

Research on High-Temperature Resistance of Iron Tailings Concrete

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Abstract

Iron tailings, as industrial solid waste generated during the mineral processing operations, are experiencing a continuous increase in their reserves due to ongoing mining activities. The massive accumulation of iron tailings not only occupies valuable land resources but also causes severe ecological damage to mining areas. The utilization of solid waste materials for the production of recycled aggregate concrete is of crucial importance for the sustainable development of the construction industry. In recent years, research on solid waste-based concrete, particularly focusing on the durability and high-temperature resistance of iron tailings concrete, has advanced rapidly, yielding a series of notable achievements. This paper analyzes multiple articles on iron tailings concrete research, summarizing the existing outcomes and identifying the gaps in the current knowledge base. The objective is to provide a reference for future research endeavors in this domain.

Keywords

Iron Tailings; Concrete; High-Temperature Resistance.

1. Introduction

Mineral resources are crucial for social development, and iron ore, as a core raw material for the steel industry, remains in high demand. Affected by the depletion of high-quality resources, the grade of iron ore mined from the original ore has declined, leading to a continuous increase in the stockpile of iron tailings. In China, the annual discharge of iron tailings is approximately 130 million tons. The massive accumulation of iron tailings not only occupies a large amount of land but also causes environmental problems such as dust pollution and groundwater contamination, posing threats to the ecological environment and residents' health. Therefore, the efficient comprehensive utilization of iron tailings has become an urgent issue.

Iron tailings are solid wastes generated during the ore dressing processes, including crushing, grinding, gravity separation, magnetic separation, etc. Iron ore resources in China are characterized by low grade, fine particle size, and complex mineralogy. The average iron grade of the original ore is only about 31.30%, significantly lower than the world average of 45.79%, and more than 60% of the original ore is discharged as tailings. These tailings contain components such as silicon, aluminum, and have high potential for resource utilization. However, the comprehensive utilization rate of tailings in China is less than 10%, and that of iron tailings is even lower, at less than 7%, which is far behind the 60% utilization rate in developed countries, resulting in a huge pressure of stockpiling.

With the increasingly stringent environmental protection requirements, the Chinese government has implemented strict controls on the discharge of iron tailings. Meanwhile, the expansion of infrastructure construction has led to a surge in the demand for cement and sand and gravel aggregates. The excessive mining of natural river sand has damaged riverbeds and caused potential safety hazards, prompting the government to introduce a series of policies to restrict river sand mining. Iron tailings share similarities with cement raw materials and river

sand in terms of chemical composition, particle gradation, and mechanical properties. Using iron tailings to prepare concrete can replace traditional resources and consume a large amount of stockpiled iron tailings, bringing both resource and environmental benefits.

However, due to the complex composition of iron tailings sand, the high-temperature mechanical properties of iron tailings concrete are unstable. Key mechanical indicators such as strength and elastic modulus are significantly affected by high temperatures, which restricts its large-scale application in engineering. Therefore, conducting research on the high-temperature performance of iron tailings concrete and revealing its damage mechanism are crucial for promoting its engineering application. This paper will review the research progress on the high-temperature resistance of iron tailings concrete at home and abroad in recent years, aiming to provide theoretical and technical support for its practical application.

2. Properties of Iron Tailings

2.1. Apparent Morphology

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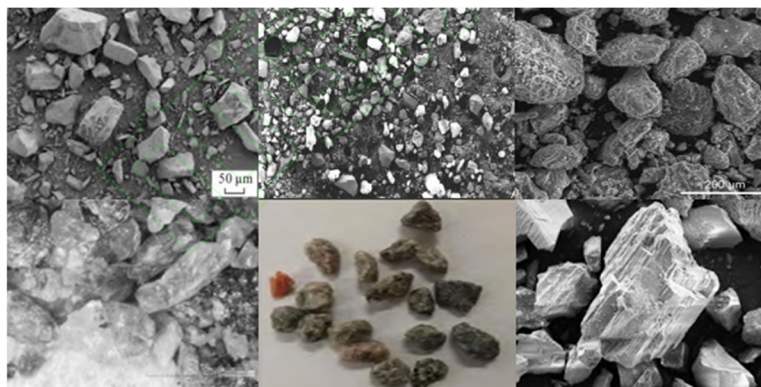


Fig 1. Apparent morphology of iron tailings from different regions[1]

2.2. Particle Size Composition

Concrete is a composite material made by mixing cementitious materials, aggregates (including coarse and fine), and some additives. The gradation of concrete describes the bonding state between cement and aggregate particles. The gaps of coarse aggregates are filled by fine aggregates, and the gaps of fine aggregates are further filled by cementitious materials. A good filling state means reasonable gradation design, making the concrete more dense and with excellent performance. Therefore, when using iron tailings as raw materials for concrete, their particle size and overall gradation must be carefully considered. The particle sizes of iron tailings in different regions vary.

2.3. Chemical Composition

When preparing concrete with iron tailings, special attention should be paid to their harmful components, such as sulfur, chlorine, iron oxide, etc., which are common in iron tailings. Table 1 shows the elemental compositions of iron tailings in different regions. From the data in the

table, it can be seen that although the SiO_2 content varies by region, SiO_2 has the highest proportion, and most regions exceed 60%, which provides favorable conditions for iron tailings to be used as concrete raw materials.

Table 1. Chemical composition of iron tailings from different regions

Region	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Other
Liaoning Jiguan Mountain iron tailings	69.60	7.48	12.87	2.90	3.77		3.38
Tangshan a certain iron tailings	70.21	7.08	18.46	3.34	0.31		0.60
Fujian a certain iron tailings	37.10	4.70	22.20	19.90	1.30	5.50	9.30
Hebei Qian'an a certain iron tailings	64.71	7.49	12.17	3.69	6.89	0.19	4.76
Beijing Miyun area iron tailings	61.73	9.09	14.89	5.86	3.52	0.71	4.20

3. Research on High-Temperature Resistance of Iron Tailings Concrete

Compared with ordinary strength concrete, the advantage of iron tailings concrete lies in the compactness of its microstructure. However, good compactness greatly reduces fire resistance. When a fire occurs, the concrete structure is subjected to high temperatures of 1000 °C or higher in a short time, leading to explosive spalling of its protective layer, or even local damage and collapse, which seriously reduces the bearing capacity and fire resistance of the concrete structure. Therefore, studying the fire resistance of iron tailings, especially the blasting performance after high-temperature exposure, is of great significance.

Scholars have carried out a large number of studies on the high-temperature resistance of concrete components. Wang Weiwei and Liu Haiqing [2] took the replacement rate of iron tailings sand fine aggregate (0, 25%, 50%, 75%, 100%) as the change parameter to complete the high-temperature test of 90 iron tailings sand concrete cube specimens at 20-800 °C. The study shows that with the increase of temperature, the mass loss rate continues to increase, and the mass loss rate of 100% iron tailings sand concrete at 800 °C reaches 9.3%; with the increase of temperature, the residual compressive strength continues to increase, and the residual compressive strength loss rate at 800 °C reaches 78%; Wu Kai [3] used two iron tailings sand reinforced concrete beams with different strengths (C30, C40) to carry out fire tests using the ISO834 heating curve. The experimental results show that the C40 iron tailings sand reinforced concrete beam has more surface cracking cracks than the C30 one, and the concrete is loose, bulging, and spalling seriously. The fire resistance limits of C30 and C40 iron tailings sand concrete beams are 93.05min and 106.1min, respectively. The bending performance of C40 iron tailings sand concrete beams under fire has been significantly improved compared with C30. After the fire test, the fire-exposed surface of the iron tailings sand reinforced concrete beam is slightly yellowish, while the fire-exposed surface of the natural sand reinforced concrete beam is grayish white. Iron tailings sand and natural sand concrete have little effect on the bending performance of simply supported beams and continuous beams under fire.

According to Grubeša et al., high temperatures affect the properties of concrete, including steel slag in coarse aggregates. In addition, they studied the effects of fly ash as a Portland cement substitute and polypropylene fibers as reinforcing materials. Their samples were heated to temperatures from 100°C to 800°C throughout the 56-day curing process. In addition to the

residual mechanical properties of the cooled specimens, their weight loss and the residual velocity of ultrasonic pulses were evaluated and compared with concrete containing dolomite aggregates. The results showed that the residual properties of concrete made from steel slag aggregates were comparable to those of dolomite concrete at temperatures up to 600°C [4]. In the experiment conducted by Talaei and Mostofinejad, the use of steel fibers reduced the compressive strength drop by 20% and 30% at temperatures of 400°C and 800°C, respectively. On the other hand, polypropylene fibers do not change mechanical properties such as compressive strength or tensile strength, while they can keep the concrete intact and prevent spalling [5].

4. Conclusion

In recent years, China has made remarkable progress in the comprehensive utilization of iron tailings. With the increase in iron ore mining volume, the comprehensive utilization rate of iron tailings has also gradually increased. Facing the current situation of gradually depleting mineral resources, the development and utilization of iron tailings have become inevitable, which has a positive impact on resource conservation, environmental protection, and social and economic benefits.

In concrete preparation, iron tailings are mainly applied by replacing cementitious materials and aggregates. Although some iron tailings concrete has entered practical application, most of it is still in the laboratory research and development stage. The main current problems include insufficient activity of iron tailings, poor workability of concrete, and low utilization rate of iron tailings in concrete. Therefore, future research on iron tailings concrete should focus on the following aspects:

- (1) On the basis of ensuring the workability and durability of concrete, strive to improve the high-temperature resistance of iron tailings to better apply iron tailings concrete in practical engineering;
- (2) Strengthen the research on the activity of iron tailings to better replace cement as a cementitious material;
- (3) Strengthen the exploration of reducing the mass loss and strength loss of iron tailings concrete after high temperature.

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