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Utilization of limestone powder and water-reducing admixture in cemented paste backfill of coarse copper mine tailings

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HIGHLIGHTS

- Increasing finer LP up to 10 wt% improves workability of coarse tailings CPB.
- Coupled effects of LP and WRA are outstanding beneficial to workability of CPB.
- The complex incorporation of LP and WRA benefits mechanical performance of CPB.
- The UCS of CPB becomes larger when the pores of CPB samples becomes finer.

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ABSTRACT

The purpose of this study is to assess the coupled effects of limestone powder (LP) and water-reducing admixture (WRA) dosages (by dry total mass) on the properties of cemented paste backfill (CPB) of coarse copper mine tailings. The mineralogical analysis and pore structure of the hardened samples are investigated by X-ray diffraction (XRD) and mercury intrusion porosimeter (MIP). Increasing LP dosages up to 10 wt% is beneficial to the workability of CPB mixtures, thereafter, the slump of CPB mixtures tends to decrease. The complex incorporation of LP and WRA remarkably improves the workability of CPB mixtures and increases the unconfined compressive strength (UCS) and the long-term stability of CPB samples by reducing W/B ratio without decreasing the slump value. The pores of CPB samples tend to become finer with increasing curing times and the incorporation of LP and WRA at the same slump value of CPB mixtures.

1. Introduction

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 [1], whereas the coarse tailings mixed water and a hydraulic binder are transported by gravity into underground voids. The relatively high binder contents (10–20 wt% by dry mass) are used to produce a flowing backfill (containing typically 60–75 wt% solid) that has about 20 wt% bleeding rate during setting and a uniaxial compressive strength (UCS) of 0.5–5 MPa at 28 days [2,3].

The copper mine tailings are often rich in pyrite and contain toxic metals such as arsenic (As), copper (Cu) and zinc (Zn). The oxidation of pyrite in presence of water and oxygen generates acidity and facilitates the release of toxic metals contained in the tailings [5,6]. Nowadays, the method of the hazardous mill tailings posed by the flowing backfill is restricted and used increasingly less. As a relatively new mine waste management technology, cemented paste backfill (CPB) is extensively applied in underground mine operations around the world because of its significant environmental, technical and economic benefits [7–9]. CPB is a cementation material produced with three ingredients: (1) filtered mine tailings (containing typically 70–85 wt% solid), (2) hydraulic binders (1–7 wt% by dry mass of tailings), and (3) mixing water to ensure the paste's flowability in the pipeline for final deposition [4].

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 [10–12]. Benzaazoua et al. [13] demonstrated the beneficial effect of the partial replacement of OPC with GBFS only for low- to medium-grade

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Table 1
Chemical and physical properties of binder and tailings used.

Composition		SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	Cu (%)	Zn (%)	S (%)	Loss
Tailings		44.54	–	16.18	8.14	3.58	0.11	0.65	5.14	18.92
OPC		25.26	6.38	4.05	54.67	2.68	–	–	0.06	–
GBFS		31.68	12.77	2.02	40.80	4.76	–	–	0.84	–
LP		2.40	0.15	2.89	49.50	2.35	–	–	–	42.5%
Physical properties	SSA (m^2/kg)	Gs (–)	>90 μm (%)	>45 μm (%)	D10 (μm)	D30 (μm)	D60 (μm)	Cu (–)	Cc (–)	%Fine (<20 μm)
Tailings	119.7	2.81	37.52	61.71	10	35	85	8.5	1.44	18.73
OPC	461.9	3.08	–	5.67	5.12	9.19	18.28	3.6	0.90	65.65
GBFS	454.7	2.90	0	5.0	6.47	11.97	19.99	2.1	1.11	62.15
LP	1013	2.78	0.3	2.0	0.23	1.13	4.50	19.6	1.23	90.68

sulphide tailings, but not for sulphide-rich tailings (≧32% S). Fly ash as pozzolanic additive was found to be not particularly suitable for CPB [11]. The addition of silica fume reduced the severity of the strength losses observed after 56 days [4]. Recently there has been considerable interest in the utilization of nonpozzolanic (i.e. marble waste) and artificial pozzolanic (i.e. waste bricks) admixtures for the partial replacement of OPC to reduce binder costs, improve the resistance to acid and sulphate attack, and increase the strength and durability of CPB [9]. The influence of water-reducing admixture (WRA) on the rheological properties of CPB mixtures and the strength and stability performance of CPB was also investigated in previous studies [14,15]. The effects of the fine portions of tailings (<20 μm) on the properties of fresh and hardened CPB were investigated in previous studies [16,17]. However, reports about the coupled effects of limestone powder (LP) and water-reducing admixture (WRA) on the properties of cemented paste backfill of coarse copper mine tailings are scare.

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

(1) To investigate the effects of LP and WRA dosages on the workability of CPB mixtures.
(2) To investigate the coupled effects of LP and WRA on mechanical strength development of hardened CPB.
(3) To analyze the relationship between micro-structure and UCS of hardened CPB.

2. Materials and methods

2.1. Tailings and binder

The tailings sample used in this study is obtained from an underground copper mine located in the south of China. Particle size analysis of the tailings indicates that the tailings can be

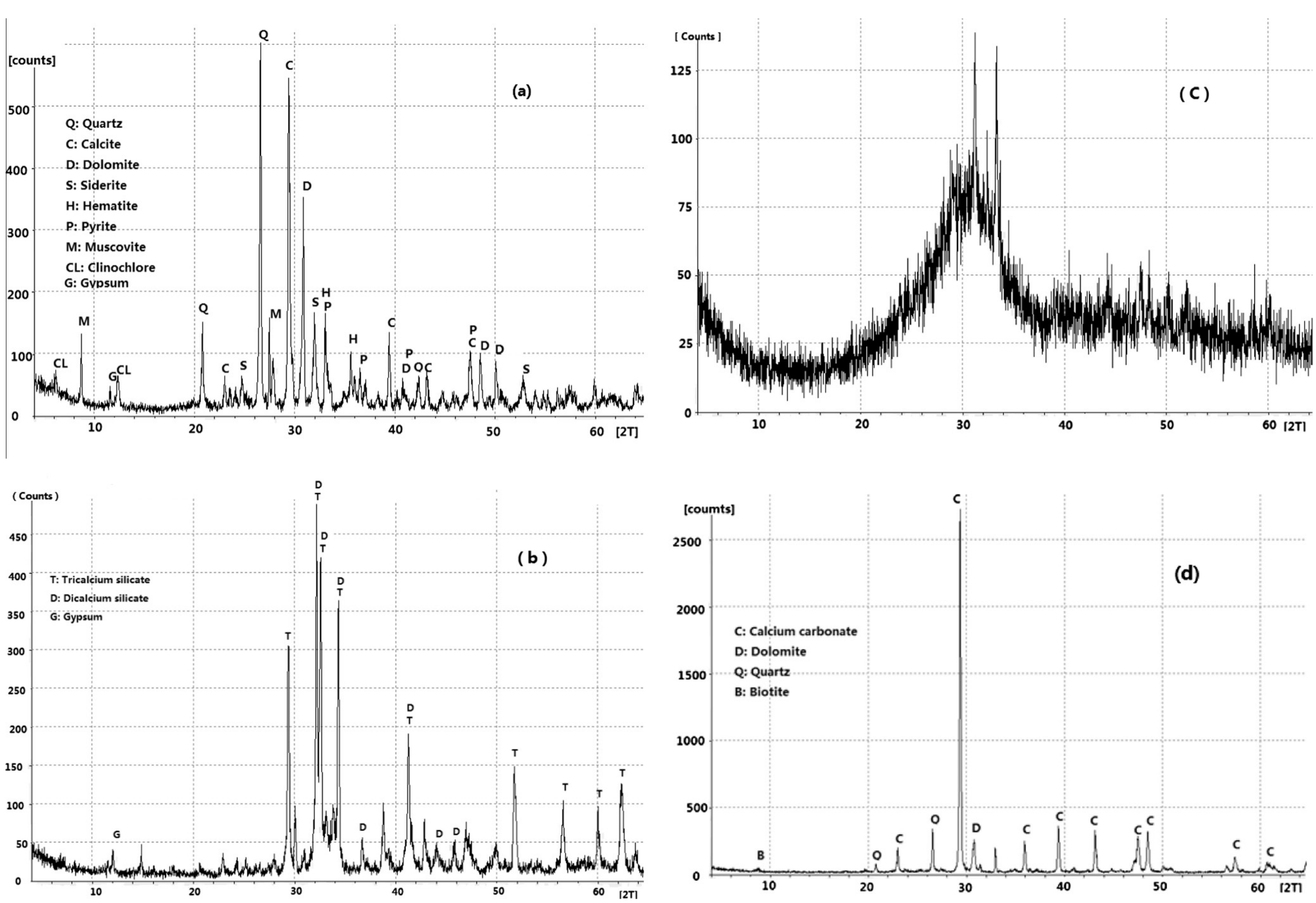

Fig. 1. XRD profiles of copper mine tailings (a), OPC (b), GBFS (c) and LP (d).