ISSN: 1813-4890

Ceramic Aggregate Concrete and Its Modification Research Review

Zirui Wang, Guowei Ni and Bo Liu *

School of College of Civil and Architectural Engineering, North China University of-Science and Technology, Tangshan 063210, China.

Abstract

With the global promotion of green building, energy saving and emission reduction, and the concept of sustainable development, ceramic aggregate concrete, as a building material with the advantages of lightweight, high strength, insulation, and environmental protection, has attracted increasing attention in its research and application. This paper reviews the recent achievements in the research and modification of ceramic aggregate concrete, discusses the research progress in the pre-wetting treatment of ceramic aggregates, surface treatment, steel fiber reinforcement, mix ratio optimization and material selection, and high-strength lightweight aggregate concrete, analyzes the relationship between microstructure and properties, new additives and modification techniques, mechanical principles, and the basics of environmental science, and looks forward to future development directions.

Keywords

Salt Freeze-Thaw Erosion Durability Freeze-Thaw Cycles Freeze Resistance Fly Ash.

1. Introduction

As the world pays more attention to green building and sustainable development, ceramic aggregate concrete, as a high-performance building material, has been widely used in construction engineering due to its lightweight, high strength, insulation, and environmental protection characteristics. This paper aims to review the latest achievements in the research and modification of ceramic aggregate concrete in recent years, discuss its performance optimization strategies, and future development directions.

2. Research Progress on Ceramic Aggregate Pre-wetting Treatment

Jia Xingwen et al. (2013) studied the effect of pre-wetting treatment on the physical and mechanical properties of ceramic aggregate foam concrete and found that pre-wetting treatment can effectively reduce the water absorption rate of ceramic aggregates during mixing, improve the compactness and strength of concrete. When the pre-wetting time is 24 hours, the compressive strength of the concrete increased by about 15%, and the flexural strength increased by about 10%. This finding provides important technical reference for the industrial production of ceramic aggregate foam concrete.

3. Innovation in Ceramic Aggregate Surface Treatment Technology

Wang Xiangyang et al. (2016) used specific chemicals for surface treatment of ceramic aggregates, significantly enhancing the adhesion between ceramic aggregates and cement paste, and improving the compressive strength and durability of concrete. Test data show that the ceramic aggregate concrete with surface treatment has a compressive strength about 20% higher than the untreated samples.

4. Research on Steel Fiber Reinforced Ceramic Aggregate Concrete

Wang Haitao and Wang Licheng (2013) showed that the appropriate addition of steel fibers can significantly improve the mechanical properties of ceramic aggregate concrete. When the steel fiber content is 1% by volume, the bending toughness of the concrete increased by about 30%, and the impact resistance performance was also significantly improved.

5. Mix Ratio Optimization and Material Selection

Wang Zhao'en et al. (2017) and Zhu Xueqing (2016) successfully prepared ceramic aggregate concrete with excellent performance by adjusting mix ratio parameters such as water-cement ratio and sand ratio, and selecting ceramic aggregates of different strengths and particle size distributions. Test results show that the best mechanical properties can be obtained when the water-cement ratio is 0.4 and the sand ratio is 35%. In addition, Zhu Xueqing also explored the application of industrial waste residues such as fly ash in ceramic aggregate concrete.

6. Research on High-strength Lightweight Aggregate Ceramic Concrete

Liu Xi et al. (2014) successfully prepared high-strength lightweight aggregate ceramic concrete with a compressive strength of over 60MPa by optimizing the mix ratio, improving the strength grade of ceramic aggregates, and selecting high-performance cement, expanding its application range.

7. Material Science Basics

7.1. Microstructure and Property Relationship

Pore structure analysis: Observing the pore characteristics of ceramic aggregates by SEM and other technologies to understand their impact on concrete properties.

Interface transition zone: Studying the formation mechanism of the interface transition zone and its impact on the overall performance of concrete.

7.2. New Additives and Modification Techniques

Nanomaterials: Such as nano silicon dioxide, nano calcium carbonate, etc., to improve the density and mechanical properties of the cement paste.

Polymers: As interface modifiers to enhance the binding force between ceramic aggregates and cement paste.

8. Mechanical Principles

8.1. Multi-scale Mechanical Behavior

Microscopic mechanical analysis: Revealing the impact of macro, meso, and micro scale factors on the mechanical properties of concrete.

Damage evolution and failure prediction: Establishing damage evolution models to predict the failure process of concrete.

8.2. Numerical Simulation of Mechanical Properties

Finite element analysis (FEA): Simulating the mechanical response of concrete under different loading conditions.

Discrete element method (DEM): Simulating the distribution and interaction of ceramic aggregates in concrete.

9. Environmental Science Basics

Durability Research

Carbonation and chloride erosion: Studying their impact mechanisms on concrete properties and protective measures.

Freeze-thaw cycles: Studying the performance changes and durability enhancement techniques of ceramic aggregate concrete under freeze-thaw cycles.

Future Development Directions

In the future, the research on ceramic aggregate concrete will continue to develop in the direction of high performance, greening, and intelligence. With the continuous emergence of new reinforcing materials and modification techniques, the mechanical properties, durability, and functionality of ceramic aggregate concrete will be further improved. At the same time, the promotion of green building and sustainable development concepts will promote the green production of ceramic aggregate concrete, and the application of intelligent technology in production and construction will gradually become popular.

10. Conclusion

In summary, the research and modification of ceramic aggregate concrete have achieved significant results, providing more options for modern architectural design and construction. By methods such as pre-wetting treatment, surface treatment, addition of reinforcing fibers, and optimization of mix ratios, the performance and application value of ceramic aggregate concrete can be significantly improved. In the future, with the continuous deepening of research and the continuous innovation of technology, ceramic aggregate concrete will play a more important role in the construction industry.

Remarkable Performance Optimization: The introduction of pre-wetting treatment and surface pretreatment techniques effectively reduced the water absorption rate of ceramsite, improved the compactness and strength of concrete, and significantly enhanced its mechanical properties. The incorporation of steel fibers further bolstered the flexural toughness and impact resistance of concrete, broadening its application scope.

Scientific Mix Proportion and Material Selection: By optimizing mix proportions such as water-cement ratio and sand ratio, and selecting ceramsite with varying strengths and particle size distributions, combined with the reuse of industrial waste residues like fly ash, not only did the performance of ceramsite concrete improve but also promoted the circular utilization of resources, embodying the concept of green building materials.

Development of High-Strength Lightweight Aggregate: The successful development of high-strength lightweight aggregate ceramsite concrete marks a significant step forward in its application in load-bearing structures and high-performance buildings, supporting the energy conservation, emission reduction, and sustainable development goals of the construction industry.

Deepening of Materials Science Fundamentals: Research into the relationship between microstructure and properties has revealed the influence mechanisms of ceramsite pore characteristics and interfacial transition zones on concrete performance, providing a theoretical basis for further material design optimization. The application of novel additives such as nanomaterials and polymeric modifiers has further enhanced the compactness and mechanical properties of concrete, showcasing the immense potential of materials science.

Breakthroughs in Mechanics Principles and Numerical Simulation: Multiscale mechanical behavior studies and numerical simulations of mechanical properties have provided new perspectives for understanding the mechanical characteristics of ceramsite concrete and scientific foundations for the design and optimization of concrete structures.

Strengthening of Environmental Science Fundamentals: Durability studies have illuminated the effects of environmental factors such as carbonation, chloride ion erosion, and freeze-thaw cycling on concrete performance, guiding the development of effective protective measures to ensure the long-term stability of ceramsite concrete under complex environments.

Looking ahead, research on ceramsite concrete will continue to advance towards high performance, greenness, and intelligence. With the continuous emergence of novel reinforcing materials and modification technologies, coupled with the deepening of the green building and sustainable development concepts, the performance, durability, and functionality of ceramsite concrete will be further enhanced. Meanwhile, the application of intelligent technologies in production and construction will inject new vitality into the development of ceramsite concrete, propelling it to play an even more crucial role in the construction industry and contributing to the achievement of carbon peaking and neutrality targets.

References

[1] Jia Xingwen, Wu Zhou, He Bing, et al. The influence of ceramsite pre-wetting treatment on the physical and mechanical properties of ceramsite foam concrete. Materials Guide, 2013, (6): 131-135.

[2] Wang Xiangyang, Pan Zhihua, Xing Yabing, et al. The influence of ceramsite surface pre-treatment on the performance of ceramsite foam concrete. Materials Guide, 2016, (7): 130-134.

[3] Zhao Hongchun. The influence of ceramsite pre-wetting time on the physical and mechanical properties of ceramsite foam concrete. Brick and Tile, 2014, (6): 39.

[4] Wang Haitao, Wang Licheng. Bending toughness and impact performance of steel fiber high-strength lightweight aggregate concrete. Journal of Building Materials, 2013, 16(6): 1083-1085.

[5] Wang Zhao'en, Feng Shaoying, Lin Rongbin, et al. Research on the preparation and strength test of ceramsite concrete. Concrete and Cement Products, 2017, (10): 70-72.

[6] Zhu Xueqing. Optimization design and comprehensive application of fly ash ceramsite concrete mix ratio. Qingdao: Qingdao University of Technology, 2016.

[7] Liu Xi, Lv Beibei, Liu Quan, et al. Experimental study on the mix ratio and strength influencing factors of high-strength lightweight aggregate ceramsite concrete. Bulletin of Silicate, 2014, (4): 847-852.