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A Practical Research based on Steel Fiber Reinforced Concrete Construction Technology in Road and Bridge Engineering

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Abstract: This paper conducts practical research on the application of steel fiber reinforced concrete construction technology in road and bridge engineering. The study emphasized in its core advantages of tensile strength, impact resistance, fatigue resistance and high toughness, and introduces its applications in scenarios such as bridge deck pavement, expansion joints and tunnel opening sections. The key points of construction techniques such as material ratio and fiber selection, mixing, pouring and vibration, as well as quality control difficulties and solutions such as steel fiber dispersion, shrinkage cracks and temperature control was analyzed. The development trends of intelligent material research and development and automated construction technology, and propose application suggestions for engineering design and construction management was discussed in this study, which can serve as a references to improve the quality of road and bridge engineering.

Keywords: Steel fiber concrete; Construction techniques; Road and bridge engineering; Application practice

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1. Introduction

With the continuous development of contemporary road and bridge engineering, especially the increasing traffic load and the demand for structural durability, the shortcomings of ordinary concrete, such as low tensile strength and poor crack resistance, are far from meeting the requirements for use [1]. Steel fiber concrete, due to its superior mechanical properties compared to ordinary concrete, has played a crucial role in the application of contemporary road and bridge engineering. This paper presented a study on the construction technology of steel fiber reinforced concrete, explored the application of the construction technology of steel fiber reinforced concrete from the perspective of contemporary road and bridge engineering, and analyzed the advantages and prospects of the application of steel fiber reinforced concrete from the key points of construction technology and construction quality control [2].

1.1. Core advantages of steel fiber reinforced concrete

First, the composite reinforcing properties of mechanical properties fundamentally improve the stress defects of concrete. Ordinary concrete, as a typical brittle material, has significant difference performance in tensile, flexural and compressive strength, and is prone to cracking failure under tensile stress. When steel fibers are embedded in the concrete matrix in a three-dimensional transverse distribution form, a synergistic force system was formed through interfacial bonding force. When the material was under tension, the steel fibers can effectively bridge the matrix on both sides of the crack, converting concentrated stress into dispersed stress, thereby increasing the tensile and flexural strength of the concrete by magnitude. This equalization of mechanical properties, Essentially, it alters the brittle failure mode of concrete [3].

Second, the improvement in durability and reliability has been valued throughout the engineering life cycle. The external medium infiltration that resulted by crack development was the main cause of durability defects in concrete structures. Steel fibers constrained the shrinkage deformation of concrete, confining cracks before they occur, while improving the pore structure of the matrix enhances impermeability and corrosion resistance. The frost resistance of steel fiber concrete in severe cold regions can adapt to environmental conditions; in coastal environments, the resistance of steel fiber concrete to chloride penetration can extend the time of steel bar corrosion. This improvement in durability ensures lower maintenance costs and more reliable safety performance throughout the entire life cycle of steel fiber concrete structures.

Third, the technical and economic balance provides wide applicability for engineering applications. Although the price of steel fibers themselves will lead to an increase in the price of concrete, combined with the selection of material ratios and fine-tuning of construction procedures, it can save cement and reduce later usage and maintenance costs and other economic inputs without reducing material performance. At the same time, in line with the concrete construction process, it is highly operable and does not require a large number of updated tooling equipment. Only the mixing method needs to be improved to fully disperse the concrete. This economic and operational feasibility makes it suitable for engineering use in many fields such as urban Bridges and heavy traffic roads, so that the performance advantage can be translated into practical engineering applications [1].

1.2. Application scenarios of steel fiber reinforced concrete in road and bridge engineering

First, the functional application of the bridge deck system demonstrates its performance compatibility advantage. The pavement is in the load-bearing layer that directly receives the load of vehicle travel, and is also affected by external forces such as load bending moment, pavement wear and temperature displacement. The damage of conventional cement concrete bridge decks is mainly manifested as cracks and pavement damage. The enhanced hardness and ductility properties of reinforced concrete materials can produce a more balanced stress sharing effect among the bridge deck pavement layers, and have better pavement wear resistance and reduce surface wear of the bridge deck material. At the same time, the reinforced concrete in the expansion joint area of the bridge deck avoids the stress concentration caused by temperature deformation of the bridge expansion joint by reducing the impact force of vehicle load transfer, thereby improving the poor state of vehicle jumping on the pavement, and the corresponding performance of the material when acting on the bridge deck structure helps to increase the service life of the material [4].

Secondly, the key parts of the main structure of the bridge show special application value. For complex stress node components such as piers, columns, caps and beams, steel fiber reinforced concrete can enhance the

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ductility of the material and increase the seismic deformation bearing capacity of the structure under accidental effects such as earthquakes; For the anchorage zone of prestressed concrete Bridges, it can relieve the concentrated compressive stress transmitted from the anchor to the component and reduce the possibility of concrete splitting. Steel fibers at the concrete flange of steel-concrete composite beams can slow down the crack width and improve the interfacial synergistic effect. This setup is based on the application of key structural parts to enhance the uniformity of mechanical properties of steel fiber concrete, compensating for the shortcomings of ordinary concrete [5].

Finally, adaptive applications in special engineering environments expand the boundaries of their scenarios. Steel fiber reinforced concrete has good adaptability to uneven settlement caused by different geological conditions, and resizes additional stress caused by soil deformation through toughness; It has the ability to resist seepage and erosion in highly corrosive areas such as salt lakes, which can prevent the penetration of chloride ions, sulfates, etc. into the concrete and extend the service life of the concrete; It has an extremely strong adaptability to the effects of long-term freeze-thaw cycles in road and bridge engineering in severe cold regions, and its frost resistance can meet the requirements of structures that have been in service for a long time under extreme climate conditions. This environmental adaptability greatly expands its application field, breaks through the application scope of conventional concrete, and has great advantages in special engineering environments [6].

2. Key points of steel fiber reinforced concrete construction technology

2.1 Material ratio and fiber selection

The selection of materials and the choice of steel fiber specifications in steel fiber concrete construction are the basis and key factors affecting the performance of the concrete and the quality of the construction. The selection of steel fibers should take into account the engineering requirements and the environment of use. In terms of the specifications and models of steel fibers, the shape, diameter, length and tensile strength of the steel fibers would have a very significant influence in the performance of steel fiber concrete. For example, wavy or hook-shaped steel fibers have a higher bonding force with concrete and could provide better reinforcement. For impact-resistant projects, steel fibers with high tensile strength and strong toughness should be selected [7].

Determining the dosage of steel fibers requires experimental optimization. Under normal circumstances, the dosage of steel fibers is 0.5%-2.5% (by volume). If the dosage was too low, the reinforcing effect will not be significant. If the dosage is too high, it would affect the workability of the concrete and increase the difficulty of construction. At the same time, cement, aggregates, water and other materials should also be properly mixed. The cement should be of appropriate strength grade, stable quality, Portland cement variety; Good aggregate gradation to ensure concrete density; The water-cement ratio was strictly controlled. If the water-cement ratio is too high, the strength and durability of the concrete will decline. If the water-cement ratio is too small, the workability of the concrete will be poor [8].

2.2 Key links of the construction process

The key links of the construction process played a decisive role in the quality of steel fiber reinforced concrete. During the mixing process, it is difficult to mix the concrete as the steel fibers were added. At the same time, it would be necessary to disperse the steel fibers into the concrete without clumping. Therefore, all of the mixing equipment, mixing time and mixing speed control were crucial. Usually, a forced mixer was used for mixing, the mixing time was extended by 1-2 minutes, and the mixing speed was chosen reasonably to disperse the steel fibers into other materials [9].

Attention should be paid to the workability and fluidity of the concrete during pouring. Steel fiber reinforced concrete has poor workability and was prone to segregation during pouring. Some effective measures need to be taken, such as controlling the pouring speed and strengthening vibration. Vibration is the key to achieving a dense concrete. Appropriate vibration equipment should be used and the vibration should be uniform to prevent missed vibration or over-vibration. When over-vibration occurs, the steel fibers will settle, and the steel fibers will easily cause a decrease in the performance of the concrete. When missed vibration occurs, there will be voids inside the concrete, and its strength and durability will be affected.

2.3 Difficulties in quality control and solutions

There are certain difficulties in the construction quality management of steel fiber reinforced concrete. The main quality control difficulties were the dispersion of steel fibers, poor dispersion of steel fibers, prone to breakpoints at weak positions, and the difficulty of steel fibers acting on the entire concrete structure. The problem of steel fiber dispersion can be solved by using scientific methods during mixing, or by first mixing the steel fibers with some aggregates when adding raw materials and then adding the remaining materials to increase the dispersion of steel fibers [11].

Shrinkage cracks in concrete are also a difficult point in quality control. While steel fibers can reduce cracks, they were unable to eliminate shrinkage cracks. During construction, the occurrence of shrinkage cracks were usually reduced by controlling the water-cement ratio and enhancing curing. Curing is a key link to ensure the strength and durability of concrete. Different curing methods, such as covering and retaining moisture, watering curing, etc. are adopted according to the ambient temperature and humidity, and the curing time should be no less than 14 days [10].

In addition, temperature control during the construction process should not be overlooked. If construction was carried out in hot weather, cooling work should be done at this time, and the temperature of raw materials should be adjusted appropriately on this basis, or construction can be carried out at night, etc. If it is during the period of low temperature, insulation work should be done well. Make sure the concrete sets and hardens properly after the pouring is completed.

3. Development trends and suggestions

3.1 Directions for technological innovation

From the perspective of technological innovation, the composite and functional innovation of material systems has becomes the core driving force for the development of steel fiber reinforced concrete. In recent years, the preparation of steel fibers has not merely focused on a single technology to improve the performance of steel fibers, but has improved the interfacial performance between fibers and concrete in terms of the shape and structure of the fibers and surface treatment methods. For example, the application of different shape structures such as square cross-section design and different diameter design can change the internal stress distribution state of the fibers under stress, and coating with zinc or copper and adding resin can also enhance the mechanical interlocking and chemical bonding effects with the concrete matrix; The development of different fiber admixtures is growing, that is, when steel fibers are mixed with different proportions of polypropylene fibers or carbon fibers, they can improve the mechanical reinforcement performance while compensating for the lack of fluidity in concrete construction, thereby expanding the application range of the material to a greater extent.

The intelligent and digital transformation of construction techniques is the key path to improving the efficiency of steel fiber concrete construction. In the context of the rapid improvement in the efficiency and quality of steel fiber concrete construction, manual methods are gradually shifting to intelligent construction methods.

In steel fiber concrete mixing, the Internet of Things technology is applied to the intelligent mixing system to enable real-time collection and analysis of parameters of raw materials and mixtures in the cloud or cloud and on-site terminal servers, and the parameters are iterated using deep learning models. The final goal is to achieve uniform dispersion of steel fibers in the mixture and stable working performance of concrete, such as pouring material mixing time and mixing speed; In the construction of steel fiber concrete, combine unmanned aerial vehicle intelligent navigation with automatic pouring and distribution equipment to achieve intelligent automatic pouring in difficult pouring areas, avoiding the occurrence of missed distribution and uneven distribution by construction workers; In steel fiber concrete pouring vibration construction, intelligent automatic vibration equipment that combines a self-excited vibration frequency detection system with a self-excited vibration positioning system, such as an automatic vibration robot combined with a positioning system, when the vibration operation parameters meet the construction requirements, the vibration frequency and path are fed back to the control system of the automatic vibration robot through the self-excited vibration frequency detection system.

Avoiding the problem of missed vibration and over vibration, enabling the automatic vibration robot to vibrate along the predetermined trajectory, improving the vibration efficiency of the poured concrete, and achieving information-based traceability and parameter control, becoming an intelligent construction system supported by data, achieving intelligent construction of steel fiber concrete [11].

3.2 Suggestions for engineering application

In the engineering design stage, a performance-oriented collaborative design mechanism should be established. Steel fiber reinforced concrete design should not adhere to the traditional concrete design system, with a standard index as the evaluation system and compressive strength requirements as the example, but should be guided by the actual performance requirements of the structure to propose the requirements of the structure for the material's tensile strength, crack resistance, fatigue resistance, etc. Designers should work closely with research institutes to propose specific material design schemes based on factors such as the actual load level of the project, regional climate or corrosive media present, and appropriately select the type of steel fiber, the amount of steel fiber and the concrete mix ratio. For complex structural parts such as large-span bridge nodes and heavy traffic roads. The finite element method can be used to simulate the stress state of steel fiber concrete under stress conditions, thereby clarifying its reasonable structural form and reinforcement method, etc., to achieve the matching of material performance and structural stress performance. At the same time, the design document should specify the construction techniques and quality control requirements to provide detailed and implementable technical guidance for the later construction [12].

At the construction management level, a specialized and refined implementation system needs to be established. Since the quality of steel fiber concrete construction is more affected by construction details, construction enterprises should establish professional construction teams to provide targeted training on issues such as steel fiber dispersion, mixing technology, pouring and vibration technology during the construction process, and improve the operators' understanding of the performance of construction materials and control of construction technology. In terms of construction organization, a refined construction plan should be established, with clear construction process parameters such as the sequence of steel fiber feeding, mixing duration, and thickness of each layer of pouring, and the feasibility of the construction process should be verified through sample projects. In terms of quality control, a quality control process was established for the inspection of incoming raw materials and the detection of formed structures.

Non-destructive testing such as ultrasonic flaw detection and infrared thermal imaging technology was used to test the quality control of key parts to ensure that the construction quality met the design requirements [13].

4. Conclusion

In conclusion, it is highly necessary to flexibly apply steel fiber reinforced concrete construction technology in road and bridge projects. This not only significantly enhances the performance and service life of the roads and bridges themselves, but also meets the relevant demands for high strength and high durability in modern road and bridge projects. In future construction projects, it is necessary to continuously enhance the exploration and practice of this technology, and further improve the relevant processes and quality control measures, so as to facilitate the wider application of steel fiber concrete construction technology in road and bridge projects and promote the better development of China's transportation industry.

Disclosure statement

The authors declare no conflict of interest

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