Experimental Study on CFRP Reinforced Concrete Column

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Abstract. Through the axial compression test of CFRP reinforced concrete column, the mechanical properties, reinforcement method, failure form, circumferential and vertical deformation were studied. Through the comparative analysis of the variation parameters of the whole package and the subpackage, the analysis shows that the whole package strengthening method can obviously improve the bearing capacity of the specimens and effectively restrain the annular deformation of the strengthened column. CFRP reinforced concrete significantly enhanced the bearing capacity of the test column, the best effect of the whole package, the two ends of the subcontract bearing capacity is economically applicable; The horizontal and vertical deformation of the concrete column is restrained after the complete and subcontracted reinforcement of CFRP.

Keywords: CFRP reinforcement; Failure state; Strain.

1. Introduction

Carbon Fiber Reinforced Plastics (CFRP) are composite materials that are woven from a given length of Carbon Fiber. Fiber-reinforced composites are widely used in civil engineering as structural reinforcement materials due to their high strength (some are higher than 3000MPa), light weight (about 1/5 of the steel), ease of construction and good corrosion resistance[1]. CFRP reinforced concrete structure technology has developed rapidly at home and abroad. It has many advantages, such as high strength, light weight, corrosion resistance, fatigue resistance, convenient construction, and no increase in the size of components, etc., and has become a hot spot in international reinforced concrete technology [2]. At present, most studies on CFRP reinforced concrete at home and abroad focus on strengthening ordinary concrete structures [3]. Carbon fiber sheets (CFRP) are wrapped around the concrete column to enhance its strength and ductility [4]. After the concrete column is strengthened with FRP, the lateral deformation of concrete obviously decreases, and the ultimate compressive strength and ductility of concrete column are greatly improved [5]. When carbon fiber sheet is pasted longitudinally on the Ramen for large eccentrically compressed column, the bearing capacity and flexural stiffness of the biased column are improved to a certain extent, and the crack width is reduced and evenly distributed. When the concrete strength is lower than C20 level, it is not suitable to use carbon fiber sheet for reinforcement [6]. CFRP reinforced concrete square columns can significantly improve the strength and toughness of concrete, give full play to the plastic deformation performance of concrete, and improve the ductility of components [7]. Under the condition of holding load, carbon fiber strips are pasted on the biased column, and its bearing capacity and deformation capacity are improved to varying degrees [8]. For both large eccentrically loaded columns and small eccentrically loaded columns, the bearing capacity and ductility of strengthened columns with longitudinal ring joint bonding are significantly
improved [9]. FRP reinforcement has a significant effect on improving the ultimate bearing capacity of axial and small-bias columns, but a poor effect on columns with large eccentricity [10]. However, the ductility, energy consumption and other seismic performance of high-strength concrete restrained by fiber cloth are improved significantly [11]. The freeze-thaw cycle has little effect on the compressive strength of concrete rectangular columns strengthened with CFRP, and has a greater effect on the cube positive tensile bond strength of concrete strengthened with CFRP. The latter is more obvious at the early stage of freeze-thaw cycle [12]. Wang Tingyan et al. [13] showed that with the increase of the ratio of longitudinal reinforcement and the number of layers of fiber cloth, the failure of reinforced short beams gradually developed to the characteristics of super reinforced beams; Xu Chengxiang et al. [14] showed that the carbon fiber cloth improved the ultimate bearing capacity, ultimate displacement and ductility coefficient of the specimens. Sticking CFRP is an effective method to reinforce reinforced concrete structure. In this paper, the axial behavior and working mechanism of CFRP sheet reinforced concrete column are studied by experiments, and the influence of the whole CFRP sheet and the subcontract method on the bearing capacity, failure state and the mechanical behavior of concrete is analyzed.

2. Specimen Preparation
Three carbon fiber reinforced concrete columns are designed. The strength of concrete is C30. Coarse aggregate for gravel, fine aggregate for river sand. The carbon fiber cloth is of CFRP / JGN type with the ultimate tensile strength of 3700 MPa, as shown in Figure 1. CFRP reinforcement types can be divided into full contracting and subcontracting. Specific test parameters are shown in table 1.

| Specimen | Specimen size (mm) | Reinforcement type                  |
|----------|--------------------|------------------------------------|
| D-1      | 100×100×350        | Un-reinforcement                   |
| D-2      | 100×100×350        | Full-reinforcement                 |
| D-3      | 100×100×350        | Reinforcement at both ends (80 at each end) |

2.1. Loading Scheme and Arrangement of Measuring Points
To obtain the vertical forces, one tension-compression load cells is used. Paste the vertical and horizontal strain gauges on the concrete surface 10mm from the top, 1/2 from the bottom and 10mm from the bottom. A displacement meter and dial gauge are placed at the top of the column to measure the deformation.

The loading system is as follows: preload twice, preload value of 1/20 limit load, three times to apply, after the completion of loading in two unloading. Ensure that all test equipment can be used normally, and start loading formally after 10min: During the formal loading, the loading method was continuous loading with a loading rate of 300N/s until the specimens were damaged.
2.2. Test Results and Analysis
The cracking load, ultimate load and failure type of the specimen are obtained through the test. The specific values are shown in table 2. As shown in the table, when the specimens were damaged, the ultimate loads of the specimens D-2 and D-3 increased by 24.6% and 19.3% respectively compared with that of the specimens D-1, indicating that the bearing capacity of the test column was significantly enhanced after the CFRP reinforced concrete was reinforced. The total bearing capacity of the test column was the best, and it was economical to subcontract the bearing capacity at both ends. When the failure of plain concrete column and subcontracted concrete column is concrete failure, the failure of the unwrapped CFRP position leads to the failure of the specimens, and the failure of the fully wrapped specimens due to the fracture of the CFRP [15].

Table 2. Characteristics of the progressive damage.

| Specimen | Concrete cracking load (kN) | Ultimate load (kN) | Damage type          |
|----------|-----------------------------|--------------------|----------------------|
| D-1      | 176.5                       | 278.5              | Concrete cracking    |
| D-2      | -                           | 345.6              | CFRP breaking        |
| D-3      | 207.3                       | 332.3              | Middle concrete cracking |

2.3. Lateral Load-Strain Curve of Specimen
Figure 2 shows the strain distribution at the axial top, middle and bottom of the test column strengthened by CFRP under different loads can be obtained. It can be seen from the figure that, at the initial stage of loading, the strain of each specimen at different positions showed a linear trend, and with the increase of load, the stress on each part began to vary. At the initial stage of loading, the strain at the top of specimen D-1 was the largest and the strain at the bottom was the smallest. After loading to about 250kN, the strain at the bottom of specimen rapidly increased to the failure of specimen. When the specimen was damaged, the strain at the bottom of the column was the largest and the strain at the middle was the smallest. At the initial stage of loading, the strain in each part of specimen D-2 was small. After loading to 50kN, the strain at the bottom of the specimen increased rapidly, while the strain at the top and middle of the specimen remained small. When the specimen was damaged, the strain at the bottom of the column was the largest, while the strain at the top and middle of the column was small. When specimen D-3 was damaged, the strain at the bottom was the largest and the strain at the middle was the smallest. According to the comparison and analysis of the figure, the horizontal deformation of the concrete column is restrained after the whole package of CFRP and the subcontract reinforcement.
2.4. Vertical Load-strain Curve of Specimen
Under different reinforcement methods, the vertical load-strain curves of the top and bottom of each strengthened column are shown in Figure 3. According to figure (a), with the increase of load, the strain on the top of each specimen gradually increases. There was no significant difference in the strain on the top of pillar between specimen D-1 and specimen D-3 in the loading process. The strain on the top of specimen D-2 was always very small, and the vertical strain of specimen D-2 and specimen D-3 was always in the rising stage, indicating that the all-inclusive reinforcement can effectively constrain the vertical deformation at the end of the strengthened column.

It can be seen from figure (b) that there is little difference in strain curves under different reinforcement methods. Before the loading reaches 250kN, the bottom strain of specimens D-1 and D-2 is greater than that of specimens D-3. After continued loading, the strain of specimen D-1 increased rapidly and reached the maximum value. At the time of failure, the bottom strain of specimen D-1 was greater than that of specimen D-3, indicating that the reinforcement of the bottom end of the carbon fiber layout limited the bottom deformation of the column. In the early stage of loading, the strain at the bottom of
plain concrete column is still very small. When it reaches about 63% of the ultimate load, there is a turning point, and the strain increases rapidly. When it reaches about 63% of the ultimate load, there is a second turning point. The strain suddenly increases and brittle failure occurs. The concrete column strengthened with carbon fiber sheet has significantly improved the bearing capacity and ductility of the concrete column [16].

3. Conclusion
(1) CFRP reinforcement can improve the bearing capacity of concrete, the best effect of the whole package, the two ends of the subcontract bearing capacity is economically applicable.
(2) The horizontal deformation of the concrete column is restrained after the full and subcontracted reinforcement of CFRP.
(3) The reinforcement of the carbon fiber layout part and all-inclusive reinforcement can limits the vertical deformation of the column. The reinforcement of the bottom end of the carbon fiber layout limited the bottom deformation of the column.

Acknowledgement
This work was supported by the Liao Ning Revitalization Talents Program (Project Name: Research on the Key Technology of Application of High-performance of the New -type antonym Material; The project number: XLYC1802018). There is no conflict of interest.

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