Development of the research of steel fiber reinforced cement

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Abstract

Steel fiber reinforced concrete is a composite material prepared by traditional concrete mixing with appropriate amount of steel fiber; it could significantly improve the performance of flexural, tensile strength, crack resistance and durability of concrete. To some extent, it can also change the brittle nature of the traditional concrete. To improve the interface property of fiber--- matrix, the generally measure is to mix the steel fiber reinforced concrete with the polymer or silica fume. Due to the excellent mechanical properties of steel fiber reinforced concrete, it is applied widely. Based on this, this paper explains and analysis the performance of steel fiber reinforced concrete, the mechanism of steel fiber modification and polymer modification. At last, it conclude part of the research and progress directions of the fiber reinforced concrete.

Keywords

Steel fiber; polymer modification; fiber--- matrix interface; modification mechanism.

1. Introduction

Concrete has become the construction works and road works indispensable building materials, its high compressive strength, energy pouring in situ, full use of local materials, reduce project cost; also can be shop-fabricated, easy to control the quality of the project and ensure its use performance to meet the requirements. However, conventional concrete also has its own big flaw: the intensity ratio of low quality; the quality of large-scale structure is too large, the higher the foundation requirements; low tensile strength, prone to fatigue cracking; temperature shrinkage, chemical shrinkage and shrinkage is easy to form the micro cracks, leading to stress concentration in the concrete under load, freezing effect, reducing the compression structure, the tensile strength and durability.

Common method of improving the low tensile strength of concrete quasi-brittle material is steel and concrete composite fiber. Steel fibers can be cut or melt scrap steel pump is made relatively low cost, wide variety of sources. Steel fiber reinforced concrete to improve the physical and mechanical properties and durability of ordinary concrete, it showed better tensile, bending, shear strength and bending toughness, impact resistance, wear resistance, fatigue resistance, anti-knock and limit shrinkage crack resistance performance significantly better than ordinary concrete. Thus, home and abroad to obtain more extensive research and application [13].In practical applications of steel fiber reinforced concrete also be showing its shortcomings. Steel fibers incorporated, can really enhance the toughness of concrete, fatigue resistance and deformation capacity, improve the brittleness of the concrete itself, but also because of weak interface bond strength greatly affected the reinforcing effect of steel fibers. Thus, many scholars experimental study found that adding a polymer or silica fume can better improve the mechanical properties of steel fiber reinforced concrete in steel fiber reinforced concrete. The article then detailed work performance and modification mechanism discussed in steel fiber reinforced concrete, further research concludes with the author summarizes the development direction.

2. Steel Fiber Reinforced Concrete on Mechanical Properties

2.1 Compressive and flexural strength

In numerous studies, we have found that the incorporation of steel fibers can significantly improve the flexural strength of the concrete, but smaller influence on the compressive strength, even negligible. Gu Zhiqiang [1] in his study found that when the steel fiber content of 1.2%, the flexural strength of concrete 28d increased by 52% than ordinary concrete, compressive strength increased by only 8.6%. After Chen Deyu [2] When using 42.5 early strength cement, steel fiber obtained, the compressive strength of concrete can be improved up to 19 percent, while the flexural strength and splitting strength can be improved up to 34%. Qin Hong root [5] when changing the fiber volume content Vf, derived in Vf increases from 0 to 2%, the compressive strength increased by 26%, the splitting tensile strength increased by 74% increase in the first crack bending tensile strength 61%, ultimate flexural strength increased by 105%. Effect of the fiber better reflected in the increase in bending, crack resistance, the compressive strength is easier to W / C to be controlled. He also made in the study, improvement in bending steel fiber reinforced concrete, the tensile strength can be achieved by an appropriate increase in Vf in SFRC mix design, compressive strength index to calculate the W / C, with a flexural strength to calculation of fiber volume fraction, the use of compressive strength and flexural strength of the two indicators for SFRC mix design.

For improved tensile strength, generally considered the results of the present study was mainly due to the stress of steel fiber transfer effect, micro-cracks appear in the concrete, the steel fiber structure began to withstand tensile stress. By bonding effect of steel fiber and concrete matrix between the steel fiber concrete stress transfer to the substrate, thereby increasing the overall strength and splitting tensile strength of concrete structures [3].

2.2 Durability

General studies have found that steel fiber can effectively prevent cracking of concrete at early age due to the temperature shrinkage, caused by dehydration, and can also reduce the pace of development in the latter part of the cracks, changing the direction of the crack, which helps to some extent, improve the fatigue resistance of concrete [2], to extend the pavement life. However, due to its steel fiber reinforced concrete workability decline in the mixing process easy to introduce air bubbles, especially micro-bubbles, their number and distribution in the concrete can lead to concrete impermeability to reduce long-term rain after frost damage can lead to erosion and water loss, so in the concrete mixing generally are required to join the anti-foaming agent. In addition, the steel fibers added to the concrete abrasion can introduce negative impact, mainly because in order to ensure the workability of steel fiber reinforced concrete, its water-cement ratio generally larger, easily lead after the concrete surface vibrators laitance layer [1]. However, this is mainly the performance of cement and relatively close relationship, so different scholars whose research results are quite different.

2.3 Deformability and toughness

For steel fiber bending and impact toughness of concrete, many scholars have done related research and analysis. Gu Zhiqiang [1] adopted in the test flexural toughness index, load - deflection graph curve and the horizontal axis around the area to characterize the toughness properties of concrete, bending toughness index of steel fiber reinforced concrete is 14 times that of ordinary concrete. Yao Wu [3] in his study also found a similar phenomenon, and with the increase of steel fiber content, the required fracture energy also increased, but it mixes with the water-cement ratio increases. Its causes, Yao Wu interpreted as SFHSC due bridging and bridging of the fibers, limiting the expansion of the macroscopic crack, so that the carrying capacity of concrete with crack width increasing slow down and eventually destroy the specimen deflection and crack opening degrees has increased significantly than ordinary high strength concrete fracture process consumes more energy, showing the characteristics of ductile failure [3].

Qin Honggen [5] noted that Vf increases from 0 to 2%, the flexural toughness of steel fiber reinforced concrete increased by 265%, the ability to crack induced inhibition of 60% improvement, crack

propagation ability to inhibit the increase of 105%, it shows that steel fiber toughness and crack resistance effect on concrete. It also described the steel fiber length of 25 ~ 35mm, the equivalent diameter of 0.40 to 0.50, an aspect ratio of 60 to 65, the toughening effect is the best; however, the tensile strength of steel fiber influence on the mechanical properties of SFRC obvious only in formulating C80 above high-strength and ultra high strength concrete, only the need to use high-strength steel fibers, otherwise, when SFRC first crack part of the fiber pull off, concrete flexural toughness smaller, so that SFRC may still exhibit brittle failure when damage from less than toughening effect.

3. Steel fiber modified mechanism analysis

After the above description, steel fiber concrete modified by different tests, different ratios and fabric type and showing a different effect. Therefore, it is necessary to steel fiber concrete modification mechanism were studied intensively analyze, provide theoretical guidance for engineering applications.

Steel fiber reinforced concrete performance depends on concrete matrix, properties and relative content of both steel fibers and the interfacial bonding, wherein the interface bonding and interfacial effects are played on concrete increased toughness and crack resistance capability of critical fibers. Therefore, the study of the interface of steel fiber reinforced concrete caused widespread concern in the domestic and foreign scholars. Generally believed that steel fiber concrete and modulus of the two materials difference is too large, and the material composition, surface molecular composition, physical and chemical properties are different, resulting in the same bond between steel fiber concrete interface is not ideal, low intensity, very easy to cause peeling fiber, steel fiber reinforced concrete such failure. Therefore, the following analysis will start from the same interface properties of steel fiber concrete, steel fiber described modification mechanism.

3.1 Interface Characteristics

Cement matrix structural steel fiber reinforced concrete steel fiber around its own structure is not the same, from the fiber surface to the cement paste layer by layer-by-point between research and testing found that there have been weaknesses in the special zones, namely transitional zone, also known as the interface layer. But this is not a surface interface layer, but a body having a certain thickness [7]. In the mixing process, the steel fibers, aggregate surface water layer having a thickness of only a few to tens of microns. When the cement compound soluble in water, dissolved ions according to ion diffusion degree turn into the active layer of water, the water layer was first produced by the hydration products it is the first of these ions diffuse into the water layer composed of crystal phase.

Yin-Wen Chan [9] in the study of steel fiber reinforced concrete with adhesion when using SEM fiber pull when shooting with steel fiber concrete matrix interface between the picture showed that steel fiber surface is substantially not subject to wear, smooth close surface, indirectly proves the direct bond between steel fiber with the concrete matrix is not together.

S. Igarashi [14] in the study also experienced a similar phenomenon. Change its steel fiber reinforced concrete in the cement matrix, we found that the rate of change of the sand can be more significant influence of steel fiber pullout by fiber pullout tests, which may be precisely because of changes in the rate of sand, causing the effect of increasing the aggregate interface Less. In addition, changes in the surface of the mortar microstructure may also be the cause of this phenomenon.

3.2 Polymer Modified Steel Fiber Reinforced Concrete

Cong Yu Zi [12] using acrylic ester copolymer emulsion in the study as the incorporation of steel fiber polymer concrete compared with steel fiber reinforced concrete, the compressive strength of steel fiber reinforced concrete mixed with the polymer, the axial compressive strength obviously not improve, increase of only 20% to 25%, and flexural strength, splitting tensile strength, increase rate was about 75%; further bending toughness have been significantly improved, toughness index may continue to increase by about 30%.

Luo Lifeng [7] in the study also received the same law, after the incorporation of the polymer, under the same curing conditions, the flexural strength of steel fiber reinforced concrete continue to grow, but there will be an optimum polymer dosage problem.

In addition, studies have found that, after the incorporation of polymers, composites impermeability greatly improved, on the adhesive properties of old concrete layer also enhance the role, which is to improve the concrete frost resistance, durability meaning major. However, to improve the performance of steel fiber reinforced concrete, and are not limited to polymers, and now research is widely used along with silica fume.

Handong Yan [6] through a set of experiments, silica fume steel fiber reinforced concrete impact resistance of 29 times, only steel fiber is much larger than 17 times, and it still withstand greater impact in the cracks energy will lead to the destruction of concrete; fatigue life correspondingly increased 134%.

Zhang Yamei [16] also found that after the incorporation of silica fume, greatly reducing the setting time of concrete, its 6h, 24h and 3d compressive strength increase rate of 30% to 50%.

Wu Guoqiang [8] analysts believe that after the incorporation of the polymer, water reduction and may exist with the binding of calcium ions, etc., can greatly eliminate steel fiber - weak interface zone between the concrete matrix, coupled with good adhesion to the polymer and thus strengthen the interface, the fiber pullout strength can be improved.

For silica fume, the fineness generally smaller than the cement, has a huge surface area. High activity of these fine particles, resulting in nucleation effect and pozzolanic effect in cement-based materials, and therefore, silica fume can absorb Ca (OH) $_2$ and generate more C-S-H gel, jams and cut off interface region with slit pores of the substrate, changing the pore structure, reducing the interfacial region Ca (OH) $_2$ crystals of average size, orientation index and reduce the degree of enrichment, more effectively improve the steel fiber - between the concrete matrix interfacial bonding properties and interfacial effects of steel fiber and steel fiber concrete before and after the suppression of cracks caused by stress and the ability to scale out to play a greater extent, enhance the role of both the composite concrete reinforced, toughened and crack resistance ability [11].

4. Prospects

Steel fiber reinforced concrete with good, toughness, crack resistance ability, but with weak coupling between the concrete matrix of steel fiber reinforced hinder their potential to make steel fiber concrete often "false toughness" phenomenon. Many scholars are committed to polymer modification, in order to enhance the interface bonding steel fiber reinforced concrete, steel fiber changed radically - the interface between the concrete matrix effect, however, these different types of polymers, modification mechanism is not exactly the same, the treatment effect should be the same physical and chemical properties of the polymer, and even particle size, about incorporation, it is impossible to generalize.

And now, on the bond strength of steel fiber and concrete matrix between the mainly through direct pullout tests obtained. Test specimens are used to straight fixed number of fibers in the concrete, and then find the average anti each strand of fiber pullout by drawing test. Due to its principle clear, simple operation, without specially designed test equipment, so widely used. However, the actual steel fiber concrete mix, paving could not keep straight after steel fiber morphology, fiber chaotically distributed in space and shapes, can be found in the concrete section of the steel fibers are generally the same cross-section at an angle, which also it makes the reliability of test results greatly reduced. This will need to steel fiber concrete mixing, molding process design closer to the actual test.

The conventional concrete mix designed to flexural strength design specifications, cannot take into account the durability and toughness of concrete. Steel fiber concrete mix design, is also a continuation of this idea, therefore, the need to strength concrete material on the basis of design specifications, may be concrete parameters and fracture microscopic features characteristic parameter as an index composed of steel fiber reinforced concrete mix design theory system, taking into account the concrete strength, toughness and durability. However, this in turn requires a more in-depth study

of microscopic parameters of concrete with a clear quantitative relationship between structure and properties of concrete.

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