



Early-age hydration characteristics of composite binder containing iron tailing powder

Fanghui Han ^{a,*}, Li Li ^b, Shaomin Song ^b, Juanhong Liu ^a

^a School of Civil and Resource Engineering, University of Science and Technology Beijing, Beijing, China

^b School of Civil and Transportation Engineering, Beijing University of Civil Engineering and Architecture, Beijing, China

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ABSTRACT

The early-age hydration characteristics of composite binder containing iron tailing powder were investigated by determining the hydration heat, non-evaporable water content, pore structure, and morphology of hardened paste as well as the compressive strength of mortar. The results show that the reaction degree of iron tailing powder is extremely low at early age. Addition of coarse iron tailing powder negatively affects the properties of composite binder paste and mortar. Compared to samples containing coarse iron tailing powder, the samples containing fine iron tailing powder show a large amount of hydration heat, high non-evaporable water content, fine pore structure of hardened paste and high compressive strength of mortar. The iron tailing powder significantly promotes the hydration of binder at low water-to-binder ratio. The iron tailing powder particles are well graded with cement particles in the paste, but the large iron tailing powder particles bond poorly with the surrounding hydrates. The decreasing ratio of compressive strength of mortar is much lower than the replacement level of iron tailing powder, especially for the mortar containing fine iron tailing powder at low water-to-binder ratio.

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1. Introduction

With the rapid development of the national economy, the construction of infrastructure and buildings has greatly increased in China. The increasing demand for natural energy and resources has produced considerable industrial wastes. To reduce the environmental impact and achieve sustainability, industrial wastes should be used for secondary purposes. Most industrial waste is used in the concrete industry [1], where these wastes can be used to partially replace clinker in blended cement or to partially replace cement or aggregate in concrete [2–5]. Using industrial waste saves energy and resources, reduces the cost of concrete and decreases carbon dioxide emissions. The most commonly used industrial wastes in modern concrete are ground granulated blast furnace slag, fly ash and silica fume. The physical and chemical properties of these materials contribute to the strength development and durability of concrete [6]. However, at present, the quantity of these industrial wastes is limited in China and their prices are increasing rapidly. To ensure the sustainable development of the concrete industry, other industrial wastes must be used in concrete.

Iron tailings are mining waste obtained during the beneficiation process to concentrate the iron ore [7]. More than six hundred million tons of iron tailings are generated in China each year. The accumulated

quantity of iron tailings has reached five billion tons, which accounts for more than 80% of industrial solid waste [8,9]. However, the utilization rate of iron tailings in China is only 7% [10]. Thus, large quantities of iron tailings are piling up, occupying land, and polluting air and water. Therefore, disposing iron tailings using proper methods is crucial. Because iron tailings mainly contain silica, alumina, iron, magnesium, and calcium, iron tailings can be used in the construction industry [11].

Shettima et al. [12] found that iron tailings can be used as fine aggregate replacement in concrete. Adding iron tailings decreased the workability of concrete while increasing the strength and elasticity modulus compared to conventional concrete. Zhao et al. [13] found that the mechanical properties of ultra-high performance concrete were comparable to control concrete when no more than 40% of the fine aggregate was replaced with iron tailings. Huang et al. [14] reported that engineered cementitious composites using iron tailings as the aggregate obtained good tensile and compressive strength and that fine iron tailings resulted in better fiber dispersion. Li et al. [15] found that the mechanical properties of cementitious material prepared by blending 30% clinker, 34% blast furnace slag, 30% iron tailings and 6% gypsum were comparable with those of 42.5 ordinary Portland cement. Yunhong et al. [16] reported that mechanochemically activated iron tailings have pozzolanic characteristics and can be used as supplementary cementitious material in concrete; in ordinary concrete, the maximum replacement level is 30%, but could be up to 40% for concrete at low water-to-binder ratio. Ma et al. [17] noted that substituting 40%–60% of silica

* Corresponding author.

E-mail address: hanyang-1120@163.com (F. Han).

Table 1
Chemical compositions of cement and iron tailing powder wt%.

Composition	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	Na ₂ O _{eq}	f-CaO	LOI
Cement	20.55	4.59	3.27	62.50	2.61	2.93	0.53	0.83	2.08
Iron tailing powder	67.29	8.49	8.95	3.63	4.80	0.45	2.90	–	2.39

Na₂O_{eq} = Na₂O + 0.658K₂O.

sand with iron tailings in autoclaved aerated concrete could sufficiently improve the density and compressive strength of the concrete to satisfy the requirements of B05, A2.5 grade in the Chinese National Standard. The C-S-H gel and tobermorite contribute to the compressive strength. Iron tailings were also used for the production of fired brick [18] and in combination with fly ash to produce geopolymers [19,20].

According to the current literatures, iron tailings are usually used as fine aggregate in concrete. There is little information about using iron tailings as supplementary cementitious material in concrete, mainly due to its low activity; the content of iron tailings in clinker is only 5% [21]. In addition, the early-age hydration characteristics of composite binder are very important to understand the hydration mechanism, but there is little deep study on the early-age hydration characteristics. In this paper, iron tailings are ground to decrease their particle size. Then, the iron tailing powder is used partially replace cement in composite binder. The early-age hydration characteristics of the composite binder containing iron tailing powder are investigated. The fineness of the iron tailing powder, the water-to-binder ratio, and the replacement level are all considered. The purpose of this research is to investigate the effect of iron tailing powder on the hydration mechanism of the binder and the possibility of using iron tailing powder as mineral admixture in concrete.

2. Experimental

2.1. Raw materials

P.I 42.5 Portland cement that conformed to Chinese National Standard GB 175-2007 and iron tailings from a mining enterprise in Miyun County of Beijing were used in this study. The chemical compositions of the cement and iron tailing powder determined using X-ray fluorescence (XRF) are shown in Table 1. The main chemical composition of the iron tailing powder is SiO₂, followed by Fe₂O₃ and Al₂O₃. The iron tailings fall into the category of high-silicon iron tailings. The X-ray diffraction (XRD) pattern of the iron tailing powder is presented in Fig. 1, which shows that the main mineral phase of the iron tailing powder is

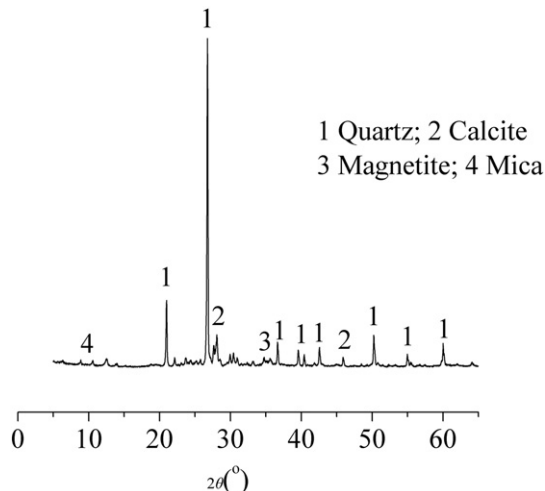


Fig. 1. XRD patterns of iron tailing powder.

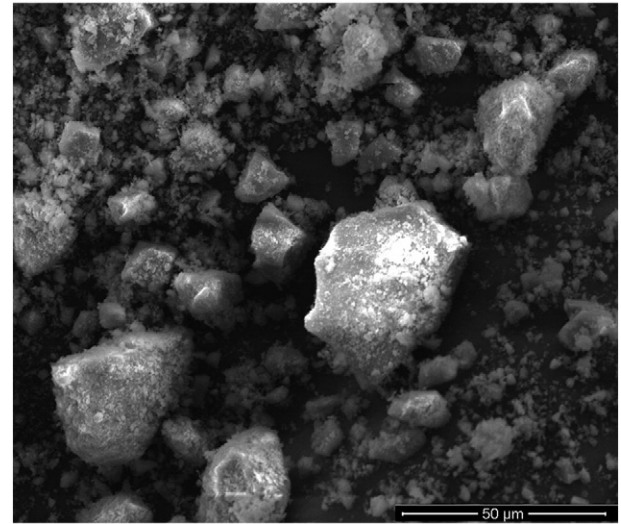


Fig. 2. Morphology of iron tailing powder.

quartz. Fig. 2 shows the morphology of the iron tailing powder; many fine particles exist after mechanical grinding along with some coarse particles with irregular shapes. The coarse iron tailing powder and fine iron tailing powder are used in this study; these powders were ground in a ball mill for 20 min and 60 min, respectively. The particle size distributions of the raw materials are given in Fig. 3, which clearly shows that the iron tailing powder is finer than Portland cement. The medium particle size (d_{50}) for the cement, coarse iron tailing powder and fine iron tailing powder are 17.17 μm, 7.31 μm and 3.56 μm, respectively. The water requirement ratio of fine iron tailing powder is 104%, which indicates that the water requirement of iron tailing powder is slightly higher than that of Portland cement.

2.2. Mix proportions

The mix proportions of pastes and mortars containing iron tailing powder are shown in Tables 2 and 3, respectively. The replacement levels of iron tailing powder were 0, 20% and 50% by mass, and water-to-binder (w/b) ratios of 0.3 and 0.4 were used in this study. The pastes were prepared by mixing binder with water according to Table 2. The mortars were prepared by mixing ISO standard sand, binder and

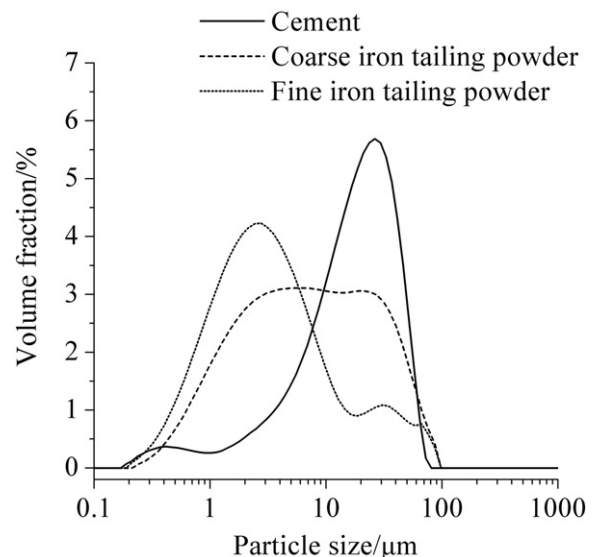


Fig. 3. Particle size distributions of raw materials.

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