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BASIC REQUIREMENTS OF BACKFILLING WITH FLOTATION TAILINGS IN THE BOR RIVER UNDERGROUND MINE[***]

Abstract

The use of backfill in underground mining is increased due to a need for systematic backfilling the mine openings and workings. Backfilling is applied in order to prevent fires and explosions, improve the mine ventilation, improve the rock stability, reduce the subsidence effects on surface, as well as for economical and environmental factors. Sources of materials are usually from mining industry (e.g. fly ash, gypsum, slag, infertile overburden, tailings, filter dust, residues from mineral processing) or other industries. The ore body Bor River of the Bor Copper Mines is planned to be exploited by the sublevel stopping method. In order to ensure greater efficiency in the exploitation of the ore body, it is proposed, after the excavation of chambers, to move on to the excavation of the main pillars. To ensure the stability of the excavation area, it is necessary to fill the excavated chambers with material of good physical and mechanical properties.

For this purpose, a possibility of filling the chambers with backfilling consisted of flotation tailings, small amount of cement and water, will be tested. This paper reviews the basic requirements of backfilling that will be applied in the excavated chambers.

Keywords: *backfilling, flotation tailings, sublevel stopping, basic requirements*

1 INTRODUCTION

The underground **cemented paste backfill** (CPB) is an important component of underground stope extraction. As the mining operations progress, paste backfill is placed into previously mined stopes to provide a stable platform for miners to work on and ground support for the walls of the adjacent adits by reduction the amount of open space that could potentially be filled by a collapse of the surrounding pillars [1]. The underground paste backfill provides not only ground support to pillars and walls, but also helps in preventing caving and roof falls and enhances pillar recovery, thereby improving productivity [2], [3]. Thus, the placement of paste backfill provides an extremely flexible system for coping with changes in the ore body geometry that result in changes in stope width, dip, and length [4]. Paste backfill is usually transported underground through the reticulated pipelines. Paste backfill is composed of mill tailings generated during mineral processing, mixed with additives such as the Portland cement, lime, pulverized fly ash, and smelter blast furnace slag, which react as the binding

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agents. Binding agents develop a cohesive strength within CPB so that exposed fill faces become a self-supporting when adjacent stopes are extracted.

Backfilling costs in underground mining operations must be critically examined to identify the potential cost savings [5]. Although paste backfilling is somewhat expensive, it is indispensable for the most underground mines as it provides a crucial ground support for mine safety and mining operations. Therefore, the fill should be cost-effective and capable of achieving the desired ground support and stability. An analysis of fill stability must consider the geometric boundaries of the fill in terms of optimal economic use of CPB. Mine openings and exposed fill faces in large underground mines vary in shape from high and narrow to low and wide. Additionally, a wall rock next to the backfill may be either steeply dipping or relatively flat-lying. The extraction sequence can be modified to reduce the number of CPB-filled stopes, or the stope geometries could be modified to reduce the required strength for CPB exposure [7].

This paper reviews the basic requirements in terms of physical and mechanical characteristics of the backfill that will be applied in the excavated chambers.

2 CALCULATION THE HORIZONTAL PRESSURE ON FILLED STOPE

In general, since self-weight stresses govern backfill design, the traditional design has been a freestanding wall requiring a **uniaxial compressive strength** (UCS) equal to the overburden stress at the bottom of the filled stope. In many cases, however, the adjacent rock walls actually help support the fill through boundary shear and arching effects. Therefore, backfill and rock walls may be mutually supporting [2]. In backfilled stopes, when arching occurs (which is the case in many mines, depending on stope dimensions), the vertical pressure on the bottom of the filled stope is less than the weight of overlying fill (overburden weight) due to a horizontal pressure transfer, somewhat like a trap door [7]. This pressure transfer is due to the frictional and/or cohesive interaction between fill and wall rock. When the pillars or stope walls begin to deform into the filled opening, the fill mass provides lateral passive resistance. Passive resistance is defined as the state of maximum resistance mobilized when force pushes against a fill mass and the mass exerts resistance to the force [8]. The pressure transferred horizontally to the sidewalls should be included in the required fill strength design. Horizontal pressures affected by fill arching are determined by five analytical or semi-analytical solutions that account for cohesion at the fill-sidewall interface and/or frictional sliding along the sidewalls. These solutions are the Martson's model and its modified version, Terzaghi's model, Van Horn's model and Belem-Benzaazoua model [9].

3 REQUIRED CHARACTERS OF PASTE BACKFILL

The required strength for paste backfill depends on the intended function. To provide an adequate ground support, the required uniaxial/unconfined compressive strength (UCS) of the fill should be at least 1.5 MPa (in case of the Bor River mine), whereas for free-standing fill applications, UCS is commonly lower than 1 MPa [10]. A typical vertical exposure measures 4–6 m wide by 30–45 m high. A UCS of 100 kPa is commonly adopted as the liquefaction potential limit. The required static strength for paste without exposures may be arbitrarily selected at 200 kPa. Previous work indicates that fill mass UCS varies from 0.2 MPa to 4 MPa, while the surrounding rock mass UCS varies from 5 MPa to 240 MPa [9].

The mechanical effects of fill differ from those of the primary ore pillars. Research and in situ testing have shown that fill is incapable of supporting the total weight of overburden ($\sigma_v = \gamma H$), and acts as a secondary support system only.

The fill modulus of elasticity varies from 0.1 GPa to 1.2 GPa, while the surrounding rock mass elasticity varies from 20 GPa to 100 GPa. It can be assume that any vertical loading is a result of roof deformation (Fig. 1), and that design UCS can be estimated by the following relationship:

$$UCS_{\text{design}} = (E_{\text{p}}\varepsilon_{\text{p}})FS| = E_{\text{p}}\left(\frac{\Delta H_{\text{p}}}{H_{\text{p}}}\right)FS$$

where E_p = rock mass or pillar elastic modulus; e_p = pillar axial strain; ΔH_p = strata deformation (m); H_p = strata initial height (m); and F_S = factor of safety.

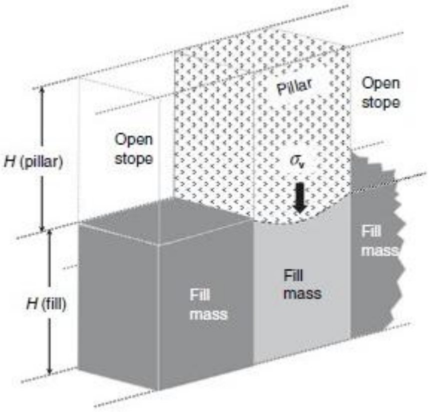

Figure 1 *Schematic view of vertical loading on the backfill block next to a pillar*

Once the required strength has been determined, mix variables are optimized to provide the desired mix that achieves target strength and minimum cementation usage. Mix variables considered include binder content Bw% (by dry mass of tailings) and binder type, tailings particle size distribution (PSD) and mineralogy, mix solids concentration by mass (Cw%) or volume (CV%), and mixing water geochemistry. To design a certain uniaxial compressive strength (UCS design), the variables are adjusted to produce an optimal mix design. The other essential requirement is that the backfill must be economical. These costs wield a significant impact on the mine operating costs. Paste backfill costs alone are typically between 10% and 20% of total mine operating costs, with binder agents accounting for up to 75% of backfill costs.

One of the most important characters of the paste backfill is pumpability. It can be determined using the standard or modified ASTM slump test, Fig. 2.

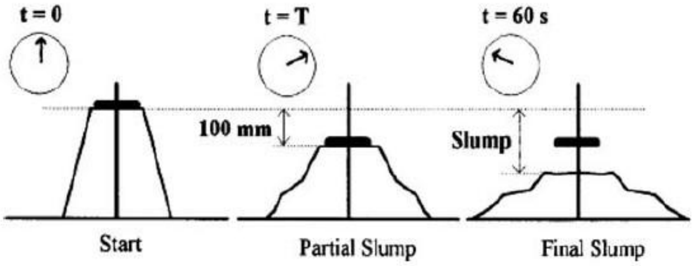

Figure 2 *Schematic diagrams of the modified slump cone test based on measuring slumping time T*

4 CONCLUSION

This paper provides an overview of the design and application the paste backfill in the Bor River underground mine. In applying the paste backfill, the limiting strength and pressures developed in the fill mass must be determined according to the geometry of the opened stopes and initial stress conditions. To define this criteria, optimization of paste backfill mix design is essential to determine the optimal mixture to achieve the desired limiting strength, rheological behavior, cost effects, pumpability and many other crucial properties.

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