Construction and Building Materials 165 (2018) 138–148

Contents lists available at ScienceDirect

Construction and Building Materials

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

Expansion and strength properties of cemented backfill using sulphidic mill tailings

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HIGHLIGHTS

- Sulphur content has significant effect on the free expansion ratio of sulphidic backfill.
- Increasing the amount of binder (8–16%) cannot restrict the expansion of sulphidic backfill.
- Solids concentration also affects the expansion behaviour of the filling body.
- There is an obvious negative correlation between strength and expansion ratio.

ARTICLE INFO

Article history:
Received 3 August 2017
Received in revised form 24 December 2017
Accepted 2 January 2018

Keywords:
Cemented tailings backfill
Sulphidic tailings
Deformation
Expansion
Strength
Waste management

ABSTRACT

The expansion and strength properties of cemented tailings backfill (CTB), especially prepared from sulphidic mill tailings, are valuable for the estimation of design parameters for underground stope filling as well as for numerical simulation. In this paper, the effect of the curing time, sulphur content, cement dosage and solids concentration effect on the free expansion ratio (FER) of CTB specimens was investigated using an invented lab apparatus called (free expansion measuring instrument). And the relationship between the FER and the unconfined compressive strength (UCS) was analyzed. And then, mineralogical composition of CTB samples was tested by X-ray diffraction. The backfill recipe (sulphur content, binder dosage and solids concentration) and curing days had significant influences on the expansion performance. The research results indicated that with the increase of sulphur content, the FER showed no obvious growth at the curing of 28 days. However, after 120 days, FER increased from 4.856% (S: 3.64 wt%) to 9.613% (S: 20 wt%). As the solids concentration increased, the FER also rose. And this growth was distinctive only when the solids concentration is relative high (65–75 wt%) and at the long-term curing time (120 days). The proportions of binder and the obtained FER clearly showed a sub-linear and proportional relationship. Increasing the amount of binder (8–16 wt%) cannot restrict the increment of expansion ratio, and ultimately the specimens would generate cracks and collapse. Meanwhile, there was a significant negative correlation between the UCS and the FER from the same group of specimens. When the FER reached a certain value, the strength value dropped sharply.

1. Introduction

Cemented tailings backfill (CTB) is a homogeneous material in which tailings are bonded together by the hydraulic binder and mixing water. Its components (tailings, water, cement) are combined and mixed in a plant usually located on the ground of mine [1–4]. CTB is potentially one of the best practical approaches for the management of process tailings since it offers significant environmental, technical and economic benefits. These include the alleviation of the environmental impact of potentially hazardous mill tailings (e.g. sulphidic tailings, in particular) by their safe disposal into the underground (up to 60–75 wt% of the plant tailings), the support of underground stopes to provide a safe working environment and to minimize surface subsidence, as well as the reduction of the tailings disposal and rehabilitation costs [5–8]. A considerable number of metals (e.g. Cu, Pb, Au, and Zn) can be mined from metalliferrous sulphide ores [9]. So the process tailings from these deposits often contain a certain amount of iron sul-

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https://doi.org/10.1016/j.conbuildmat.2018.01.005
0950-0618/

phidic minerals, such as pyrite (FeS_2), arsenopyrite (FeAsS) and pyrrhotite ($Fe_{1-x}S$) [10,11]. The sulphidic minerals would generate acid mine drainage in the presence of water and oxygen, hence resulting in the migration of heavy metals [12]. An effective disposal of backfill materials is to place them into the underground using sulphidic mill tailings as aggregate. The most commonly used binder material is the ordinary Portland cement (OPC), which has certain limitations when using sulphidic-rich mill tailings [13,14]. The presence of sulphidic minerals results in sulphate attack which may decrease the strength and lead to an expansion of the CTB material. Sulphate attack can occur rapidly during curing and depends on the binding agents used. The reaction involves dissolution of hydrated calcium phases followed by the formation of expansive phases resulting in the degradation of the mechanical properties [15]. Meanwhile, the accumulation of expansive phases also leads to deformations such as expansion in most cases. These issues have all affected the long-term stability of the mine [10,16].

The unconfined compressive strength (UCS) of CTB samples is the most frequent property used to assess the mechanical performance of CTB structures because UCS testing is relatively inexpensive and quick, and can be easily incorporated into the routine quality control programs in the mine [17,18]. The results of the strength tests on the specimens with micro cracks are very discrete, which significantly reduces the accuracy of the experiment. Belem, Benzaazoua and Yilmaz [19–21] invented the laboratory apparatus (called CUAPS, curing under applied pressure system) to simulate the situ curing conditions of CTB. The sulphidic paste specimens were cured in a cylindrical mold and they were more intact, so the results of strength tests were more reliable.

The quality and performance of CTB are greatly affected by its intrinsic and extrinsic factors (Fig. 1) [22]. Due to the geometric expansion of the filling body, the expansion effect enhances the backfill–rock interaction, such as interfacial interaction, wall convergence, arching effect et al.

Some investigation about the mechanical performance of interfacial interaction has been conducted by backfill direct shear property test [23]. Arching effect defined as the transfer of pressure from a yielding mass of soil onto the adjoining stationary parts [24–26] has been researched. It is clear that the expansion behavior is an important role effecting the interfacial strength and the arching effect. Furthermore, in addition to the important role of UCS in underground stopes supporting, the expansion behavior is also a key aspect of major interest. Wu et al. (2017) [27] propose that, in inspecting the stability of the backfill body with an empty lateral, the expansion behavior of the filling body should be seriously considered. Huang et al. (2016) [28] have studied the deformation behavior of controlled low strength materials (CLSM) at different temperatures in the early curing time to improve the quality of backfill. Nevertheless, few studies have investigated the deformation behavior of CTB materials, especially the short- and long-term expansion behavior.

The objective of this paper is to present an invented lab apparatus called FEMI (free expansion measuring instrument) and introduce its application method in detail, which allows accurately investigating the deformation behavior of CTB materials in the standard curing environment. The evolution of the expansion ratio of CTB in the short- and long-term under the influence of the recipe factors (binder/cement dosage and solids concentration) and sulphur content and their interactions was investigated by utilizing the FEMI. Meanwhile, the unconfined compressive strength (UCS) of CTB specimens with different free expansion ratios was tested to analyze the relationship between mechanical strength and deformation behavior, which can provide a theoretical basis for further improving the quality and performance of the sulphidic filling body.

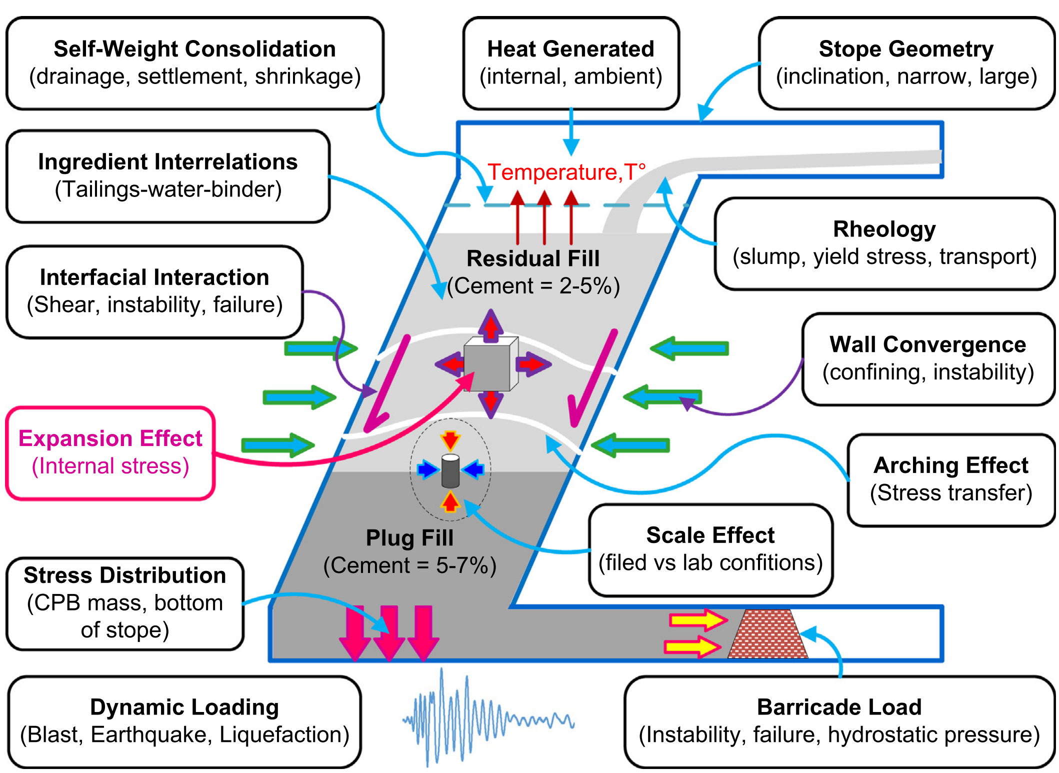

Fig. 1. Intrinsic and extrinsic factors affect the quality of cement tailings backfill (modified after E. Yilmaz, et al. [22]).