Innovation Series https://www.innoseries.com

Preliminary Study on the Mix Proportion of Translucent Concrete and its Concentrated Admixtures

Yongzhong Xi, Yao Li
Hunan Kezhijie New Material Co., Ltd 411202, China

Abstract: This study systematically explores the optimization of the mix proportion of light-transmitting concrete and the mechanism of action of concentrated admixtures. Through multiple sets of controlled experiments, it quantitatively analyzes the influence of different dosages of light-transmitting materials and proportion parameters of concentrated admixtures on the light-transmitting performance, mechanical properties, and durability of concrete. The results show that scientific regulation of the mix proportion can achieve the synergistic improvement of light transmittance and compressive strength, while the rational use of concentrated admixtures can significantly improve the workability of concrete and effectively enhance its impermeability, frost resistance, and other durability properties. The results of this study provide important technical parameters and theoretical support for the engineering application of light-transmitting concrete.

Keywords: Light-Transmitting Concrete; Mix Proportion Design; Concentrated Admixtures; Performance Optimization; Durability

1. Introduction

In the context of the innovative development of building materials, light-transmitting concrete has become a new type of material attracting much attention in the construction field due to its unique advantages of integrating optical properties and mechanical performance. By incorporating light-transmitting media such as optical fibers and glass particles into the traditional concrete matrix, this material breaks the inherent impression of concrete as "heavy and closed". It can realize the organic combination of light and building structures, and show unique aesthetic value and functional potential in scenarios such as building curtain walls, artistic decorations, and landscape lighting. However, the practical engineering application of light-transmitting concrete still faces many technical challenges. Among them, the mix proportion design directly affects the balance between the light-transmitting property and mechanical performance of the material. An unreasonable proportion may lead to a significant decrease in mechanical strength while improving light transmittance, which is difficult to meet the engineering load-bearing requirements. In addition, as a key component to improve concrete performance, the mechanism of action of concentrated admixtures in light-transmitting concrete has not been fully studied. In view of the characteristics of concentrated admixtures such as high-efficiency water reduction, strength enhancement and modification, and environmental protection, in-depth exploration of their adaptability and effect in light-transmitting concrete is of great significance for promoting the large-scale application of light-transmitting concrete.

2. Test Materials and Methods

2.1 Test Materials

Guided by the protection of sports rights for special groups in China, this research aims to identify the application predicaments and legal problems in the development of smart sports in China's special education sector, and propose relevant solutions through legal approaches, hoping to better promote the development of smart sports in this field and thus protect the physical exercise needs of special education students in accordance with the law.

2. Dilemmas in the Application of Smart Sports in Physical Education for Students in China's Special Education Sector

Smart sports in the special education sector is a service model that, against the backdrop of the rapid development of intelligent technology, utilizes technological means such as artificial intelligence, big data, and sensors to better provide personalized and high-quality physical exercise services for students in special education, targeting their diverse physical exercise needs. Smart sports equipment has, to some extent, improved the physical exercise conditions of special education students, yet there are still many issues in practical use.

2.1 Technical Aspect

Cementitious Materials: PO42.5 ordinary Portland cement is selected, and its performance indicators strictly comply with the GB175-2023 "General Portland Cement" standard to ensure the stability of the cementitious system and the basis for strength development.

Aggregate System: The fine aggregate adopts grade 2 granite sand with a mud content controlled within 3% to ensure good bonding between the aggregate and the cement paste, so as to meet the mechanical performance requirements of concrete.

Light-Transmitting Medium: Optical fibers with a diameter of 2mm and a light transmittance of more than 80% are used as light-transmitting materials. This diameter range can not only ensure effective light transmission but also reduce the negative impact on the workability of concrete.

Admixtures: A high-efficiency concentrated water reducer is used, with a water reduction rate of ⩾25%, which can significantly reduce the water-binder ratio of concrete. Its 1-day compressive strength ratio is not less than 130%, accelerating the early strength development of concrete. Other admixtures include heavy calcium carbonate powder and expansive agents.

Mixing Water: Tap water that meets the standard for concrete mixing water is used to avoid the impact of water quality on concrete performance.

2.2 Test Equipment

High-precision electronic balances are used for material weighing in the test. Forced mixers are adopted to achieve uniform mixing of materials. Vibration tables are used to ensure the dense forming of concrete specimens. Pressure testing machines are used for mechanical performance testing. Professional light transmittance testers are used to determine the light-transmitting performance, and standard slump cones are also equipped for workability testing.

2.3 Test Methods

2.3.1 Mix proportion Design Scheme

Based on a cement dosage of 800kg/m^3, a two-factor variable control method is adopted. Among them, the dosage of light-transmitting materials is changed in gradients of 10%, 15%, and 20% of the component surface area, and the dosage of concentrated water reducer is set in four gradients of 1.0%, 1.5%, and 2.0% of the cement quality to systematically explore the influence of each factor on concrete performance.

2.3.2 Specimen Preparation Process

In strict accordance with the designed mix proportion, aggregate, cement, and solid admixtures are sequentially put into the mixer and dry-mixed for 1-2 minutes to make them initially mixed evenly. Then, a certain amount of mixing water and concentrated admixtures are added and wet-mixed for 3-5 minutes until the concrete mixture reaches a good working state. The mixture is quickly put into prefabricated standard molds, vibrated on a vibration table to form, and air bubbles are removed. The molds are demolded after 24 hours, and the specimens are cured to 7d and 28d ages for performance testing.

2.3.3 Performance Testing Standards

1) Workability: According to GB/T 50080-2016 "Standard for Test Methods of Performance of Ordinary Concrete Mixtures", the slump test is used to evaluate the fluidity of the concrete mixture.

2) Mechanical properties: In accordance with GB/T 50081-2019 "Standard for Test Methods of Physical and Mechanical Properties of Concrete", the compressive strength of standard cube specimens is tested. Each group of tests is set with 3 parallel specimens, and the average value is taken as the test result.

3) Optical properties: A professional light transmittance tester is used to test the light transmittance of the specimens in multiple directions, and the average value is taken to ensure the accuracy of the data and comprehensively characterize the light-transmitting performance of the concrete.

3. Test Results and Analysis

3.1 Mechanism of the Influence of Light-Transmitting Material Dosage on Concrete Performance

3.1.1 Reasons for the Attenuation of Mechanical Properties

The dosage of light-transmitting materials is negatively correlated with the compressive strength of concrete. Both 7d and 28d compressive strengths decrease with the increase of dosage. When the area dosage is 10%, the 28d compressive strength is 40MPa; when the dosage increases to 20%, the strength drops to 22MPa. This is because the elastic modulus and strength of optical fibers are lower than those of cement stone and aggregate, forming weak links in the interface transition zone inside the concrete, which hinders the effective transmission of loads and reduces the overall mechanical properties of the material.

3.1.2 Principle of Improving Optical Properties

The dosage of light-transmitting materials is significantly positively correlated with light transmittance. When the dosage is 10%, the light transmittance is only 18%; when the dosage reaches 20%, the light transmittance increases to 35%. This is because optical fibers, as light-transmitting media, their increased quantity directly increases the light propagation paths, providing more channels for light to penetrate the concrete.

3.2 Characteristics of the Influence of Concentrated Water Reducer Dosage on Concrete Performance

3.2.1 Effect of Improving Workability

With the increase of concentrated water reducer dosage from 0.5% to 2.0%, the concrete spread increases from 730mm to 820mm. Through adsorption and dispersion, water reducer molecules effectively destroy the flocculation structure of cement particles, release the wrapped water, significantly improve the fluidity of the concrete mixture, and enhance the construction operability.

3.2.2 Law of Optimizing Mechanical Properties

Within a certain dosage range (0.5%-1.5%), the increase of water reducer dosage can improve the compressive strength of concrete. When the dosage is 1.5%, the 28d compressive strength reaches the peak value of 40MPa, which is 20% higher than that of the group without water reducer. This is because the water reducer reduces the water-binder ratio, promotes the full progress of cement hydration reaction, and makes the cement stone structure more denser. However, when the dosage exceeds 1.5%, due to excessive water reducer, the cohesion of concrete becomes poor, segregation and bleeding occur, which instead leads to a decrease in strength.

3.2.3 Analysis of the Influence on Optical Properties

Under different water reducer dosages, the light transmittance of concrete fluctuates in a small range, basically maintaining between 18% and 35%. This indicates that the water reducer mainly acts on cement particles, has little influence on the spatial distribution of light-transmitting materials and light transmission paths, and thus has no significant impact on light transmittance.

3.3 Comprehensive Analysis of Multi-Factor Synergistic Effects

Comprehensive analysis of the above test results shows that the dosage of light-transmitting materials is the core factor determining the light-transmitting performance of light-transmitting concrete, but excessive dosage will weaken the mechanical properties and workability. Concentrated water reducers mainly improve the workability and mechanical properties of concrete, with little influence on light transmittance. Therefore, in the actual mix proportion design, it is necessary to seek the optimal proportion combination of each component through optimization methods such as orthogonal test or response surface analysis based on the multiple requirements of the project for light transmittance, mechanical properties, and construction performance, so as to realize the comprehensive balance and optimization of material performance.

4. Exploration of the Influence of Concentrated Admixtures on the Durability of Light-Transmitting Concrete

4.1 Analysis of the Improvement of Impermeability

The impermeability test using the water seepage height method shows that the water seepage height of concrete specimens mixed with concentrated admixtures is significantly reduced. When the dosage of concentrated water reducer is 1.5%, the water seepage height is only 80mm, while that of the group without admixtures reaches 150mm. This is because the incorporation of admixtures optimizes the internal pore structure of concrete, reduces the number of connected pores, improves the compactness, and thus effectively blocks water penetration and enhances impermeability.

4.2 Mechanism of Enhancing Frost Resistance

The frost resistance test using the rapid freezing method shows that after 200 freeze-thaw cycles, the mass loss rate of concrete mixed with admixtures is 3%, and the dynamic elastic modulus loss rate is 15%; the mass loss rate of the group without admixtures is 8%, and the dynamic elastic modulus loss rate is as high as 30%. Concentrated admixtures can improve the internal pore structure of concrete, reduce the freezing point of pore solution, reduce frost heaving stress, and enhance the bonding force between cement stone and aggregate, thus significantly improving the frost resistance durability of concrete.

5. Conclusions

1) The dosage of light-transmitting materials has a significant impact on the performance of light-transmitting concrete. While improving light transmittance, it will reduce mechanical properties and workability. In practical engineering, the dosage of light-transmitting materials should be reasonably controlled within the range of 10%-15% according to specific needs to achieve a good balance between light-transmitting property and mechanical properties.

2) Concentrated water reducers can effectively improve the workability of concrete and increase compressive strength. The optimal dosage range is 1.0%-1.5%, within which both good construction performance and high mechanical strength can be ensured.

3) Concentrated admixtures can significantly improve the impermeability, frost resistance, and other durability properties of light-transmitting concrete, and effectively extend the service life of the material by optimizing the internal pore structure and enhancing interface bonding.

4) Considering the light transmittance, mechanical properties, workability, and durability, the recommended mix proportion of light-transmitting concrete is: the dosage of light-transmitting materials is 10%-15%, and the dosage of concentrated water reducer is 1.0%-1.5%, which provides an important reference for subsequent engineering applications.

References

[1] Li Yue, Guo Hui. Research Progress of Light-Transmitting Concrete.

[2] GB175-2023, General Portland Cement.

[3] GB/T 50080-2016, Standard for Test Methods of Performance of Ordinary Concrete Mixtures.

[4] GB/T 50081-2019, Standard for Test Methods of Physical and Mechanical Properties of Concrete.

[5] Wang Xinggang, et al. Erosion Resistance of Optical Fiber Light-Guiding Concrete with Different Types of Cement. Journal of Jiangsu University, 2014.

[6] Light-Transmitting Performance and Erosion Resistance of Optical Fiber Light-Guiding Concrete. Journal of Building Materials, 2016.

[7] Processing Method of Intelligent Transparent Concrete Based on Optical Fibers. Chinese Patent, 2018.