International Core Journal of Engineering Volume 10 Issue 1, 2024
ISSN: 2414-1895 DOI: 10.6919/ICJE.202401_10(1).0001

Fly Ash Ceramic Concrete: A Comprehensive Study of Properties, Preparation and Application

Bo Liu, Zirui Wang*, Guowei Ni

North China University of Science and Technology, Tangshan 063000, China

Abstract

Fly ash ceramic concrete is a kind of special concrete made of fly ash and ceramic grains as aggregate. Due to its excellent physical and mechanical properties, durability and environmental performance, it has been widely used in construction, roads, bridges and other engineering fields in recent years. This paper reviews the current research and application status of fly ash ceramic concrete at home and abroad, discusses in detail its preparation process, physical and mechanical properties, durability and application areas, and looks forward to its future development trend.

Keywords

Fly Ash Ceramic Concrete; Preparation Process; Physical and Mechanical Properties; Durability; Application Areas; Development Trend.

1. Introduction

Fly ash ceramic concrete is a kind of green building material, which has been widely used in the fields of construction, roads and bridges in recent years due to its excellent performance and resource reuse. In this paper, we will conduct a comprehensive study on the preparation process, performance and application areas of fly ash ceramic concrete, as well as its future development trend.

2. Preparation Process of Fly Ash Ceramic Concrete

The preparation process of fly ash ceramic concrete mainly includes the steps of raw material selection, batching, mixing, moulding and maintenance. Among them, the selection of raw materials is one of the key links, the commonly used fly ash is the fly ash discharged from power plants and furnace bottom slag, etc., while the ceramic granules are made of shale, clay, fly ash, etc. as the main raw materials. In the preparation process, by adjusting the proportion of fly ash and ceramic particles and adding the appropriate amount of admixtures, fly ash ceramic concrete with excellent performance can be obtained.

At present, the preparation process of fly ash ceramic concrete mainly includes the following:

Sintering method: fly ash and clay and other raw materials are mixed and sintered at high temperature, and porous ceramic particles are obtained after cooling. The advantage of this method is that the preparation process is simple and the cost is low, but the sintering process will produce environmental pollution.

Expansion method: Fly ash and the appropriate amount of chemical agents mixed with high-temperature expansion, to get lightweight ceramic particles. The advantage of this method is that the preparation process is simple, but the expansion process requires the use of chemical agents, which may have an impact on the environment.

Melting method: Fly ash and the appropriate amount of flux mixed with high-temperature melting, to obtain glassy ceramic granules. The advantage of this method is the simplicity of the preparation

ISSN: 2414-1895 DOI: 10.6919/ICJE.202401_10(1).0001

process, but the melting process requires the use of a high-temperature furnace, which consumes more energy.

In addition, in order to improve the performance of fly ash vitrified concrete, researchers have made many innovations in the preparation process. For example, by optimising the batching ratio and mixing conditions, fly ash vitrified concrete with high strength and durability can be obtained; and by adopting advanced curing methods, the early strength and durability of concrete can be significantly improved.

3. Properties of Fly Ash Ceramic Concrete

As a new type of green building material, fly ash ceramic concrete has excellent physical and mechanical properties and durability. Its advantages include light weight, high strength, heat insulation, good frost resistance, strong carbonation resistance and good corrosion resistance. In addition, fly ash ceramic concrete has excellent sound insulation and seismic performance.

The physical and mechanical properties of fly ash ceramic concrete mainly include compressive strength, tensile strength, flexural strength and so on. The research results show that its strength grade can be improved by optimising the mix ratio and adding admixtures. At the same time, fly ash ceramic concrete also has excellent ductility and toughness, which can meet the safety and stability requirements of engineering structures.

4. Durability of Fly Ash Ceramic Concrete

Frost resistance: In cold regions, fly ash ceramic concrete is able to resist the action of freeze-thaw cycles, and its frost resistance is better. This is due to the fact that the porous structure of fly ash ceramic granules can absorb water, thus reducing the effect of freeze-thaw cycles on the concrete structure.

Carbonation resistance: carbonation is one of the important factors in the deterioration of concrete. Fly ash ceramic concrete has better resistance to carbonation because the porous structure of fly ash ceramic particles can hinder the carbonation. Also, the calcium hydroxide in the cement stone is able to react with carbon dioxide, thus improving the carbonation resistance of the concrete.

Corrosion resistance: In corrosive environments, fly ash vitrified concrete is able to resist the erosion of chemicals. This is because the porous structure of fly ash ceramic granules can adsorb corrosive substances, while the calcium hydroxide in the cement stone can also react with corrosive substances, thus improving the corrosion resistance of concrete.

Factors affecting the tensile properties of fly ash ceramic concrete.

The tensile properties of fly ash granular concrete are affected by a variety of factors, including the nature of raw materials, proportion, preparation process and maintenance conditions.

The nature of raw materials: the particle gradation of fly ash, burning loss, moisture content and other properties have a certain impact on the tensile properties of concrete. The particle size, density, shape and other properties of ceramic particles will also affect the tensile properties of concrete.

Mixing ratio: the mixing ratio of fly ash ceramic concrete has an important influence on its tensile properties. Reasonable selection of parameters such as cement dosage, water-cement ratio and sand rate can significantly improve the tensile properties of concrete.

Preparation process: the preparation process also has a certain effect on the tensile properties of fly ash ceramic concrete. The mixing method, mixing time, vibration method, etc. will affect the internal structure and tensile properties of concrete.

Maintenance conditions: maintenance conditions have a great influence on the tensile properties of fly ash ceramic concrete. Proper curing can promote the hydration reaction of cement and improve the compactness and tensile properties of concrete.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202401_10(1).0001

5. Measures to Improve the Tensile Properties of Fly Ash Ceramic Concrete

In order to improve the tensile properties of fly ash vitrified concrete, the following measures can be taken:

Optimising the mix ratio: the mix ratio of fly ash vitrified concrete is optimised by adjusting the parameters such as cement dosage, water-cement ratio and sand rate in order to improve its tensile properties.

Adding reinforcing agent: Adding appropriate amount of reinforcing agent, such as steel fibre, polymer, etc., in fly ash ceramic concrete can significantly improve the tensile strength and toughness of concrete.

Improve the quality of curing: Adopting appropriate curing methods, such as wet curing, steam curing, etc., can promote the hydration reaction of cement and improve the compactness and tensile properties of concrete.

Surface treatment: anti-cracking treatment on the surface of fly ash ceramic concrete, such as coating waterproof coating, paste glass fibre mesh cloth, etc., can effectively prevent cracks from arising and expanding, and improve the tensile properties of concrete.

Enhancement of interface: the tensile property of concrete can be improved by improving the interface property between aggregate and cement stone. Surface treatment and mechanical mixing can be used to enhance the interface bond.

6. Research on Compressive Properties of Fly Ash Ceramic Concrete

The compressive performance of fly ash ceramic concrete is affected by a variety of factors, including the nature of raw materials, mixing ratios, preparation process and curing conditions. In terms of compressive performance, fly ash ceramic concrete shows better advantages. Compared with ordinary concrete, fly ash ceramic concrete has higher compressive strength and durability. This is mainly due to the porous structure of fly ash ceramic particles, which can improve the pore structure and interfacial properties of concrete, and improve its impermeability and resistance to the erosion of harmful substances.

In order to better study the compressive properties of fly ash ceramic concrete, systematic experimental studies and theoretical analyses can be carried out. In the experimental aspect, the compressive properties of fly ash ceramic concrete can be optimised by designing different mix ratios, selecting different raw materials and adjusting the parameters of the preparation process. At the same time, advanced testing instruments and experimental means, such as microseismic test and acoustic wave test, can be used to accurately test and analyse its compressive performance.

In terms of theoretical analysis, the compressive properties of fly ash vitrified concrete can be predicted and evaluated by establishing mathematical models and numerical simulation methods. This helps to gain an in-depth understanding of its mechanical behaviour and damage mechanism, and provides theoretical support for optimising its design and application. It can also further deepen the understanding of the compressive performance of fly ash vitrified concrete by comparing and analysing it with the research results of other scholars.

The compressive test is one of the important methods to assess the quality of concrete. Usually carried out in the laboratory, the tester places the concrete specimen on the pressure testing machine and determines the compressive strength of concrete by gradually increasing the pressure until the specimen is destroyed.

The specific steps of the compressive test are as follows:

Preparation of specimens: Samples are usually taken from the project site, or standard-sized test blocks are prepared in the laboratory. The size and shape of the specimen depends on the specific test requirements, generally using 150mm × 150mm × 150mm cube. After the specimen is prepared, it needs to be placed in a constant temperature and humidity environment for maintenance.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202401_10(1).0001

Installation of specimen: place the specimen block between the bearing plates of the pressure testing machine and adjust the position of the specimen block so that it is in complete contact with the bearing plates of the press.

Loading pressure: Apply pressure to the test block at a certain rate through the transmission mechanism of the press. The size of the pressure depends on the specific requirements of the test, and generally adopts a graded loading method. During the loading process, the pressure and the deformation of the test block need to be recorded.

Observation and recording of data: Under pressure, the specimen will deform. By recording the deformation, the mechanical properties of concrete can be analysed. It is also necessary to record the damage modes, such as brittle damage, plastic damage, and so on.

Result processing: according to the test data, the stress-strain curve can be plotted, and then the compressive strength of concrete can be calculated. Generally speaking, the higher the compressive strength of concrete, the better its quality. In addition, the durability and fatigue resistance of concrete can be assessed according to the test data.

The compressive test needs to pay attention to the following points:

1) The preparation and curing of test blocks should comply with the relevant standards to ensure their quality and authenticity.

2) The loading pressure should be gradually increased to avoid the sudden application of large pressure leading to the destruction of the test block.

3) Data should be recorded in a timely manner during the test, and calculations and analyses should be carried out to produce accurate test results.

7. Research on Anti-carbonation Performance of Fly Ash Ceramic Concrete

Carbonation resistance is an important consideration in the application of vitrified concrete. Carbonation is a process in which calcium hydroxide in concrete reacts chemically with carbon dioxide in the environment to produce calcium carbonate and water. This process leads to a decrease in the alkalinity of the concrete, which has a corrosive effect on the steel reinforcement, thus affecting the structural performance of the concrete. Therefore, the carbonation resistance of vitrified concrete is critical to its long-term performance and durability.

The carbonation resistance of vitrified concrete is mainly affected by the following factors:

Alkalinity of cement stone: Calcium hydroxide in cement stone is the main alkaline substance, and its content and distribution have an important influence on the carbonation resistance of vitrified concrete. Generally speaking, the higher the alkalinity of cement stone, the better its carbonation resistance.

Pore structure: The pore structure in vitrified concrete, especially capillary pores and cracks, accelerates the carbonation process. Therefore, the pore structure has an important influence on the carbonation resistance of vitrified concrete.

Environmental factors: carbon dioxide concentration, humidity and temperature in the environment will affect the anti-carbonation performance of vitrified concrete. Especially in the environment of high humidity and high temperature, the anti-carbonation performance of ceramic concrete will be more challenged.

In order to improve the carbonation resistance of vitrified concrete, the following measures can be taken:

Optimising the mix ratio: by optimising the mix ratio of cement, sand, ceramic and other materials, the pore structure and alkalinity of cement stone in ceramic concrete can be adjusted so as to improve its anti-carbonation performance.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202401_10(1).0001

Adding admixtures: Adding the right amount of admixtures can improve the pore structure of the ceramic concrete and increase its compactness, thus reducing the penetration and diffusion of carbon dioxide.

Improvement of curing quality: Reasonable curing can improve the compactness and strength of granular concrete, thus improving its carbonation resistance.

Surface coating protection: applying a layer of waterproof coating or wear-resistant material on the surface of vitrified concrete can effectively prevent the penetration of carbon dioxide and the corrosion of steel reinforcement, thus improving its anti-carbonation property.

Overall, the carbonation resistance of vitrified concrete is an important research area that needs further in-depth study and research. Through the in-depth understanding and mastery of its anti-carbonation properties, it can provide a more reliable basis for its application in engineering practice.

8. Conclusion

Fly ash ceramic concrete is a new type of building material with good physical and mechanical properties, durability, environmental performance and economic benefits. This paper reviews the current research and application status of fly ash ceramic concrete at home and abroad, and discusses in depth its preparation process, physical and mechanical properties, durability and application areas. The study shows that an appropriate increase in the amount of fly ash can significantly improve the strength and durability of concrete; fly ash ceramic particles of the porous structure makes it has a good thermal insulation properties, suitable for the building of the exterior walls, roofing and other parts; in addition, the use of fly ash ceramic concrete can be made of lightweight high-strength artificial reefs, and other new areas of application. Looking to the future, fly ash ceramic concrete will play an important role in the resourcefulness of construction waste and energy saving and environmental protection. At the same time, it is also necessary to strengthen basic research and technological innovation, promote standardisation and normative construction, strengthen cooperation between industry, academia and research and personnel training, etc., to provide a strong guarantee for the wide application of fly ash ceramic concrete.

References

[1] WANG Xiaofei, LI Xiaohong, ZHANG Zejiang. Research progress and engineering application of ceramic concrete[J]. Construction Technology, 2020, 49(12): 43-48.

[2] MA Kunlin, WANG Ticheng, WANG Xiaowei. Preparation process of ceramic concrete and its application[J]. Building Materials Technology and Application, 2019, (3): 1-5.

[3] CHEN Yimin, XU Shan, ZHANG Peng. Physical and mechanical properties of ceramic concrete and its application[J]. Building Science, 2018, 34(5): 109-114.

[4] ZHANG Sanqiang, WANG Zhiwei, LI Ming. Research on durability of fly ash ceramic concrete[J]. Concrete and Cement Products, 2021, (4): 23-28.

[5] LIU Si-Ping, WANG Jian-Hua, ZHANG Lu. Application of fly ash ceramic concrete in bridge engineering[J]. Highway Traffic Science and Technology, 2020, 37(4): 14-19.

[6] ZHOU Jiangbo, HUANG Yinghao. Research on the preparation and performance of fly ash ceramic concrete[J]. New Building Materials, 2019, (9): 1-5.

[7] WANG Ruixue, WANG Linlin, ZHANG Min. Research on mechanical properties of fly ash ceramic concrete based on microstructure[J]. Journal of Materials Science and Engineering, 2021, 39(1): 78-84.

[8] LI Si-Ping, ZHANG Yu-Chao, WANG Hai-Long. Optimisation of mechanical properties of fly ash ceramic concrete based on response surface method[J]. Journal of Building Materials, 2020, 23(6): 947-954.