Mix proportioning of underground cemented tailings backfill

M. Fall a,*, M. Benzaazoua b, E.G. Saa c

a Department of Civil Engineering, University of Ottawa, 161 Louis Pasteur, Ottawa, Ont., Canada K1N 6K7
b University of Quebec in Abitibi-Temiscamingue (UQAT), Rouyn-Noranda, Que., Canada J9X 5E4
c Ecole Polytechnique Fédérale de Lausanne, Switzerland

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Abstract

The usage of cemented tailings backfill (cemented paste backfill) in the underground by mining industry is becoming increasingly important. However, until now, the mix proportioning of CTB has been mainly based on the realization of extensive laboratory tests on a large number of CTB mixes. Therefore, this paper presents a design method for mix proportioning of CTB to minimize the number of trial mixes and provide an appropriate mix proportion. This method is based on the pairing of the response surface method (RSM) and the desirability approach. First, the RSM was used to develop predictive models for the performance properties of CTB. The predicted properties in question are the uniaxial compression strength (UCS), the slump, the solid concentration (solid percent, %Solid) and the cost (based on cement cost) of the CTB. The predictive models that were developed were able to accurately represent the relationships between the physical and chemical characteristics of the CTB components (tailings, binder, water) and the above properties. The results of the modeling phase were then used as input data in the optimization phase (based on desirability approach) to develop optimal recipes for the studied CTBs. This study has demonstrated that the combination of the RSM and desirability approach represents an effective tool for CTB mix proportioning. The developed design method can be useful in reducing the laboratory test protocol needed for the determination of the optimal mix composition.

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1. Introduction

Cemented tailings backfill (cemented paste backfill studied in this paper) is a heterogeneous material in which tailings are held in place by a hardened cement paste binder. Its components (tailings, water, cement) are combined and mixed in a plant usually located on the surface and transported (by gravity and/or pumping) to the underground mine (Fig. 1). Cemented tailings backfill (CTB) is extensively used in Canadian underground mines and in many parts of the world and is following an increasing trend as it offers a number of technical and economical benefits (Lerche and Renetzeder, 1984; Landriault et al., 1997; Hassani and Archibald, 1998; Fall and Benzaazoua, 2003a). Indeed, the CTB technology is considered superior to conventional mine backfill methods in terms of cost-effectiveness (Hassani and Archibald, 1998; Fall and Benzaazoua, 2003b). It is especially important in ensuring the stability of underground mine openings and in maximizing the safe recovery of ore. In addition, the maximum underground disposal of mill tailings is a significant environmental advantage (Huynh et al., 2006).

In order for the CTB to assume the aforementioned roles in a safe and cost-effective manner in underground mining, proper proportioning of the CTB mixtures is necessary. In other words, the mix proportioning of CTB is a vital step in obtaining a CTB that meets desired technical
and economical design requirements. The technical design requirements in question are sufficient compression strength (generally between 0.7 and 2 MPa according to Brakebusch, 1994), acceptable technical consistency (frequently measured by slump test) and high solid concentration (70–85%). While the economical design requirement is that the cost of the CTB must be low. This cost depends on the binder consumption. The binder can represent up to 75% of the cost of the CTB (Grice, 1998).

However, there are no guideline or specifications on CTB mix proportions. In fact, CTB mix proportioning today is still based primarily on traditional experimental methods. The latter require a large number of trial mixes to determine the desired concentrations of the CTB components, whereas a good mix proportioning method serves to minimize the number of trial mixes and provides a satisfactory, economical mixture possessing the desired properties (Bharatkumar et al., 2000). This lack of engineering approach for mix proportioning of CTB is due to several factors. On the one hand, CTB is a relatively new, complex cemented material which is different from concrete (Fall et al., 2005a); studies on CTB have only been ongoing for about 15 years. At the same time, the majority of the studies performed on the optimising of CTB properties (Archibald et al., 1995; Amaratunga and Yaschyshyn, 1997; Hassani and Archibald, 1998; Kesimal et al., 2003; Fall et al., 2004) were only experimental and did not simultaneously take into account all of the performance properties of the CTB. These works were based primarily on the experience of the experts and for the most part, have only allowed a qualitative evaluation of the quality of CTB mixes. Unfortunately, these studies are often largely affected by subjectivity. Additionally, the mathematical approach for the analysis and modeling of performance properties of CTB has not been considered until now in this type of study.

Considering the aforementioned problems and the fact that today’s increasingly competitive environment in the mining industry, combined with strict environmental (Benardos et al., 2001) and safety legislations, demand a higher quality CTB production in a shorter time, the goal of the research was:

- to develop a methodological approach and mathematical models for CTB mix proportioning in order to minimize the number of trial mixes and provide appropriate mix proportion;
- to predict the technical (compression strength, slump, %Solid) and economical (binder cost) performance properties of the CTBs studied;
- to analyze the interactions between the main components of CTB and their effect on its properties;
- to develop optimal mixes for the CTBs studied.

2. Methodology

Fig. 2 shows the methodological approach that was developed and the different steps for predicting the performance properties of CTB and for optimizing its mixture. The methodology comprises three main stages: experimental, modeling, and optimization stage.

The purpose of the first experimental study was to identify and assess the effects of the physical and chemical properties of the main components of CTB (tailings, water, binder) on its mechanical (compression strength) and physical (slump, %Solid) properties. The main results of this experimental investigation are given in Benzaazoua et al., 2004; Fall et al., 2004, 2005a, submitted. An analysis of the results made it possible to define the main mix param-