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Research progress on the substitution of iron tailings sand for natural sand to prepare concrete

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Abstract

With the increasing application of concrete in various projects, there is a serious crisis in the aggregate resources of concrete. Iron tailings sand is made from waste residue after beneficiation, and if it can be used to replace natural sand to prepare iron tailings sand concrete, it will have a positive impact on the environment and the secondary recycling of resources. In this paper, the physical and chemical composition of mineral waste iron tailings sand and the mechanical properties applied to concrete and concrete made of natural sand are reviewed, in order to explore the feasibility of iron tailings concrete in practical engineering.

Keywords

Iron tailings; natural sand; iron tailings concrete; viability.

1. Introduction

With the rapid development of urbanization in China, the demand for concrete in buildings is increasing, so more natural resources such as sand and gravel are needed. A large number of mountains and quarrying have caused irreversible ecological damage such as soil erosion and river diversion. Many large cities in the country have banned the mining of river sand, which makes the contradiction of lack of construction sand increasingly prominent, so the selection of alternative materials for sand has become a major problem. Iron tailings sand is a solid mineral waste formed by natural dehydration of tailings slurry discharged from a concentrator, which is the main component of solid industrial waste, and can be regarded as a composite mineral material such as silicate or carbonate. The content of the main useful components in the tailings is called the tailings grade, and the iron tailings sand is used as a fine aggregate in concrete instead of natural river sand.

The use of iron tailings as concrete aggregate instead of natural sand and gravel, and the use of iron tailings sand instead of natural river sand, as a fine aggregate in concrete materials, can not only solve the problem of concrete shortage, but also achieve the purpose of rational use of iron tailings. It is of great significance to save resources, improve the environment, realize the optimal allocation of mineral resources and the sustainable development of mining economy. At present, many scholars [1,2,3,4,5] have carried out studies on the mechanical properties and durability of iron tailings concrete with different dosages, and found that with the increase of the substitution rate of iron tailings, the compressive strength of iron tailings concrete shows a change law of increasing and then decreasing, and the properties of iron tailings concrete are basically the same as those of ordinary concrete at the optimal dosage. Iron tailings can be used as a fine aggregate to replace depleted natural river sand by optimizing the mix ratio of ordinary concrete [6,7].

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2. The current state of iron tailings sands

The amount of tailings stored in China's existing mines is nearly 5 billion tons, and the annual discharge of tailings is as high as more than 500 million tons, of which the annual discharge of iron ore is 150 million tons, accounting for about 60% of the selected iron ore. The comprehensive treatment and development and utilization of iron tailings is a major issue we are facing, and in recent years, tailings as a secondary resource has been valued by countries around the world. About 60%~70% of the tailings sand discharged from the iron concentrator plant can be screened out as artificial sand for construction, which can undoubtedly consume a large amount of iron tailings.

The tailings are easy to flow when they are stockpiled, causing vegetation damage and injury accidents, especially in the rainy season, which can easily cause collapse and landslides. The tailings dam body is high, and there are unsafe hidden dangers. There are too few mineral resources with large iron content in China, the operation technology of mineral processing is relatively backward, and the waste discharged after mineral processing is not well treated, which makes China's iron tailings solid waste occupy a large number of land resources and damage the environment [8]. In recent years, China's industry has developed rapidly, resulting in more and more serious phenomena, which has attracted everyone's attention. For example, the accumulation of iron tailings sand not only wastes land resources but also pollutes the environment. Enterprises have economic pressure, forming potential safety hazards and generating waste of resources. It can be seen that the accumulation of waste materials after beneficiation has caused serious harm to our lives, so the performance research of iron tailings should be accelerated to ensure that it can be fully utilized.

3. Physicochemical properties of iron tailings concrete

3.1. Physical properties of iron tailings sands

The physical morphology of iron tailings usually exhibits inhomogeneity, including the angle and shape of the particles. The tailings particles exhibit distinct angular characteristics, and the brightly colored particles are usually iron oxides. The apparent density of iron tailings sands is typically between 2.6 and 3.0 g/cm^3, depending on its particle composition and moisture content. This value is higher than the density of natural river sand, which leads to certain advantages in its application in concrete and other building materials. Iron tailings sands have a wide particle size distribution, usually containing fine particles of less than 75 μm and coarse particles of more than 4.75 mm. Iron tailings sands are mainly composed of fine sand and silt, showing the characteristics of a transitional homogeneous material. Iron tailings that meet the requirements of "Construction Sand" [9] can replace natural river sand to make concrete for use in the construction industry.

The water absorption rate of iron tailings is relatively low, usually between 1% and 3%, which indicates that it can maintain good strength and stability during the mixing process. According to the experimental data, the water content of iron tailings is usually kept below 5%, and the moisture ratio can be effectively controlled to ensure the strength of the concrete when used in concrete.

3.2. Chemical properties of iron tailings sands

In this paper, iron tailings in Qian'an District, Tangshan City, are used to analyze the material properties of iron tailings and natural sand. As shown in Table 1 and 2, the mineral composition of iron tailings sand and natural sand contains more Si02 and Al2O3, and the proportion of silicon and calcium oxides in the chemical composition is similar to that of natural sand, and after inspection, the light substances and harmful impurities in iron tailings that affect the overall performance of concrete do not exceed the requirements of national standards.

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The high content of iron oxide in iron tailings makes iron tailings show excellent activity in concrete, and can react with cement to form hydration products with high strength. In addition, iron tailings also contain some trace elements, which can improve the performance of concrete under certain conditions.

Table 1 Chemical composition of tailings sand

chemical composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Other substances
content（%）	68.6	6.7	12.0	2.8	3.8	6.1

Table 2 Chemical composition of natural sand

chemical composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Other substances
content（%）	76.97	10.90	1.89	2.77	2.23	5.24

4. Mechanical properties of iron tailings concrete

Li Zhiyuan, Chen Feng [10] used the same ratio to prepare natural sand and iron tailings green concrete with different substitution rates, and studied the mechanical properties and durability of the iron tailings green concrete, and the experimental results pointed out that when the substitution rate of iron tailings was 60%, the strength and durability of the concrete were significantly improved, and the tensile strength of other iron tailings sand, The carbonization resistance is also higher than that of natural sand concrete to varying degrees. In order to explore the feasibility of using iron ore tailings to replace natural aggregates to produce ultra-high performance concrete, Zhao S et al. [11] found that when the iron tailings content is 100%, the workability and compressive strength of concrete are significantly reduced, and when the content is not more than 40%, the mechanical properties of standard curing 90 days are basically the same as those of natural sand concrete, indicating that it is feasible to use iron ore tailings to partially replace natural sand to produce ultra-high performance concrete within a certain range. Cheng Heping [12] conducted an experimental study on the mechanical properties, hydration characteristics and durability of iron tailings concrete, and found that the 20% iron tailings content had a significant impact on the mechanical properties, impact resistance, permeability and hydration properties of concrete, and the compressive strength of other contents was higher than that of concrete without iron tailings. Xu F et al. [13] used different proportions of iron tailings to replace ordinary silica sand to prepare recycled aggregate concrete, and explored the influence of iron tailings on the durability and mechanical properties of recycled concrete, and pointed out through experiments that the addition of iron tailings has a significant improvement on the compressive strength of concrete, the splitting tensile strength of recycled concrete with a large amount of iron tailings is slightly lower than that of traditional concrete, and the iron tailings has better durability under 10% and 20% replacement rates. Yin Shaoning [14] studied the shrinkage cracking performance of iron tailings concrete at different ages and dosages, and the experimental results showed that the compressive strength and flexural strength of the mortar were significantly improved with the increase of the substitution amount of iron tailings under the same mix ratio, especially when the substitution amount reached 100%, the strength increase was more significant, but the shrinkage cracking at 90d was greater than that of natural sand concrete.

Zhang Y et al. [15] used iron tailings sand, finely ground blast furnace slag and fly ash to replace fine aggregates and some cementitious materials in concrete to prepare high-performance concrete, and found that when the developed 100% iron tailings concrete replaced 30% cement with fly ash and blast furnace slag, the compressive strength and impermeability of high-performance concrete with iron-doped tailings were improved to varying degrees. Duan Y et al. [16] used iron tailings and natural sand as fine aggregates to prepare concrete, and found that the 28d compressive strength of all-iron tailings concrete was slightly higher than that of concrete with natural sand as fine aggregate, and the elastic modulus of iron tailings concrete mixed with iron tailings powder was not much different from that of ordinary concrete mixed with fly ash. Cai Jiwei et al. [17] used iron tailings sand to completely replace natural sand as the fine aggregate of concrete to prepare a comparison of the workability of tailings sand and gravel concrete with different strengths and ordinary concrete, and the experimental results showed that under the same mix ratio, the fluidity of ordinary concrete was slightly higher than that of iron tailings sand and gravel concrete, but the compressive strength between the two was about the same. Ma X et al. [18] used iron tailings ore and iron tailings sand as coarse aggregate and fine aggregate respectively, and used iron tailings powder as admixture to prepare all-iron tailings concrete beams, and their bending properties were studied, and the experimental results showed that the structural properties of all-iron tailings concrete beams such as yield, crack resistance and ultimate bending moment were similar to those of ordinary concrete beams, and the utilization rate of iron tailings in the all-iron tailings concrete beams accounted for 87% of the total solid materials, which greatly promoted the green development of concrete. Chen Jialong et al. [19] prepared iron tailings sand concrete and natural sand concrete through comparative experiments under the same conditions, and the experimental results showed that the compressive strength of iron tailings concrete with different strengths was higher than that of natural sand concrete to varying degrees, and the workability was basically the same as that of natural sand concrete mixture. Shettima U et al. [20] conducted splitting tensile and compressive strength, elastic modulus and durability experiments on iron tailings concrete with different contents, and found that the mechanical properties of iron tailings concrete with different substitution rates were better than those of ordinary concrete under the same water-cement ratio, and the elastic modulus of concrete was increased by 39.5% compared with ordinary concrete when the iron tailings content was 100%.

In summary, scholars at home and abroad have done a lot of in-depth research on the mechanical properties and durability of iron tailings sand concrete at room temperature. The above studies found that the appropriate amount of iron tailings sand instead of natural river sand to prepare concrete can significantly improve the compressive strength, elastic modulus and splitting tensile strength, and the compressive strength of 100% iron tailings concrete is basically the same as that of traditional concrete, or even better than that of natural sand concrete.

5. Conclusion

The physical and chemical properties of iron tailings are similar to those of natural sand. Through reasonable proportioning and mixing process, its mechanical properties are not much different from natural river sand concrete, and meet the requirements of use as concrete fine aggregate, iron tailings can become an excellent choice of building materials to provide support for the sustainable development of the modern construction industry.

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