Paste 2023 – GW Wilson, NA Beier, DC Sego, AB Fourie & D Reid (eds)

doi:10.36487/ACG_repo/2355_15

Natural mixing behaviour of waste rocks poured in a paste backfill

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Abstract

In underground mines, large quantities of waste rock can be produced during development in order to access ore bodies. The waste rock is typically hoisted to the surface and transported to a specific place to make a structure called a waste rock pile. This practice requires energy consumption and generates additional operating costs for transporting waste rock from underground to the surface. Alternatively, the waste rock can be poured directly into underground mine stopes filled with paste backfill. As a result, energy consumption and additional operating costs for transporting the waste rock from underground to the surface are avoided or significantly reduced. However, the natural mixing behaviour of waste rocks poured in paste backfill has never been studied. The fill mass generated by this practice can fail and collapse upon a side-exposure associated with the excavation of an adjacent stope if a poor mixture between the cohesionless waste rocks and cemented paste backfill takes place around the exposed face. Thus, it is critical to understand the mixing behaviour of waste rocks poured in paste backfill. To this end, a series of physical model tests have been performed in the laboratory. The results, in part, are presented and discussed in this paper.

Keywords: *underground mines, mine backfill, waste rock, paste backfill, natural mixture*

1 Introduction

Waste rock is a product of underground mining operations during the development works to access ore zones. In most cases, the underground produced waste rock is transported from production points to the main shaft, hoisted to the surface, and then transported to a storage place to make a structure called a waste rock pile (Aubertin 2013). This manner of waste rock management requires energy consumption and generates additional operating costs associated with transporting waste rock from underground to the surface.

An alternative practice is to place this underground-produced waste rock into mine stopes filled with cemented paste backfill. All sizes of waste rock can be directly poured into cemented paste backfill stopes right after the excavation without transporting the waste rock from underground to the surface. The energy consumption and additional operating costs usually required for the transportation and hoisting from underground to the surface can then be avoided. In addition, this practice neither needs prior mechanical mixing between the waste rocks and cemented paste backfill nor any secondary crushing, blasting or sieving. If a complete mixing of the waste rocks and cemented paste backfill can be ensured, the mechanical properties of the mixture can be even better than those of individual paste backfill and waste rocks. Lee & Gu (2017) outline other advantages to this practice, especially cost saving.

Despite numerous advantages, waste rock placement in stopes filled with cemented paste backfill also involves risks. For example, suppose poor mixing between the cohesionless waste rocks and cemented paste backfill takes place around the exposed face. In that case, the backfill mixture can fail and collapse under side exposure associated with excavating an adjacent stope, resulting in significant ore dilution and even loss of the stope. Thus, it is critical to understand the mixing behaviour of waste rocks poured into paste backfill.

However, almost all publications on mining backfill have focused on the behaviour of a single type of backfill, including the extensive works conducted by Li and co-workers over the past two decades (Aubertin et al.

2003; Béket Dalcé et al. 2019; El Mkadmi et al. 2014; Jaouhar et al. 2018; Jaouhar & Li 2019; Keita et al. 2021a, 2021b; Li et al. 2003; Li et al. 2005; Li & Aubertin 2012; Li 2014a, 2014b; Li & Aubertin 2014; Liu et al. 2017a, 2017b, 2018; Pagé et al. 2019; Qin et al. 2021a, 2021b; Sobhi et al. 2017; Sobhi & Li 2017; Wang et al. 2021a, 2021b; Wang & Li 2022; Yang et al. 2017, 2018; Zhai et al. 2021; Zheng & Li 2020; Zheng et al. 2019, 2020a, 2020b, 2020c). Research on the natural mixing behaviour between the waste rocks and paste backfill is absent in the literature.

It should be noted that the natural mixture of waste rocks and paste backfill is entirely different from the mechanical mixture of graded waste rock and tailings to produce a paste rock (Wickland & Wilson 2005; Wilson 2001; Wilson et al. 2008) or a mechanical mixture between the graded waste rock and paste backfill to produce a paste aggregate fill (Kuganathan & Sheppard 2001). It also differs from a waste rock structure wrapped in cemented paste backfill (Veenstra & Grobler 2021).

In order to fill the identified gap, a series of physical model tests have been performed in the laboratory to investigate the natural mixing behaviour of waste rocks poured in paste backfill. The results, in part, are presented and discussed below.

2 Laboratory tests

2.1 Materials

This study uses uncemented paste backfill to facilitate the mixing analyses of waste rocks and paste backfill. The uncemented paste backfill is made of tailings taken from a mine in the province of Québec in Canada. Figure 1 presents the tested tailings' particle size distribution curve (PSD). It has a specific gravity of 2.71 and a maximum particle size of 0.63 mm, containing approximately 77% of particles smaller than 80 µm and 36% smaller than 20 µm. The backfill made of such tailings meets the paste backfill's PSD criterion of Hassani & Archibald (1998) and Potvin et al. (2005). In this study, the tested paste backfill has a solids content by mass of 72.5% (Figure 2).

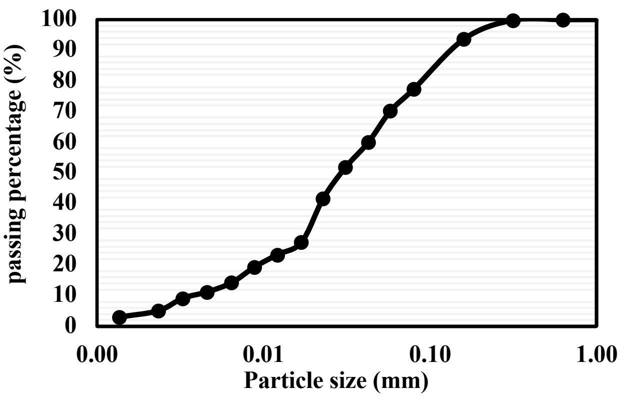


Figure 1 Particle size distribution (PSD) curve of tested tailings

Figure 2 Tested paste backfill with solids content by mass of 72.5%

The tested waste rocks are made of waste rock from the same mine where tailings were taken. To facilitate the mixing analyses, the waste rocks were sieved, and only the portion having particle sizes ranging from 2.5 to 5.0 mm was retained. These waste rocks were dyed blue to facilitate the distinction between the particles of waste rocks and paste backfill once mixed (Figure 3).

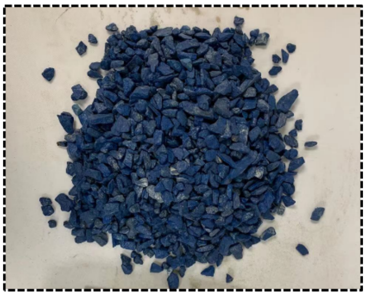
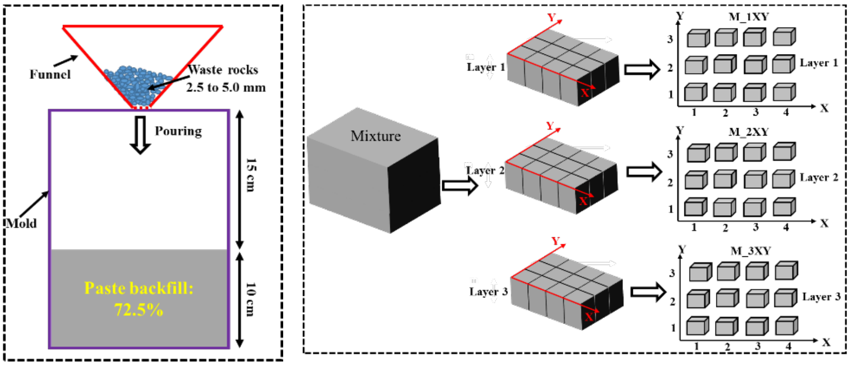


Figure 3 A picture of the tinted waste rocks

2.2 Testing procedure

Figure 4 schematically shows the testing procedure from pouring (Figure 4a) waste rocks into paste backfill to cut (Figure 4b) the mixture for PSD analyses. In the model with a size of 16.5 cm long, 20 cm large and 25 cm high, the paste backfill was first poured at the height of 10 cm. The waste rocks with a total mass of 1000 g were then poured into the paste backfill using a funnel from the top centre area of the model. The falling height of waste rocks was 15 cm. When the mixture became hard enough, it was cut into small blocks. The mixture was divided into three equal layers, each cut into 12 blocks. Each block was identified by its layer number and number in X and Y directions. After being oven-dried, the small blocks were gently crushed by hand for sieving analysis.



(a) (b)

Figure 4 Testing procedure: (a) The pouring of waste rocks into a paste backfill; (b) Cut the mixture into small blocks

3 Test results and interpretation

Figure 5 presents a top view of the mixture after pouring waste rocks in the paste backfill with solids contents by mass of 72.5%. We can see that a large number of waste rocks remain on the top surface without mixing with the paste backfill, forming a waste rock pile.

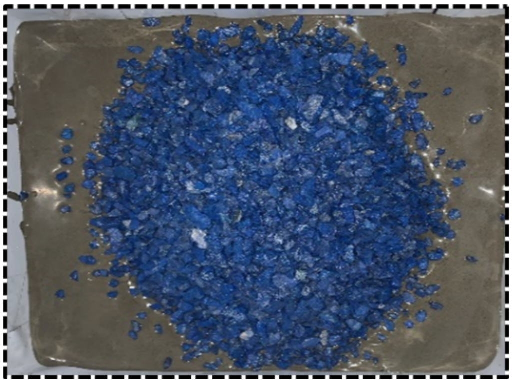


Figure 5 Top view of the mixture after the waste rocks were poured into the paste backfill having solids content by mass of 72.5%

Figure 6 presents the internal structure of the mixture after cutting and exposure. In Layer 1, one sees a large pocket of waste rocks, which does not have any mix with the paste backfill, indicating a poor mixture between the two materials. In Layers 2 and 3, the waste rocks particles are entirely wrapped by paste backfill, indicating a total mix between the two materials. These results demonstrate the mixing degree between the poured waste rocks and paste backfill varies in space (depth). For a given solids content of paste backfill and a given falling height of waste rocks pour, the amount of poor mixture between waste rocks and paste backfill can be expected to increase as the quantity of poured waste rocks increases.

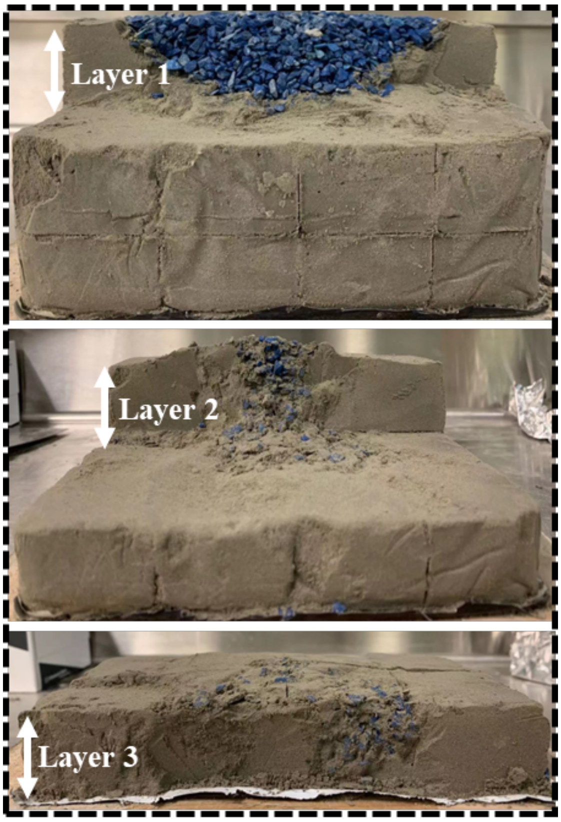


Figure 6 Internal structure of the mixture after the cut

Figure 7 presents the PSD curves of the small blocks. We note that the PSD curves of blocks M_122 and M_132 at the centre of Layer 1 overlap with the waste rocks, indicating that there is no mixture between paste backfill and waste rocks at the centre of Layer 1. Around the four side walls, the mass proportion of paste backfill of blocks M_111, M_141, M_113 and M143 varies from 87.5 to 96.1%, indicating a high degree of wrapping of waste rocks particles by paste backfill.

In Layer 2, the mass proportion of paste backfill in blocks M_222 and M_232, at the centre, increases to about 54%, compared to 0% at the centre of Layer 1. The result indicates that the mixing degree between waste rocks and paste backfill can be expected to increase at deeper positions in the paste backfill. Around the four side walls, the mass proportion of paste backfill of blocks M_211, M_241, M_213 and M243 ranges from 92.7 to 100%, indicating a small number of waste rocks penetrating the paste backfill.

In Layer 3, the mass proportions of paste backfill of blocks M_332 and M_322 at the centre are 70 and 74.2%, respectively. The values are much higher than those of centre blocks of Layers 1 and 2, confirming the improvement of wrapping of waste rock particles by paste backfill with increased depth. Around the four side walls, the PSD curves of blocks M_311, M_341, M_313 and M343 are very close to that of the paste backfill, indicating the almost absence of waste rocks moving in the paste backfill.

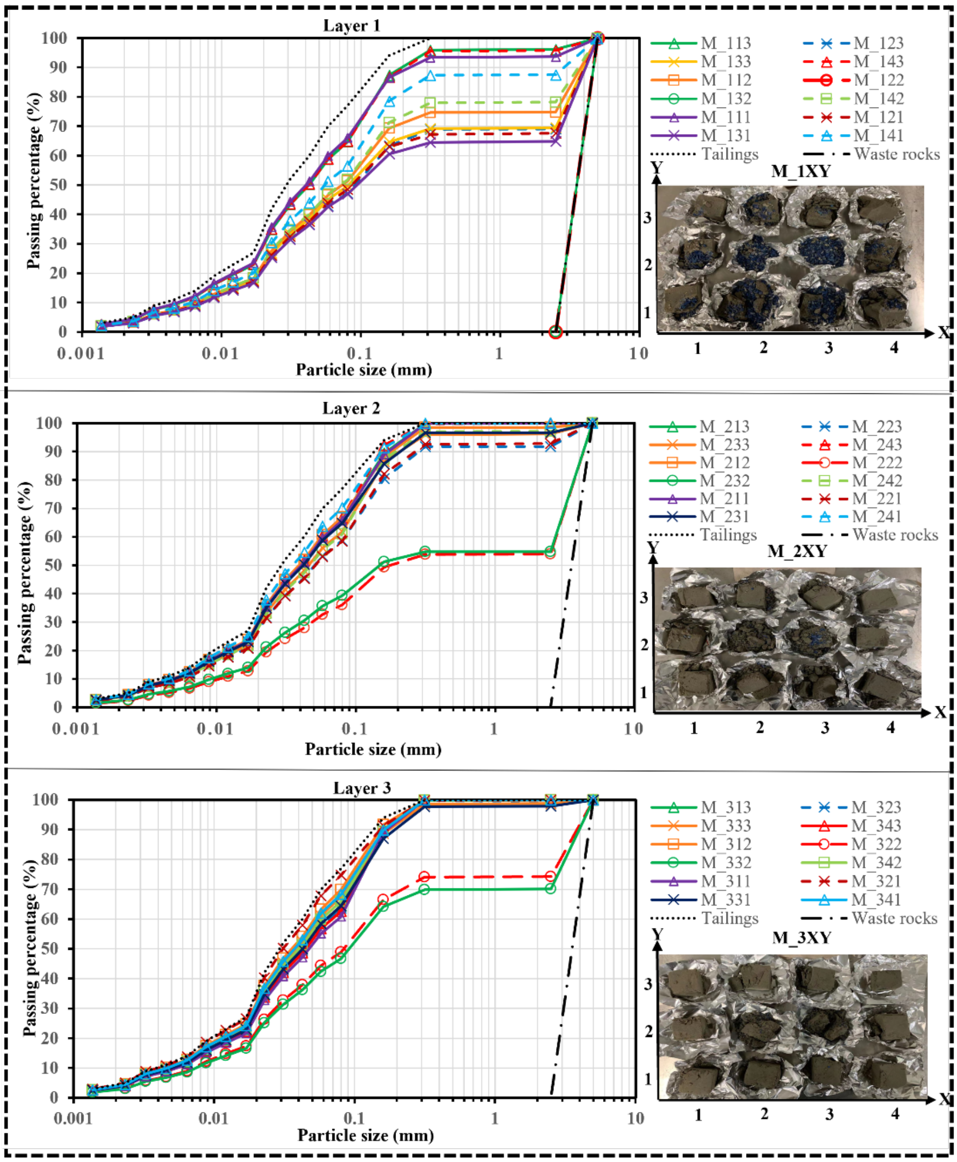


Figure 7 **PSD curves of small blocks**

4 Conclusions

In this study, the natural mixing behaviour of waste rocks poured in a paste backfill has been, for the first time, illustrated by physical model tests. The results demonstrate that waste rock pockets having poor or no mixture with paste backfill can take place on the surface of paste backfill. In practice, this can happen when a large quantity of waste rocks is suddenly poured into a stope filled with paste backfill, especially when the paste backfill has a high solids content. A sign of poor or no mixture between waste rocks and paste backfill with the formation of cohesionless waste rock pockets is the occurrence of waste rock piles on the top surface of the paste backfill. A good mixture between the waste rocks and paste backfill can be expected at the base around the waste rock pocket.

Although these observations are both interesting and promising, the results presented in this study are preliminary as the number of tests is small and the investigated conditions are limited. More experimental work is thus needed to evaluate the effect of different influencing factors on the natural mixing behaviour of pouring waste rocks in paste backfill, which will be part of our future publications. Nevertheless, this study paves the way for further and ongoing analyses.

Acknowledgement

The authors acknowledge the financial support from the Natural Sciences and Engineering Research Council of Canada (NSERC RGPIN-2018-06902), Fonds de recherche du Québec – Nature et technologies (FRQNT 2017-MI-202860), industrial partners of the Research Institute on Mines and the Environment (RIME UQAT – Polytechnique; http://rime-irme.ca), and Mitacs Elevate Postdoctoral Fellowship (IT12569).

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