Study on the influence of fibers to the physical mechanical properties of foam concrete

Abstract: foam concrete has been widely used in building, infrastructure and fire prevention fields because of its lightweight, excellent heat and sound insulation performance. However, due to its high porosity, the compressive strength of foam concrete is usually low, which limits its application in some high-strength structures. In order to solve this problem, researchers improve the mechanical properties of foam concrete by adding different types of fiber materials. This paper summarizes the research progress of fiber on the performance of foam concrete, and analyzes the influence of different types of fiber (such as polypropylene fiber, basalt fiber, polyvinyl alcohol fiber, etc.) on the performance of foam concrete. The research shows that adding proper amount of fiber into foam concrete can effectively improve the mechanical, durability, dry shrinkage and other properties of foam concrete.

Key words: Foam concrete; Fiber; Compressive strength; Thermal conductivity

Introduction

Foam concrete is a special type of building material with micropores. Due to its advantages such as self leveling, low thermal conductivity, less raw materials required and light weight, as well as its excellent properties such as light weight, environmental protection, sound absorption and fire resistance, it has attracted much attention, and is widely used in the external wall and roof insulation of residential buildings, tunnel filling and pipeline filling of underground projects, and sculpture and decoration elements in the decoration field. Its flexibility and versatility have become a popular choice of materials in the construction field [1,2]. But at the same time, it also leads to its relatively low compressive strength and flexural strength, and its high water content, which is prone to cracking, leakage and other problems], seriously hindering the promotion and application of foam concrete [3]. In order to solve this problem, scholars modified foam concrete by adding different types of fibers, thus improving its mechanical properties.

The research of fiber reinforced foam concrete has received extensive attention. Fiber foam concrete uses fiber as the doping phase. This kind of foam concrete has the advantages of corrosion resistance, low density, crack resistance, and has good thermal insulation effect in external walls and other occasions [4-5]. The addition of fiber can effectively improve the mechanical properties and dry shrinkage of foam concrete, and solve the problems of poor mechanical properties and easy cracking of foam concrete. Fiber materials have high tensile strength and toughness, which can effectively inhibit the generation and expansion of cracks, and enhance the crack resistance, compressive strength and impact resistance of foam concrete. At the same time, the addition of fiber may also affect the thermal conductivity of foam concrete, thus affecting its thermal insulation

effect. This paper will comprehensively analyze the influence of fiber on foam concrete, including the improvement of its compressive strength and thermal conductivity, and explore the synergistic mechanism of different types of fiber.

1 Material properties of foam concrete

Foam concrete foam concrete is a kind of porous lightweight material formed by mechanically preparing foam from the aqueous solution of foaming agent, introducing an appropriate amount of micro bubbles into the cement slurry or cementitious material slurry, mixing and making foam slurry, forming or casting in situ, and natural curing, steam curing or autoclaved curing.

The density of foam concrete is generally 600-1800 kg/m ^{3}, which is far lower than ordinary concrete, so it has the advantages of lightweight and reducing the dead weight of the structure. The porosity of foam concrete is high, which makes it excellent in thermal insulation and heat insulation in buildings. The compressive strength of foam concrete is usually low, usually 2-10 MPa, which limits its application in high-strength structures. Foam concrete is easy to produce cracks, especially in dry or temperature changing environment, cracks may affect its performance.

2 Main application of foam concrete

Foam concrete is a new building material with broad application prospects. Its application in civil engineering, aerospace, transportation, energy, environmental protection and other fields will continue to expand and improve [6].

Because of its low density and high porosity, foam concrete is widely used as the thermal insulation layer of building walls and roofs. The exterior wall insulation utilizes the advantages of foam concrete in thermal insulation and durability; The subgrade expansion mainly takes advantage of the comparative advantages of foam concrete in tension and bending resistance and durability [7]. Foam concrete can be used as backfill material for underground pipelines, roads and other infrastructure construction because of its lightweight characteristics. Foam concrete has certain durability [8] and high fire resistance, which can be used as firewall body and fire barrier.

The good pore structure of foam concrete makes it have a good sound insulation effect, which is suitable for building environments with high noise. The use of foam concrete for pouring and backfilling has greatly facilitated the construction, without noise pollution, dust, etc; Foam concrete is also used for road load reduction in the road and bridge works of the overlapping part of Guangzhou Expressway and Guangzhou Metro Line 3 [9].

Although foam concrete has significant advantages in these fields, its low compressive strength and crack susceptibility limit its application in some demanding structures. Therefore, how to improve the compressive strength of foam concrete has become a research hotspot.

3 Influence of fiber on compressive strength of foam concrete

3.1 Mechanism of fiber reinforced foam concrete performance

The main mechanism of fiber reinforced foam concrete is to improve the microstructure of concrete and increase its toughness and crack resistance. Fibers form a three-dimensional network

structure in concrete, which can effectively bridge cracks, prevent crack propagation, and thus improve compressive strength. Improve toughness: fiber materials can make foam concrete withstand greater stress before failure by delaying crack propagation, thus improving toughness. Improving pore structure: the addition of fiber can reduce the formation of macropores, optimize the pore structure of foam concrete, improve its mechanical properties, slow down the transfer of heat flow, and thus improve the thermal insulation. Thermal conductivity of fibers: Different types of fibers have different thermal conductivity. The thermal conductivity of steel fiber and glass fiber is high, and their addition may slightly increase the thermal conductivity of foam concrete.

3.2 Influence of different fiber types on the performance of foam concrete

Polypropylene fiber: Polypropylene fiber is a synthetic fiber spun from polypropylene as raw material. Polypropylene fibers have high strength, good elasticity, wear resistance, and corrosion resistance. Polypropylene fiber is widely used in foam concrete because of its high tensile strength and chemical stability. The research shows that polypropylene fiber has more obvious improvement effect on the coagulation performance of foam [10]. Polypropylene fiber can effectively prevent foam concrete from cracking and improve its mechanical properties. Feng Shuo et al. [11] research suggests that, The synergistic effect of silica fume and PP fiber can improve the compressive strength of foam concrete. Chen Bing et al. [12] studied the influence of polypropylene fiber on the splitting flexural strength, compressive strength and shrinkage of foam concrete with density of 800kg/m^3~1500 kg/m3. The results show that polypropylene fiber can significantly improve the splitting flexural strength and compressive strength of foam concrete, and the compressive strength of foam concrete will increase with the increase of foam content, up to 45%. The shape of polypropylene fiber and its bonding performance with the matrix are also important factors affecting the performance of foam concrete. Liu Yifei et al. [13] believed that reticulated polypropylene fiber is better than filiform polypropylene fiber in improving the mechanical properties of foam concrete. The research results of Qiu Changhuai [14] show that compared with the polypropylene fiber modified by water glass, the adhesion between the polypropylene fiber modified by polyvinyl alcohol and the foam concrete matrix is better, and the effect of improving the compressive strength and flexural strength is more significant. It can be seen that proper surface modification of polypropylene fiber can improve the bonding performance between it and foam concrete matrix, thus improving the performance of foam concrete.

Basalt fiber: Basalt fiber is a new type of inorganic, environmentally friendly, green, high-performance fiber material with good stability, as well as various excellent properties such as electrical insulation, corrosion resistance, combustion resistance, and high temperature resistance. Cheng Xin [15] and others found that adding basalt fiber with different length and content in foam concrete can improve its compressive strength, flexural strength and elastic modulus. At the same length, the higher the dosage, the higher the strength and elastic modulus; At the same dosage, the longer the length, the higher the strength and elastic modulus. When the fiber content is constant, its compressive strength and flexural strength both increase with the increase of basalt fiber length; As the volume weight of foam concrete decreases, its water absorption will increase; The water absorption of foam concrete has no obvious correlation with the specification and amount of basalt fiber; The addition of basalt fiber will improve the thermal conductivity of foam concrete, and the thermal conductivity of foam concrete is greatly affected by the addition of basalt fiber.

Polyvinyl alcohol fiber: Polyvinyl alcohol fiber is a polymer synthetic material prepared by hydrolysis of polyvinyl acetate aqueous solution in acidic and alkaline solutions. The hydroxyl

group in the polyvinyl alcohol fiber can form a hydrogen bond in the cement matrix, making it hydrophilic, which determines the bonding performance between the polyvinyl alcohol fiber and the foam concrete matrix, thus affecting the mechanical, durability and other properties of foam concrete. Bai Guang et al. [16] studied the influence of polyvinyl alcohol fiber content (0~1.8 kg/m3) on the performance of foam concrete. The results show that when the polyvinyl alcohol fiber content is 0.6~1.2 kg/m3, it has the effects of strengthening, toughening, reducing drying shrinkage, reducing water absorption of foam concrete, and has no obvious effect on the dry density of foam concrete. Yang Ruihuan et al. [17] analyzed the influence of the adhesive degree between polyvinyl alcohol fiber and foam concrete and its dosage (0~2.0 kg/^{m3}) and length (^{6}~19 mm) on the pore structure and mechanical properties of foam concrete. The results showed that an appropriate amount of polyvinyl alcohol fiber has good compatibility with the cement paste, which can protect foam, improve the pore structure, prevent the generation and development of microcracks, so as to improve the compressive and flexural strength of foam concrete. The optimal polyvinyl alcohol fiber dosage is 1.2 kg/m3, and the length is 9 mm.

4 Conclusion and Prospect

Adding proper amount of fiber into foam concrete can effectively improve the mechanical, durability, dry shrinkage and other properties of foam concrete.

Choosing the appropriate fiber type and content according to the actual needs can optimize the comprehensive performance of foam concrete and meet the needs of different projects.

As a new type of material for building production, foam concrete has excellent characteristics and high economic benefits, and has broad prospects for development. At present, the research on foam concrete added with fiber is not very mature in China, so the development of more durable, lightweight and environmentally friendly products has far-reaching significance for the future industry. Researchers should strengthen in-depth research in this area, develop relevant standards, and meet the needs of the industry.

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Reference

[1]LiHou,JunLi,ZhongyuanLu,etal.InfluenceofFoamingAgentonCementandFoamConcrete[J].ConstructionandBuildingMaterials,2021,280:122399.

[2]LinaChica,AlbertAlzate.CellularConcreteReview:NewTrendsforApplicationinConstruction[J].ConstructionandBuildingMaterials,2019,200:637-647.
[3]Pan Xiaobing, Li Jing Characteristics, Application and Future Development Trend of foam Concrete [J]. Concrete and Cement Products, 2020 (6): 98-102
[4]Liu Hao, Chen Ping, Xie Fuzhen, etc The influence of basalt fiber on the crystallization properties of polylactic acid composite materials [J]. Journal of Xinyu University, 2022, 27 (5): 1-8
[5]Du Jiegui, Wang Xiongfeng, Chen Bo, etc Research on the flowability and compressive strength of fiber hybrid ultra-high performance concrete [J]. Construction Technology: Chinese English, 2023, 52 (15): 73-78
[6]Liu Xinhao Preparation of concrete foam agent and study on performance of foam concrete [D]. Chongqing: Chongqing Jiaotong University, 2022
[7]Sun Xiaoyong, Yang Dong Application of foam concrete technology in cement engineering [J]. Cement Technology, 2019206 (02): 73-76
[8]Gao Yali, Tian Chunming, Liu Zheng Study on the properties of polyurethane filled foam concrete composites [J]. Plastic Science and Technology, 2022,50 (1): 27-30
[9]Li Yangrui Study on preparation and performance of magnesium based salt fly ash foam concrete [D]. Inner Mongolia: Inner Mongolia University of Technology, 2021
[10]Xiao Xiao, Cheng Baojun, Wang Xiaobo, etc Influence of organic fiber type and content on the performance of foam concrete [J]. Sichuan Building Materials, 2020, 46 (6): 7-9
[11]Feng S, Gao Y, Xiao H, Xue C. Influence of fibers and bubble structure on thermal conductivity and mechanical performances of foam concrete. Construction and Building Materials. 2024 Sep 27;445:137956.
[12]Chen Bing, Liu Ci Experimental study on fiber reinforced foam concrete [J]. Journal of Building Materials, 2010, 13 (3)
[13]Liu Yifei, Li Tiancheng, Zeng Xuehua, etc Mechanical strength and water absorption performance of fiber reinforced foam concrete [J]. Journal of Civil and Environmental Engineering (Chinese and English), 2019,41 (3): 120-126
[14]Qiu Changhuai Research on mechanical properties of polypropylene fiber fly ash foam concrete [J]. Comprehensive utilization of fly ash, 2018 (3): 65-67
[15]Cheng Xin, Zhan Binggen Research on the performance and crack resistance evaluation of basalt fiber foam concrete [J]. Journal of Hefei University of Technology (Natural Science Edition), 2020,43 (09): 1223-1228
[16]Bai Guang, Tian Yi, Yu Linwen, etc Effect of polyvinyl alcohol fiber on the performance of alkali slag foam concrete [J]. Materials Herald, 2018,32 (12): 2096-2099
[17]Yang Ruihuan, Xie Zhengfen, Zhang Shuo, etc Research on the influence of fiber on the performance of foam concrete [J]. Cement Engineering, 2021 (3): 81-83,92