, stope geometry, and different configurations of draining system. It is aimed to investigate the possibility of continuous filling of CPB using wick drains.

## 2. Conceptual application of wick drains in backfilled stopes

In civil engineering, wick drains (or prefabricated vertical drains) are commonly used to promote the drainage and consolidation of silty and clayey soils [31–37]. A wick drain is usually composed of a Polypropylene core and geotextile fabric as shown in Fig. 2. The Polypropylene core plays the role of draining channel while the geotextile acts as the filter. Compared with the other vertical drains such as sand or waste rock columns, the installation of wick drains is more convenient in backfilled stopes. Fig. 3 shows the conceptual application of a wick drain in a backfilled stope [9,29].

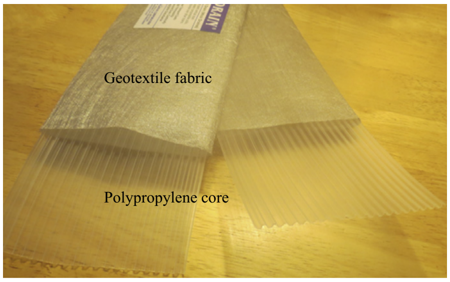

**Fig. 2.** A commercial wick drain made of geosynthetic material (samples provided by AMERDRAIN®).

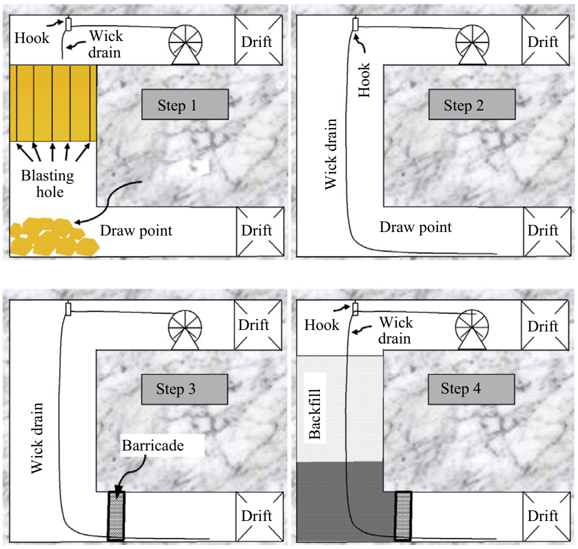

**Fig. 3.** Flowchart of conceptual application of a wick drain in a backfilled stope [9,29].

## 3. Numerical modeling of continuous filling

### 3.1. Model configuration

Fig. 4 presents a schematic view of CPB backfilled stope with a barricade located in an access drift near the drawpoint. Here, a nearly impervious mechanical barricade is considered. As shown in Fig. 4, $H$ (m), $H_{plug}$ (m) and $H_{final}$ (m) represent the total height, plug pour height and final pour height of CPB, respectively; $B$ (m) and $L$ (m) are the stope width and length, respectively; $H_d$ (m) and $L_d$ (m) are the height and width of drift and barricade, respectively. The stope and drift geometries of the numerical modeling are given in Table 1.

Table 2 lists some hydraulic and mechanical properties of CPB and wick drains taken for the numerical modeling. A rising rate of 0.1 m/h is taken for the backfilling operation. This corresponds to a backfill flow rate of 30 $m^3$/h when the base section of the stope is 10 m × 30 m. In practice, a rising rate of 0.2–0.4 m/h has been reported depending on the backfill flow rate and section area of the stope [17]. The CPB is considered as a soft linear-elastic material with saturated hydraulic conductivity (also termed as coefficient of permeability) of $k_{sat} = 1.0 \times 10^{-7}$ m/s (i.e. 0.00864 m/day) and a coefficient of volume change $m_v = 0.0002$ $kPa^{-1}$. The variations of the hydraulic properties of CPB are plotted in Fig. 5. The variations of volumetric water content and hydraulic conductivity as a function of the suction are presented in Fig. 5a and b, respectively. As self-weight consolidation develops, the hydraulic conductivity decreases as the effective stress increases, as shown in Fig. 5c.

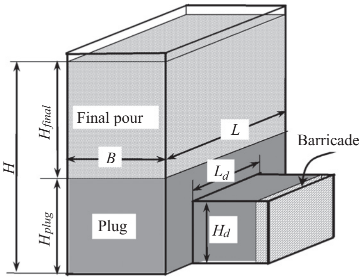

**Fig. 4.** A CPB backfilled stope and a barricade in an access drift [27].