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Effect of particle gradation on properties of fresh and hardened cemented paste backfill

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HIGHLIGHTS

- Increasing of finer parts in CPB mixture is detrimental to workability of fresh CPB.
- Blending with finer tailing particles can improve gradation of tailings.
- Higher packing density of tailing particles benefits mechanical performance of CPB.

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ABSTRACT

The purpose of this study is to assess the influences of the gradation of tailings on the qualities of coarse tailings used for cemented paste backfill (CPB). Two reference mixtures of tailings (T and W) with CPB and four blended mixtures of tailings with CPB with T/W ratios (the weight ratio of tailings T and W) of 8/2, 6/4, 4/6, and 2/8 were prepared. The moisture content in hardened CPB generally increased as the tailings fineness increased. The relationship among tailings fineness, packing density and unconfined compressive strength (UCS) is discussed. As the tailings fineness increased, the flowability value decreased.

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1. Introduction

The CPB material is a mixture of water, hydraulic binders, and dewatered tailings from mine processing operations [1,2]. As a relatively new mine waste management technology, CPB is extensively applied in underground mine operations around the world because of its technical and economic advantages [3–5].

The tailings are cycloned to separate fine tailings (average particle size less than 0.037 mm) and coarse tailings in China. The fine parts are generally stored in a surface impoundment, whereas the coarse tailings are pumped into underground voids [6]. The tailings in India share the same situation with China [7]. To improve the mechanical performance of CPB, experimental studies have investigated promoting the hydraulic performance of binders by adding ordinary Portland cement (OPC) with granulated blast-furnace slag (GBFS), fly ash and, silica fume [8–11]. The effects of the fine portions of tailings (<20 μm) on the properties of fresh and hardened CPB were investigated in previous studies. The strength of deslimed tailings by sedimentation was significantly higher than as-received mill tailings [12]. The tailings fineness can not only influence the strength of CPB, but also affect its microstructure [13]. Deslimed tailings contribute to strength gains and cost reduction [14]. Desliming of tailings significantly improves the short and long term mechanical strength of CPB [15]. Similar results were also observed in previous research [16]. Desliming is the main method for changing the gradation of these tailings to improve the mechanical performance. The effect of curing under pressure on the strength development of coarse tailings using CPB was studied. The consolidated CPB samples gave significantly higher UCS than the unconsolidated samples [17]. However, reports about the effect of tailings fineness on the properties of coarse tailings using CPB are scarce.

Given the problems mentioned above, the main objectives of this study are as follows:

– To investigate the effects of the tailings fineness on the transportation of fresh CPB.
– To analyze the relationship between tailings fineness and the moisture content of hardened CPB.

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– To investigate the effects of tailings fineness on the packing density and mechanical strength development of coarse tailings using CPB.

2. Materials and methods

2.1. Tailings

Two types of tailings samples (T and W) were obtained from two copper plants located in Hubei Province, China. The specific gravities of these tailings were measured in accordance with the Chinese standard GB/T 208-94 [18]. The particle size distributions of the tailings were measured using a Microtrac S3500 Particle size Analyzer (Fig. 1). The physical and chemical characteristics of the tailings used are given in Table 1. The main mineral composition of the tailings is shown in Fig. 2.

2.2. Binder

Portland Composite Cement (PC, 32.5), which meets the requirements of the Chinese National Standard GB 175-2007, was used in this research [19]. The chemical information of the binder is listed in Table 1.

2.3. Compacted packing density

Compacted packing density was determined as the ratio of compacted bulk density to solid density [20,21]. The compacted bulk density was measured according to the Chinese standard method JGJ 52-2006 [22]. The tailings were filled into the container in two equal portions, and each time a half portion was added, the tailings particles were compacted by applying 25 vibrations against the ground. The compacted packing densities are listed in Table 2.

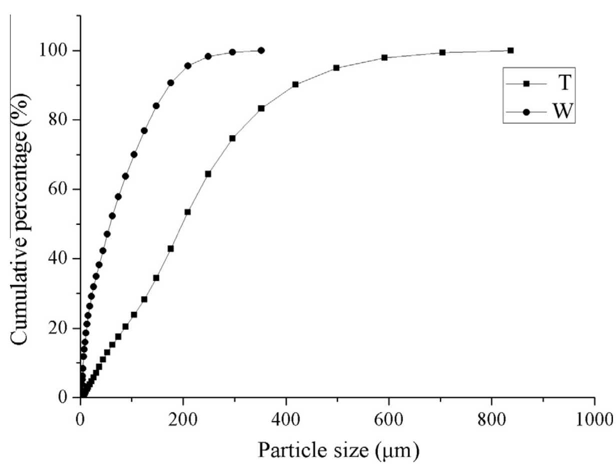

Fig. 1. Particle size distributions of tailings T and W.

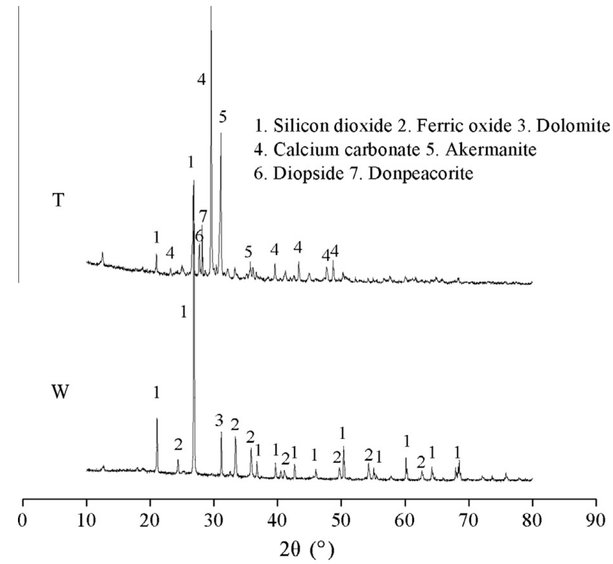

Fig. 2. XRD pattern of tailings T and W.

Table 1
Physical and chemical information of the tailings and binder used in the study.

Characteristic	T tailings (%)	W tailings (%)	Binder (%)
Chemical composition			
CO_2	9.03	–	0.351
Na_2O	0.026	0.14	0.342
MgO	7.065	2.41	5.001
Al_2O_3	5.99	5.12	11.00
SiO_2	27.52	59.67	26.94
P_2O_5	0.14	0.089	0.065
SO_3	0.304	0.045	5.249
K_2O	0.649	0.861	0.739
CaO	27.07	2.45	47.66
TiO_2	0.188	0.076	0.607
MnO	0.410	0.027	0.284
Fe_2O_3	21.03	29.06	1.341
CuO	0.182	–	0.009
Physical properties			
Specific gravity (g/cm^3)	2.91	2.93	2.90
Cc	1.82	1.15	–
Cu	5.68	13.20	–

$C_C = D_{30}^2/(D_{10} \times D_{60})$.
$C_U = D_{60}/D_{10}$.

Table 2
Mix proportions of CPB.

Name	Mixture	Tailings fineness (%)	Weight proportion of binder in the dry mixture (%)	w/c Ratio	Slump (cm)	Compacted packing density
M-1	T	4.181	10	2.99	24.8	0.533
M-2	T/W = 8/2	8.856	10	2.99	23.0	0.553
M-3	T/W = 6/4	13.531	10	2.99	22.2	0.567
M-4	T/W = 4/6	18.205	10	2.99	21.5	0.579
M-5	T/W = 2/8	22.880	10	2.99	20.9	0.585
M-6	W	27.554	10	2.99	20.0	0.589

2.4. Mixture preparation

Tap water was used to mix the binder and tailings. Two types of reference tailings and four types of blended tailings with T/W ratios of 8/2, 6/4, 4/6 and 2/8 were prepared. The particle size distributions of the four blended tailings are shown in Fig. 3. The required amounts of tailings were weighed and mixed with cement in a metal container. A designated volume of tap water was added, and the mixture was mixed until a homogeneous paste was obtained. The produced CPB mixtures were molded in 40.0 mm × 40.0 mm × 40.0 mm metal cubes and cured in a moist cabinet at 20 ± 1 °C with a relative humidity of 80 ± 5% for 24 h (sealed). The mixtures were then demolded and placed in the same cabinet under the previously mentioned curing conditions until the mechanical testing was conducted. The proportions of the mixtures are shown in Table 2.

2.5. Flowability tests

Flowability tests, in accordance with the Chinese Standard GB/T 2419-2005, were conducted to measure the transportation of the fresh CPB mixture [23]. The cone has a base diameter of 100 mm, a top diameter of 70 mm, and a height of 60 mm. The binder, tailings and tap water were weighed and mixed in a container until a homogeneous paste was obtained. Then, the cone was placed centrally on the disc of the flow table and mortar paste was introduced in two layers. The first layer was compacted by 15 short strokes of a tamper, and the second layer was compacted by 10 strokes to ensure uniform filling of the cone. The excess mortar was removed with a knife. Then, the cone was vertically raised, and the mortar was spread on the disc by jolting the flow table 25 times at a constant frequency of one per second. The diameter of the mortar in two directions at right angles was measured. The average value of the two diameters was the value of the

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