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Study on mechanical properties of recycled steel fiber reinforced iron tail sand lightweight aggregate concrete

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Abstract

In order to respond to the national "double carbon" strategy, fully, accurately and comprehensively implement the new development concept to achieve carbon peak carbon neutral work, give play to the advantages of solid waste resource utilization, explore the mechanical properties of recycled steel fiber reinforced iron tail sand lightweight aggregate concrete and the reinforcement effect of recycled steel fiber on lightweight aggregate concrete. Iron tailing ore is used to replace fine aggregate in lightweight aggregate concrete and pulverized coal ash ceramide is used to replace coarse aggregate. Meanwhile, recycled steel fiber is added. In order to explore the feasibility of replacing fine aggregate in lightweight aggregate concrete with iron tailings ore, replacing coarse aggregate with pulverized coal ash ceramite and adding recycled steel fiber, the influences of iron tailings ore, pulverized coal ash ceramite and recycled steel fiber on concrete are analyzed, and the influences on mechanical properties of concrete are studied through flexural and compressive tests.

Keywords

Iron tailings, Steel fiber, Recycling steel fibers.

1. Introduction

As one of the main representative materials of building materials, concrete has become the most widely used building materials because of its characteristics of high strength, low cost and easy processing. With the increasing dosage of concrete, a large amount of sand is mined, which leads to serious river damage and aggravated soil erosion in our country, which is contrary to the strategic principle of sustainable development in our country [1]. As a composite mineral raw material, iron tailings are the remaining waste of iron ore after a series of beneficiation processes. A large amount of iron tailings not only occupy a large amount of land area, but also easily lead to ground collapse, mountain cracking, collapse, soil erosion, debris flow, excessive heavy metals in soil and other hazards [2,3]. On May 25, 2021, the "Opinions of the Ministry of Housing and Urban-Rural Development and other 15 departments on strengthening the green and low-carbon construction of county towns" was written, emphasizing the significance of implementing green and low-carbon construction for many times. On October 24, 2021, the CPC Central Committee and The State Council issued the Opinions on Fully, Accurately and Comprehensively Implementing the new Development Concepts to achieve carbon Peaking and carbon neutrality, which also stressed that ecological priority, green and low-carbon high-quality development path should be taken to ensure the realization of carbon peaking and carbon neutrality as scheduled. Concrete as an important part of carbon emission, how to reduce the carbon emission of concrete has become the research goal and direction of many experts. The use of iron tailings sand, recycled steel fibers and other materials that were once considered waste can effectively reduce the stock of tailings, reduce carbon emissions and promote the development of green and energy-saving buildings.Urban and industrial solid

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wastes, along with cement and steel industries, are the main sources of greenhouse gas emissions, which have severe environmental consequences [错误!未找到引用源。]. Therefore, green and eco-friendly constructions with partial replacement can be a suitable solution to reduce greenhouse gas emissions, such as replacing cement with micro silica as industrial waste and replacing used fibers with recycled fibers[错误!未找到引用源。].

The compressive strength is one of the most important performance indexes of concrete. Scholars have conducted a lot of studies on the influence of iron tailings replacement rate on the compressive strength of concrete, and also consider the influence on the fluidity of concrete. The workability of concrete includes fluidity, cohesiveness and water retention. As iron tailings are absorbent, the slump of concrete will decrease when their content is too high.

2. Influence of steel fiber on the mechanical properties of concrete

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Lightweight aggregate concrete can reduce the quality of concrete, and has the characteristics of heat preservation and fire resistance, pulverized coal ash pottery has the characteristics of light weight, low cost, rich raw materials and so on. Copper-coated steel fiber lightweight aggregate concrete can improve the brittleness, crack resistance and bending resistance of ordinary concrete [10].

Li Ji [11] et al. studied the mechanical properties of copper-coated steel fiber high-strength concrete. The results show that the copper coated steel fiber can effectively improve the brittle failure characteristics of concrete, improve the impact resistance, knock resistance and fatigue resistance of concrete.

Steel fiber reinforced concrete is currently the most widely used fiber reinforced concrete with a large amount of engineering structural materials [12]. Steel fiber concrete is a kind of concrete composed of discontinuous discrete steel fibers. After steel fiber is added into concrete, the generation and expansion of concrete cracks can be significantly inhibited. Compared with ordinary concrete, it has better mechanical properties, long-term deformation properties and durability. When the fiber concrete is in the stretching and bending state, after the concrete cracks in the stretching zone, the fiber will bear the stress and keep the concrete crack developing slowly. There is a certain residual stress between concrete cracks. With the continuous development of cracks, the residual stress between concrete cracks gradually decreases. The steel fiber has a large deformation capacity and can continue to withstand the tensile force on the interface until the steel fiber is pulled out or pulled out from the concrete.

However, if excess fiber can also have adverse effects, the fiber volume fraction used for SFRCS should be between 0.5% and 1.5%. Because the addition of fiber reduces the workability of concrete, resulting in spheroidization or agglomeration, it is difficult to separate by vibration [13,14,15].

Nan Xueli [16] et al. used steel fiber as a comparison to conduct a fluidity test on the feasibility of recycled steel fiber replacing industrial steel fiber in ultra-high performance concrete, analyzed the influence of recycled steel fiber on the workability of freshly mixed high performance concrete, and studied the influence of recycled steel fiber on the mechanical properties of hardened high performance concrete through flexural and compressive tests. It is concluded that when steel fiber content is 1% or less, the effects of steel fiber and recycled steel fiber on mobility loss are similar, both < 10%. When the dosage increased to 2%, the mobility loss of recycled steel fiber exceeded that of steel fiber by 4.44%. However, after statistical

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significance analysis, steel fiber type has no significant effect on the fluidity of high performance concrete. When the content of steel fiber is constant, the flexural strength, area under load-displacement curve and average compressive strength of recycled steel fiber are not significant with that of industrial steel fiber, but the difference of 28-day compressive strength is only 1MPa. Therefore, in practical engineering construction, recycled steel fiber can replace industrial steel fiber applied in high performance concrete.

Cheng Xi [17] et al. analyzed the recycling availability, physical properties, mechanical properties, length-diameter ratio, working performance of beams and columns of waste tire steel fiber, etc., and believed that the incorporation of waste steel fiber has little effect on the compressive strength of concrete, and there is no significant difference between concrete containing only industrial steel fiber and waste steel fiber, and the existence of waste steel fiber makes concrete have good bending resistance. Cristina Frazão [18] studied the experimental study on the corrosion susceptibility of reinforced concrete of recycled tire steel fibers, using two different pretreatment methods to analyze the effects of small rubber particles adhering to the surface of recycled steel fibers. The results show that the rigid fiber composition of waste tires is complex and uniform compared with industrial steel fiber, and has high carbon content and slightly improved hardness. Finally, it is concluded that waste tire recycled steel fiber concrete is a new concrete material with superior performance and meets the needs of engineering.

3. Effect of iron tailings sands on mechanical properties of concrete and best replacement rate

The study by ZHEN et al. [19] shows that the ratio of prism compressive strength to cube compressive strength of iron-tailings concrete is about 0.8~ 0.9, and the elastic modulus of iron-tailings concrete increases with the increase of strength grade.

According to the study of Cheng Heping et al. [20], the compressive strength is the maximum when the iron tailing sand content is 10%, the bending strength, impact energy and fracture absorption energy are the maximum, and the carbonation resistance and permeability resistance are the best when the iron tailing sand content is 20%. With the increase of iron tailings content, the hydration heat release of concrete decreases at the same hydration time.

The test conducted by Li Zhuang [21] showed that the average strength of iron tailings and mixed sand (mixed sand is composed of 50% iron tailings and 50% coarse river sand particles after screening) was increased by 24.1% and 9.5% respectively compared with river sand concrete. The elastic modulus of iron tail sand and mixed sand concrete is 13.7% and 4.9% lower than that of river sand concrete, respectively. The peak strain of iron tailing sand and mixed sand concrete is 13.4% and 6.4% higher than that of river sand concrete.

In order to promote the engineering application of iron tailings concrete, many scholars use iron tailings concrete to prepare beams, plates, columns and other structural components. The research results are shown in the table

Table 1 Effect of iron tailings substitution rate on mechanical properties of different components

Component type	Component performance	Test index	Iron tailings replacement rate /%	Test value	Increase rate /%	Reference literature
beam	Shear resistance	$Shear\ capacity\ /KN$	0,40,50,60,70	210.1,202.1,196.4,192.7,190.4	0,-3.81,-6.52,-8.28 ,-9.38	[22]
beam	Bending resistance	$Cracking\ load/(KN*m)$ $Ultimate\ bending\ moment/(KN*m)$	0,20,50,70,100 0,20,50,70,100	19.0, 17.0, 14.8, 13.4,12.2 78.65,70.86,62.38,61.74 56.24	0, -10.53,-22.11,-29.47,-35.79 0, -9.90,-20.69,-	[23]

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plate	Bending resistance	$Cracking\ moment\ /(KN*m)$ $Ultimate\ bending\ moment/(KN*m)$	0,40,50,60,70 0,40,50,60,70	7.91,7.81,7.81,7.05,7.81 15.81,15.81,15.59,15.92,15.59	21.50,-28.49 0,-1.26,-1.26,10.87,-1.26 0,0	[24]
column	Seismic performance	$Bending\ capacity\ /(KN*m)$	0,100	256.70, 276.68	-1.39,0.70,-1.39 0, 7.78	[25]

It can be seen from the table that the shear performance of iron tailings concrete beam members is similar to or even higher than that of ordinary concrete. When the replacement rate of iron tailings is maximum, the shear property decreases by less than 10%. The ultimate bending moment and cracking load decrease 28.49% and 35.79% respectively when the iron tailing sand replacement rate reaches the maximum. The properties of the plate also decreased with the increase of iron tailing sand replacement rate. When the iron tailing sand replacement rate was the maximum, the ultimate bending moment and cracking moment decreased by 1.39% and 1.26%, respectively. The cracking resistance of the column is similar to that of ordinary concrete.

Huijing[26] et al. believed that the influence of iron tailings replacement rate on concrete compressive strength showed a trend of decreasing - increasing and decreasing. When the iron tailings replacement rate is 0-10%, the compressive strength shows a downward trend. When the iron tailings replacement rate is 10%, the compressive strength of concrete decreases by 3.87% compared with that of ordinary concrete. When the replacement rate of iron tailings is 10% to 30%, the compressive strength increases with the increase of the replacement rate of iron tailings. When the replacement rate of iron tailings is 30%, the compressive strength increases by 5.25% compared with that of ordinary concrete. When the iron tailing sand replacement rate is 30% to 100%, the compressive strength decreases gradually with the increase of the iron tailing sand replacement rate. When the iron tailing sand replacement rate is 100%, the compressive strength decreases 13.25% compared with ordinary concrete.

Wang Yanyan et al. [27] used iron tailing sand to partially replace river sand as fine aggregate to allocate C40 concrete, and studied the influence of iron tailing sand on the working and mechanical properties of concrete at different mixing ratios (0%, 10%, 20%, 30%). The results showed that with the increase of iron tailing sand content, the mixing performance of concrete gradually worsened. Slump and fluidity are reduced. They think it has something to do with the larger water requirement ratio of iron tailings. The 7-day compressive strength of the concrete mixed with iron tailings ore is greater than that of the natural concrete, and the 28-day compressive strength shows a slightly decreasing trend, but the overall change is little.

4. Conclusion

The mechanical behavior of concrete is brittle in nature, and the post-peak performance decreases during compression due to the limited lateral strain capacity of the material. With the increase of tailings content, the peak strain first increases and then decreases. The addition of low-content tailings optimizes the internal pore structure of concrete and increases the peak strain slightly. With the increase of tailings content, it is not conducive to the compaction forming of concrete, so that the concrete brittleness increases, the concrete damage is faster, and the peak strain decreases. Although the compressive strength of concrete is improved after carbonization, the brittleness of concrete increases and the peak strain decreases.

Before the tensile steel yield of the concrete beam, the steel strain of the iron tail sand concrete beam is basically the same as that of the ordinary concrete beam. The strain development trend of iron tailings concrete beams is similar to that of ordinary concrete beams when the tensile

reinforcement yield. It indicates that iron tailing ore can be used as fine aggregate of concrete instead of river sand.

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References

[1] Cheng X N, Zhang B, Dong X F, et al. Study on the exploiting status and countermeasures of sand ,stone and clay resources in China [J]. China Ming Maganize,2015, 24(5);23-26.

[2] CHEN Hu, SHEN Weiguo, SHAN Lai, et al. Discussion on discharge and comprehensive utilization of iron tailings at home and abroad[J]. Concrete, 2012 (02):88-9China National Standardization Management Committee. Specifications of Crane Design (China Standardization Press, China 2008), p. 16-19.

[3] SEBAIBI N, BOUTOUIL M. Reducing energy cons μ mption of prefabricated building elements and lowering the environmental impact of concrete[J]. Engineering Structures, 2020, 213:11059.

[4] P. de Wilde, D. Coley; The implications of a changing climate for buildings Build Environ, 55 (2012), pp. 1-7, 10.1016/j.buildenv.2012.03.014

[5] P. Duxson, J.L. Provis, G.C. Lukey, J.S.J. van Deventer The role of inorganic polymer technology in the development of “green concrete”Cem Concr Res, 37 (2007), pp. 1590-1597

[6] M. Amin, A.M. Zeyad, B.A. Tayeh, A.I. Saad Effects of nano cotton stalk and palm leaf ashes on ultrahigh-performance concrete properties incorporating recycled concrete aggregates Constr Build Mater (2021), p. 302

[7] D. Burchart-Korol ;Life cycle assessment of steel production in Poland: A case study J Clean Prod, 54 (2013), pp. 235-243

[8] M. Amin, A.M. Zeyad, B.A. Tayeh, A.I. Saad; Effect of ferrosilicon and silica fume on mechanical, durability, and microstructure characteristics of ultra high-performance concrete Constr Build Mater (2022), p. 320

[9] C. Frazão, J. Barros, J.A. Bogas, V. García-Cortés, T. Valente Technical and environmental potentialities of recycled steel fiber reinforced concrete for structural applications J Build Eng (2022), p. 45

[10] HUO Junfang. Research status and development of light aggregate concrete[J], Building Technology, 2009, 40(04); 363-365.

[11] LI Ji, SHI Shaoqing, WANG Min, et al. Static test study on mechanical properties of copper-plated steel fiber high-strength concrete[J].Journal of Ordnance Equipment Engineering,2016, 37(5); 153 – 157.

[12] HUANG Chengkui,Fiber concrete structure[M].China Machine Press,2004:21-25.)

[13] Song P S, Wang H S. Mechanical properties of high-strength steel fiber-reinforced concrete[J]. Construction and Building Materials, 2004, 35(2): 669-673.

[14] Şemsi Yazıcı, Gözde İnan, Volkan Tabak. Effect of aspect ratio and volume fraction of steel fiber on the mechanical properties of SFRC[J]. Construction and Building Materials, 2007, 23(6): 1250-1253.

[15] Leila S, Sudharshan N R, Mohd Z B J. Influences of the volume fraction and shape of steel fibers on fiber-reinforced concrete subjected to dynamic loading-A review[J]. Engineering Structures, 2016, 35(5): 405–417.

[16] NAN Xueli,CHEN Hao,JI Jianrui,WANG Yi,CHEN Guangzhao,LI Mei,TANG Weibin3 (1.State Key Laboratory of Advanced Processing and Recycling of Nonferrous Metals, Lanzhou University of Technology, Lanzhou 730050, China; 2. School of Materials Science and Engineering, Lanzhou University of Technology, Lanzhou 730050, China; 3. Institute of High Performance Materials, Gansu Provincial Institute of Transportation Planning, Survey and Design Co., Ltd., Lanzhou 730000,

China.Effect of recycled steel fiber on the workability and mechanical properties of ultra-high-performance concrete. Journal of Yangtze River Scientific Research Institute, 2022, 39(11): 141-148

[17] CHENG Xi, GE Teng (1.Wuhan Construction (Group) Co., Ltd., Wuhan 430056, Hubei, China;2.School of Civil Engineering and Architecture,Wuhan University of Technology,Wuhan 430000, China. Research progress of steel fiber concrete for waste tires. Energy Conservation, 1004-7948 (2021), 06-0078-03

[18] Frazao C,Diaz B,Barros J,et al.An experimental study on the corrosion susceptibility of recycled steel fiber reinforced concrete[J].Cement and Concrete Composites,2019(96):138-153.

[19] Zhen K H，WU JK，MA W H. Experimental Study on Compressive Strength and Elastic Modulus of Ferrous Mill Tailing Concrete［J］. Journal of Engineering Science and Tech- nology Review，2013

[20] CHENG Heping,LU Lu.Effect of iron tailings sand content on mechanical properties, durability and hydration characteristics of concrete[J]. Metal Mine, 2021(11): 215-220.

[21] LI Zhuang . Study on mechanical properties of iron tailings concrete [J]. Sichuan Cement, 2020(2): 10.

[22] CHEN Xiuyun. Experimental study on stress performance of green concrete components of iron tailings sand[D].Wuhan: Wuhan University of Technology,2017

[23] XU Yongze. Study on preparation and mechanical properties of iron tailings concrete with high substitution rate[D]. Shenyang: Shenyang University of Technology, 2019

[24] Good wishes. Experimental study on bending properties of concrete slab doped with tailings sand[D].Zhengzhou:Zhengzhou University,2015.

[25] KANG Hongzhen, MA Jiangbo, LI Qiang, et al. Numerical simulation analysis of hysteresis performance of iron tailings sand concrete column[J].Engineering Seismic Resistance and Reinforcement Transformation,2021,43(4):52-57.

[26] HUI Jing,XIE Qun,CHEN Tao,ZHAO Peng.Research progress on basic properties of iron tailings sands concrete.(School of Civil Engineering and Architecture, University of Jinan,Jinan, Shandong 250022)

[27] WANG Yanyan,CHEN Ying,LIAO Lin,Dai Yin Yin,HUANG Xiaoming,WANG Yajun. Application Analysis of Iron Tailings Concrete (Anhui Building Research and Design Institute, Hefei 230031, Anhui, China)