Mechanical Performance of Steel Fiber Lattice Reinforced Concrete Structure

Junfei Shen and Cuixiang Jiang
Department of engineering mechanics, Wuhan University of Science and Technology, Wuhan 430065, china
Email: 1304260604@qq.com

Abstract. The mechanical performance of steel fiber reinforced concrete was studied in this paper. The steel fibers in the concrete were processed into latticed structure. This reinforced concrete has the feature of good design ability and convenient construction. The experiment was conducted to study the influence of fiber lattice form on the bearing capacity of reinforced concrete. The results show that adjusting the included angle between the fibers and increasing the effective working length in the direction of tensile stress can retard the growth of crack. The loading capacity of the structure increases by 24 percent when the included angle decreases from 90° to 30°. Through the design of steel fiber latticed structure, the bearing capacity of steel fiber reinforced concrete can be efficiently improved.

1. Introduction
Steel reinforced concrete is commonly used in civil construction engineering because it has good mechanical performance and structural features. To satisfy the requirement of modern civil engineering structure, various building materials with excellent performance are developed. Steel fiber reinforced concrete [1, 2], as a new composite combining concrete with steel fiber, can effectively solve many difficulties in engineering. Because of its own advantages, it has a broad prospect in application. Many theoretical and experimental researches have been done on the steel fiber reinforced concrete [3-14], which promotes the practically application of steel fiber reinforced concrete in engineering. However, due to the structural specificity of steel fiber, problems in respect of the construction technology and fiber content design sometimes occur in practical engineering.

To make steel fiber reinforced concrete structures with good design ability and convenient construction, steel fibers are made into latticed structures and put into the concrete. This study presents the works on the flexural performance of the steel fiber reinforced concrete structures through the change of steel fiber latticed structures, as well as the effect of altered latticed structures on the bearing capacity of steel fiber reinforced structures.

2. Materials and experimental procedure

2.1 Materials
Raw materials: Portland cement with grade of 42.5. Two types of aggregates (coarse and medium river sand of degree of fineness 3.5 and 2.9, respectively). Water, cement, medium sand, medium sand were prepared in a proportion of 0.38:1:1:2.72. The steel fibers used in the concrete structure had a diameter of 0.45mm, Young’s modulus of 200GPa, and tensile strength of 3000MPa.
2.2 Specimen preparation and testing

2.2.1 Latticed structure of steel fiber. The steel fibers were made into the latticed structure, as shown in the figure 1.

![Figure 1. The latticed structure of steel fiber](image)

The steel fibers along the tensile stress direction in the latticed structure bear tensile stress, and the steel fibers in the other direction play the role of fixing the latticed structure mainly. By adjusting the included angle θ between the fibers, the latticed structure altered, and the bearing capacity of the reinforced concrete can be changed.

2.2.2 Specimen preparation. For testing the bearing capacity of the flexural members, 100mm×100mm×500mm concrete prisms with different steel fiber latticed structure were prepared, referring to the Code for Design of Concrete Structures (GB50010-2002). Four kinds of fiber latticed structures were designed. The included angle θ between the fibers is 30°, 45°, 60°, 90°, respectively. To all the specimens, the cross section area ratio of steel fiber to concrete is 0.1% along the direction of the tensile stress. All the specimens have the same content of steel fibers. The thickness of protective layer of the reinforced structure is Δc=10mm. As shown in figure2. After the specimens were removed from the moulds, all the sixteen specimens in four groups were cured in water for a period of 28 days and then tested.

![Figure 2. Sketch of steel fiber reinforced concrete structure](image)

2.2.3 Loading method. The experiment was based on the three point bending experiment principle. All the flexural members were tested using a 100kN Universal material testing machine, under a constant loading rate of 0.03mm/min.

3. Result and analysis

Figure3 shows the crack of a failure specimen. The failure progress of the flexural members made of steel fiber reinforced concrete is similar to which is made of steel rebar reinforced concrete. With the increase of the load, the crack appeared on the middle of the specimen’s bottom at first. It extended upwards to the top along the side of the specimen till it fractured.
The section of steel fiber reinforced concrete structure specimen after failure is shown in figure 4.

No apparent steel fiber was pulled out in the sections of failed specimens, indicating that the steel fibers in the specimens had been fully mixed with concrete. Well mixed specimens has good binding performance, which contributes to the reliability of the structure.

Figure 5 shows the change of deflection of the specimens with load.

It shows that when the included angle \( \theta \) between the fibers is 90°, the bearing capacity of the specimen is the lowest. With the decrease of included angle, the bearing capacity of the specimen
increases in contrast. Among the four fiber latticed forms, the specimen with angle $\theta$ of 30° has the highest bearing capacity. The included angle and average limit bearing capacity of four steel fiber latticed forms are shown in Table 1 respectively.

| Included angle between steel fiber (°) | 30  | 45  | 60  | 90  |
|----------------------------------------|-----|-----|-----|-----|
| Average bearing capacity of specimen (kN) | 14.31 | 13.60 | 12.54 | 11.52 |

When we use the same amount of steel fibers, the effective working length of fibers along the direction of tensile stress increases with the decreasing of included angle $\theta$ of steel fiber latticed structure, which is advantage to retard the flexural specimen’s crack growth. It means that the loading capacity of the steel fiber reinforced concrete structure is improved. As the result of the experiment, the loading capacity of the structure increases by 24 percent when the included angle decreases from 90° to 30°.

4. Conclusion

(i) The steel fiber lattice reinforced concrete structure can efficiently increase its bearing capacity. This kind of reinforced concrete structure has great advantage of good design ability and convenient construction. Along the direction of tensile stress, the effective length of the steel fiber increases through the adjustment of the included angle $\theta$ between the steel fibers. As a result, this structure significantly reduces the crack widths and enable the concrete to sustain a higher loading.

(ii) Comparing to steel rebar reinforced concrete, the flexural member with steel fiber latticed structure increases the contact area between steel and concrete, which enable the two materials to stick tightly. Meanwhile, it has better mechanical performance around the junction of steel fibers and concrete.

(iii) Steel fiber latticed structure, used for different kinds of concrete structure, can be designed and put into where it need to be enhanced. Through the design of steel fiber latticed structure, the bearing capacity of steel fiber reinforced concrete can be efficiently improved.

5. References

[1] Tadepalli P R, Mo Y L, and Hsu T C. 2013. Mechanical properties of steel fibre concrete. Concrete Research, 65 (8): 462-474.
[2] Narayanan R, Darwish I Y S. 1987. Use of steel fibers as shear reinforcement. ACI Structural Journal, 184 (3): 216-227.
[3] Lim D H, Oh B H. 1999 Experimental and theoretical investigation on the shear of steel fibre reinforced concrete beams. Engineering Structures, 21 (10): 937-944.
[4] Wu Ke ru, Li Shu jin. 2005. study of mechanical properties of different size hybrid steel fibre reinforced cement mortar. Journal of building materials, 8 (6): 599-604.
[5] Jang Seok-Joon, Kang Dae-Hyun. 2015. Feasibility of using high-performance steel fibre reinforced concrete for simplifying reinforcement details of critical members. International Journal of Polymer Science, 850562: 1-12.
[6] Shen Linghua, Wang Jiyang, Xu Shilang. 2016. Experimental study on bending mechanical behavior of textile reinforced concrete thin-plates with short dispersed fibers. Journal of architectural structure, 37 (10): 98-107.
[7] Mobasher B, Yao Y M. 2015. Analytical solutions for flexural design of hybrid steel fiber reinforced concrete beams. Engineering Structures, 100: 164-177.
[8] Amar, P., Srinivasan, S. M., and Rama Mohan Rao. 2015. A. Numerical investigation on steel fibre reinforced cementitious composite panels subjected to high velocity impact loading. Mater. Des, 83: 164-175.
[9] Eik, M., Puttonen, J., and Herrmann, H. 2015. An orthotropic material model for steel fibre reinforced concrete based on the orientation distribution of fibres. Composite Structures, 121: 324-336.
[10] Chi, Y., Xu, L., and Sui, Yu. H. 2014. Constitutive modeling of steel-polypropylene hybrid fiber reinforced concrete using a non-associated plasticity and its numerical implementation. Composite Structure, 111: 497-509.
[11] Barros, J. A., Lourenço, L. A., Soltanzadeh, F. & Taheri.M. 2014. Steel fibre reinforced concrete for elements failing in bending and in shear. European Journal of Environmental and Civil Engineering,18 (1): 33-65.
[12] Aoude, A. F, Belghiti, M., cook, W. D. & Mitchell.D. 2012. Response of steel fibre-reinforced concrete beams with and without stirrups. ACI Structure Journal, 109 (3): 359-368.
[13] Kunieda, M., Ueda, N. & Nakamura, H. 2014. Ability of recycling on fiber reinforced concrete. Construction and Building Materials, 67: 315-320.
[14] Won, J. P., Hong, B. T., Lee, S. J., and Choi, S. J. 2013. Bonding properties of amorphous micro-steel fibre-reinforced cementations composites. Composite Structures,102: 101-109.