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Numerical Simulation of Aseismatic Reinforced Concrete Frame Structure with Fiber Reinforced Plastics

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Fiber reinforced plastic reinforced concrete structure has been developed rapidly since the late 1990s in China. The optimization of the reinforce method has achieved a lot of research achievements. However, its reinforcement mechanism has not been well solved, and there are still many problems worth studying. On the basis of summarizing the strengthening methods which have been reported, this paper points out the existing problems of existing reinforcement methods and summarizes the advantages of the reinforcement of fiber plastics. Based on the experimental data, the reinforcement effect of fiber reinforced plastic reinforced concrete square columns is analyzed. Aiming at the fiber reinforced plastic confined square columns under different reinforcement amounts, the reinforcement mechanism of fiber reinforced plastic confined concrete columns is studied with theory and numerical analysis.

1. Introduction

In recent years, due to the rapid development of China's economy, the construction and renovation of civil engineering in China depend heavily on the development of reinforced concrete. Nowadays, due to aging, load grade improvement, revision of design specifications, and the change of service performance, a large number of reinforced concrete structures don't have enough bearing capacity, which affects the normal use and safe operation of the structure. The research on how to strengthen the performance of reinforced concrete has received extensive attention (Wang et al., 2005). In the aspects of reinforcement, renovation and repair technologies of concrete structure, in addition to the traditional method of enlarging cross- section, exterior-steeling method, spray concrete reinforcing technology, pre-stressed steel reinforcing technology and steel plate reinforcing technology (Xue et al., 1999; Ubertini et al., 2014), the use of fibrous materials in structural reinforcement has become a hot spot in the international civil engineering field. Due to its excellent performance, the range and amount of applications are increasing at an alarming rate (Monte et al., 2014; Zhu et al., 2014). Fiber reinforced plastics have excellent physical and mechanical properties, good adhesion, heat resistance and corrosion resistance, and are very suitable for long-term use in the field of civil engineering (Song and Yin, 2016; Zheng et al., 2017), fiber-reinforced plastics as shown in Figure 1.

Figure 1: Fiber reinforced plastics

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The fiber material used for reinforcing the building structure is an excellent material for reinforcing the structure, its strength is generally more than ten times that of the building steel, and its elastic modulus is also improved at the same level as that of the building steel (He et al., 2005). These characteristics of fiber reinforced plastics provide technical support for the repair and reinforcement of building structures. As a new type of engineering material with development potential, fiber plastic is an important supplement to traditional building materials (Zhao et al., 2007). Compared with the original reinforcement method, the carbon fiber reinforced plastic reinforcement technology has obvious technical advantages, which mainly include high strength, high efficiency, strong corrosion resistance and durability, no increase both in dead weight and volume of parts, wide applicability, convenient construction, easy guarantee of construction quality, etc. (Zhang et al., 2004). FRP materials mainly include carbon fiber, glass fiber and aramid fiber, and carbon fiber and glass fiber are widely used in engineering, so there are many international discussions about the durability of carbon fiber and glass fiber (Zhao et al., 2007). In case of normal use, it is necessary to consider the environmental factors that affect the structure, such as temperature change, humidity change, corrosion of salt mist, corrosion of chemical substances (acid, alkali, and oil stain), freeze-thaw cycle and ultraviolet radiation. Many scholars in Japan and the United States have made special studies on the durability of carbon and glass fibers. In most environments, FRP materials exhibit time-varying properties (Xu et al., 2001). The development of reinforced concrete has a history of about more than one hundred years. According to the annual calculation of the design benchmark period, there are many early reinforced concrete structures still in use. These structures are affected by aging diseases to varying degrees (Li et al., 2002). At present, most of them are in the peak of maintenance, renovation and reinforcement, and need inspection, maintenance, reinforcement and renovation. Structural maintenance and reinforcement are of great significance to economy and society. Maintenance and renovation can guarantee existing buildings, including old buildings, by economic and technical means, and constantly adapt to the development of human society (Shen et al., 2004). To repair and reinforce the engineering structure with insufficient bearing capacity can not only guarantee the life and property of the people, but also play the role of existing structure as far as possible, alleviating the shortage of manpower, material resources and funds, so that funds can be invested to the most needed places, which conforms to the thinking of healthy, stable, sustained and rapid development (Deng et al., 2006). Based on the previous researches, this study focuses on its reinforcement effect through theoretical analysis and numerical analysis in combination with the fiber plastic reinforced square column test.

2. Experimental method

2.1 Specimen raw material

The carbon fiber sheet and glass fiber (120 × 1600 mm in size) commonly used in engineering are selected as the fiber reinforced composite material, and the epoxy resin adhesive produced in Shenyang is selected as the binder. The basic physical and mechanical properties obtained by testing are shown in Table 1 and Table 2.

Table 1: Properties of fiber reinforced plastics

Number	Production Country	Thickness (mm)	Tensile strength (MPa)	Modulus of elasticity (103Mpa)	Limit tension (%)
1	China	0.158	3312(±5%)	86.4(±5%)	3.8(±6%)
2	America	0.11	3920(±5%)	189(±8%)	1.6(±8%)

Table 2: Properties of binder

Compressive strength (Mpa)	Tensile strength (Mpa)	Shear strength (Mpa)	Modulus of elasticity (Mpa)
63.2	22.7	19.3	5.2×103

Here, C30 grade concrete is selected for preliminary test, and the size of frozen soil specimen is as follows: 100×100×200 mm^3.

2.2 Preparation of specimen

The concrete shall be agitated by means of a forced mixer and then injected into a horizontally placed steel mould. The concrete shall be vibrated for minutes at the vibrating table, leveled and formed, and then cured to its age under standard conditions. Prior to the test, the concrete prism surface is ground flat and the surface floating slurry is removed. By applying a layer of uniform and full adhesive on the concrete surface, wrapping and affixing the well-cut carbon fiber cloth, and pressing and driving out air bubbles in the cloth along the force direction of the carbon fiber, the carbon fiber and the concrete surface are tightly bonded. Then, a layer of adhesive is coated on the surface of the carbon fiber cloth, with the plastic film coated, and the carbon fiber cloth is pressed with a wood template. After the adhesive is completely cured, the die is disassembled and subject to compression test. As shown in Figure 2, unwrapped a-type specimen, fully wrapped b-type specimen and segmented wrapped c-type specimen are prepared respectively; in order to study the effect of two kinds of wrapping materials, the samples are prepared by using two kinds of fiber reinforced materials with c respectively as the prototype. In order to study the influence of the number of layers, the specimen of fiber reinforced plastics with one layer, two layers and three layers are prepared by using domestic fiber material with c as the prototype.

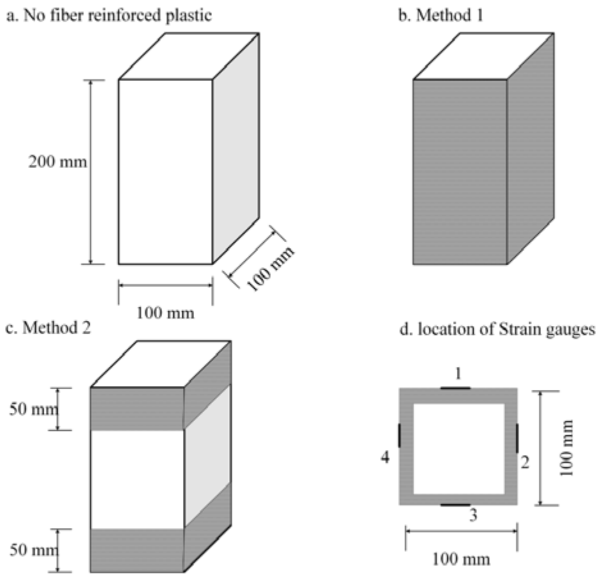

Figure 2: Preparation of test specimen

2.3 Test method of specimen

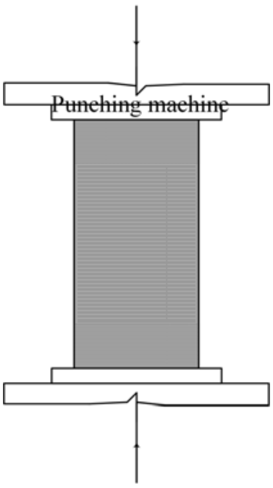

Figure 3: Test machine for specimen

The test was carried out using a ton rock tri-axial stress testing machine, as shown in Figure 3, A displacement meter is symmetrically installed at both ends of the column to measure the average axial strain of the concrete square column, and a resistance strain gauge to measure the carbon fiber strain. As shown in the figure, four strain gauges are attached to each specimen, wherein the strain gauge measures the longitudinal strain and the transverse strain. The load is measured by a force sensor at the top of the specimen and automatically collected by a data acquisition system.

3. Results and discussions

3.1 Influence of the wrapping material

As shown in Figure 4, since the plain concrete column of the comparative specimens has no lateral restraint, the lateral deformation of the upper and lower ends of the specimens is small due to the constraint of the loading pad, and the lateral expansion deformation of the middle part is the largest. The deformation of specimen increases with the increase of load. The peak stress and peak strain of fiber reinforced plastic specimens are increased compared with those of concrete specimens. When the specimen stress is one, the longitudinal strain of concrete is smaller, the outward expansion deformation of concrete in the central area of short column is small, the tensile stress and restraining effect of sheet are low, and the curve of restraining concrete and plain concrete has no big difference. When the stress increases, the longitudinal strain of concrete increases at a faster rate, which increases the transverse deformation of concrete and the stress of fiber cloth in the central area significantly. Comparing the two types of fiber plastic, the fiber plastic No. 2 has a better effect.

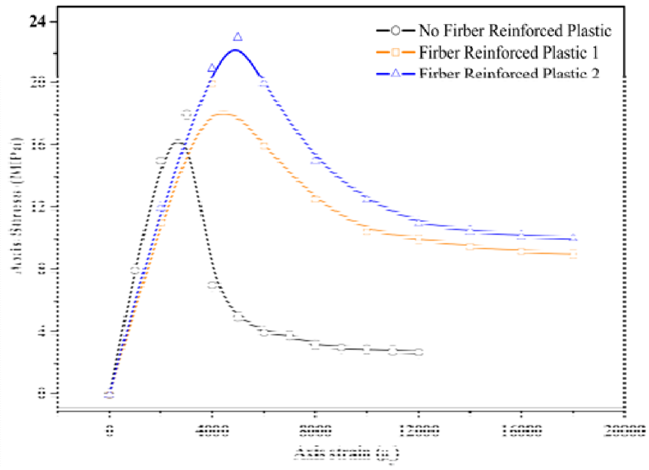

Figure 4: The Axis strain vs Axis curves for specimen made with different fiber reinforced plastic

3.2 Influence of the number of package layers

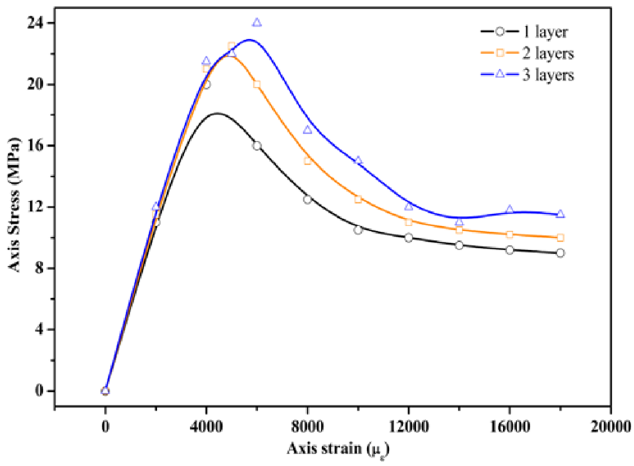

Figure 5: The Axis strain vs Axis curves for specimen made with different layers of fiber reinforced plastic

As shown in Figure 5, from the stress-strain contrast curve corresponding to different wrapping layers when the wrapping method c is adopted, it can be seen that the strength and peak strain of the concrete column are increased with the increase of the winding thickness. Although the increase of the number of layers is beneficial to the optimization of the a seismic performance of concrete, it is also necessary to fully consider the economic benefits in the process.

3.3 Influence of the way of packing

The failure modes of concrete columns under axial compression are divided into two types such as shear failure and axial compression failure. The stress-strain curve corresponding to shear has obvious peak point or obvious reverse bending point, as shown in Figure 6. However, the stress-strain curve of the specimen with axial compression failure is full near the peak point, and the falling section is corresponding to the curve of Method b in Figure 5, which has a larger area both in curve and coordinate axis, which reflects the good plastic energy dissipation ability. Considering the amount of fiber plastic, as shown in the figure, the specimen corresponding to Method c is coated with two layers, and at this time, the amount of fiber plastic used is the same as that of the sample prepared by Method b. Therefore, comparing the data in the figure, under the condition of equivalent reinforcement rate, the strip reinforcement effect is better than the full section reinforcement effect.

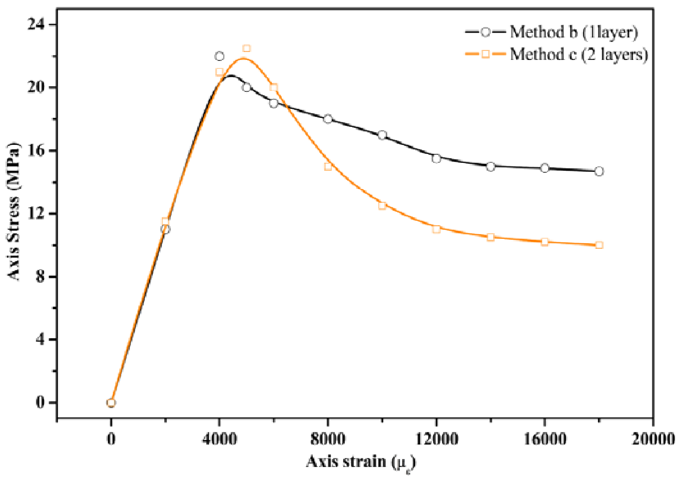

Figure 6: The Axis strain vs Axis curves for specimen made with different cover methods

4. Conclusion

The concrete square cylinder covered with different kinds of fiber reinforced plastics, different layers of fiber reinforced plastics and differen methods were studied under axial compression tests. The results show that, due to the lateral confinement of fiber reinforced plastic, make concrete become stranger in three dimensional stress state. Lateral deformation of fiber reinforced plastic restrict concrete, which delayed the concrete crushing, improve the ultimate compressive strength and peak strain. The plastic deformation properties of fully concrete, improve the ductility. Based on the result, although fiber reinforced plastics can protect concrete, they have different effective for it, for example, uder the same condition, the fiber reinforced plastic from America have a better property. For the same fiber reinforced plastic, how many layers are covered is also important, the results shows that more layers correspond to a higher strength. A further economic input also should be considered here. When same fiber reinforced plastic and same amout was used, the method with strip reinforcement is better than that of full section reinforcement. The reinforcement of concrete using fiber reinforced plastic need a optmazation of material, cover method before put into use.

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