Experimental Study on Reinforced Concrete Beams Strengthened with FRP

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Abstract. At present, the Near Surface Mounted (NSM) Fiber Reinforced Plastic (FRP) technology for concrete has a wide range of engineering applications and experimental research prospects. As a promising new reinforcement technology, the understanding of its comprehensive performance still requires a lot of research work. In this paper, the ultimate bearing capacity, crack shape, deflection and so on of the bending reinforcement of the reinforced concrete beam with the carbon fiber plate are studied and analyzed respectively according to the experiment.

1. Introduction

Since 1950s, large-scale civil engineering construction has been started in China, and the construction industry has been developing at a high speed. With the passage of time, identification assessment and reinforcement have become problems that people urgently need to solve. According to a conservative estimate[1], a large number of houses built after the founding of the People's Republic of China had approached or even exceeded the design base period[2]and entered the old age. In recent years, Fiber-Reinforced Plastic (FRP) has been widely used in the experimental research and engineering application of reinforced concrete structures[4]because of its excellent mechanical properties[3]. Compared with the traditional reinforcement method[5], the inlay method has more advantages[6]: it does not need large area to polish and stick the surface, it has good durability, large paste area, high bonding strength and good fire resistance. In this paper, an experimental study on the bending reinforcement of reinforced concrete beams with embedded Carbon Fiber Reinforced Plastic (CFRP) laths was conducted. Based on the existing research results, the form of inlaying and sticking was changed, and the experimental study on the reinforcement effect of reinforced concrete beams after overload failure was carried out.

2. Specimen design

The reinforcing bars used in this test are HPB235 and HRB335 grade reinforcing bars, and the design strength of concrete is C30. At the same time, 5 cubic specimens with a length of 150mm are made. The carbon fiber reinforced is a carbon fiber strip with a cross section of 1.2mm×10mm. This test uses a type of KY-5 type structural adhesive. The size of the test component is 150mm×250mm×2100mm. The basic situation of each specimen is shown in Table 1.

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Table 1. List of basic conditions of reinforced concrete beams.

Specimen number	Concrete strength(MPa)	Longitudinal reinforcement	Reinforcement rate（%）	Reinforcement situation
L320	C30	2Φ12	0.69	Not reinforced
L321	C30	2Φ12	0.69	Two carbon fiber plates at the bottom of the beam
L322	C30	2Φ12	0.69	Four carbon fiber plates at the bottom of the beam
L323	C30	2Φ12	0.69	Each side has a bow slat
L324	C30	2Φ12	0.69	Each side has two bow slat

3. Experimental method

The test device is shown in Figure 1. The calculation span is 1700mm, and the length of the pure bend segment is 500mm. Two points are loaded by the distribution beam. The loading level of the contrast beam is controlled at 10% of the standard load, the load is held for 30 minutes under 1.0 times the standard load, the rest load is held for 10 minutes between each load. After the end-loading, reading dial indicator measuring the deflection member, while utilizing a static strain of strain gauges recorded automatically. The length and width of all cracks that have occurred are measured after loading. All tests are performed until the specimen is destroyed. The steps for embedding CFRP reinforcement include[7-8]: etching, cleaning, processing reinforcement material and embedding.

4. Experimental phenomena and analysis

4.1. Experimental data

Table 2. Experimental data.

	L320	L321	L322	L323	L324
Cracking load（KN）	16.28	24.84	26.78	25.56	32.66
Structural adhesive cracked（KN）	60	71.77	93.32	66.5	74.65
CFRP slat slip load（KN）	/	82.81	93.32	70	93.32
Ultimate load bearing（KN）	61.3	91.09	102.82	74.73	106.85
Maximum deflection across the middle（mm）	13.385	27.235	40	23.94	24.382
Maximum crack width（mm）	2.6	1.53	3.5	3	4.2
The percentage increase in ultimate load（%）	/	48.6	67.7	21.9	74.3

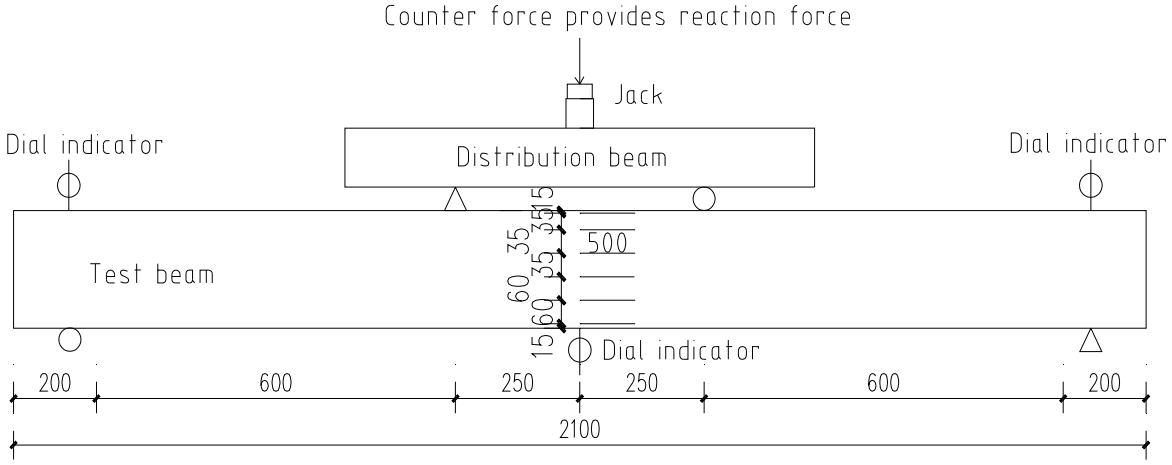


Figure 1. Test schematic and instrument, strain gauges.

4.2. Analysis of experimental results

4.2.1. Bearing capacity. Except for L323, the ultimate bearing capacity of other components after reinforcement has been significantly improved, which is 40%-80% higher than the comparison beam.L323 is due to the premature failure of the bond between the carbon fiber board and the structural rubber interface, resulting in slippage of the carbon fiber board. The test data indicate that bearing capacity of beam is mainly affected by CFRP slab reinforcement, interface bonding and embedding reinforcement.

4.2.2. Crack. After the cracks appeared, the reinforcement test beams embedded with CFRP laths appeared similar to the comparison beams in the initial stage of loading. The main cracks appeared near the middle and central loading points, and the crack development height increased with the increase of the load. Under the same load, the crack width, height, and spacing of the reinforced beam are significantly smaller, and the crack development is relatively slow; when the damage is about to occur, many small secondary cracks appear at the bottom of the beam. In general, the method of reinforcing CFRP slats can effectively inhibit the appearance and development of cracks. Under the same load, the maximum crack width and the average distance between the main cracks decreased significantly, and the number of main cracks increased.

4.2.3. Deformation analysis. The comparison of the mid-span deflection of all test beams under various loads is shown in Figure 2. Inlaying carbon fiber slats can reduce the deflection at the initial stage of loading to a certain extent, but the difference is not significant. Under the same load, the deflection of the reinforced beam is smaller than that of the strengthened beam, and this difference increases with the increase of the load. The CFRP slat reinforcement has a significant effect on the mid-span deflection. From the test data, the greater the amount of reinforcement, the greater the degree of reduction in mid-span deflection. From the test data it can be seen that embedding CFRP slats can effectively increase the bending rigidity of the specimen.

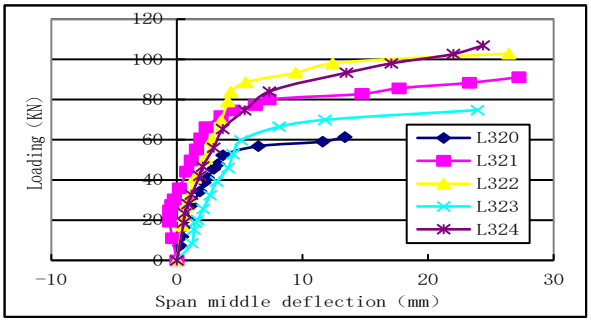


Figure 2. Comparison of load-deflection curves.

5. Conclusions

The main conclusions of this paper are as follows:

(1) Embedding CFRP slats to bending reinforcement of concrete structures is an effective method of reinforcement. The reinforcement members have a 40%-80% increase in bearing capacity compared to strengthened members.

(2) The increase in bearing capacity basically increases with the increase in CFRP slat reinforcement.

(3) After the reinforcement, the cracking load of the beam has been improved, and the crack resistance has been significantly improved.

(4) CFRP slats can effectively inhibit the appearance and development of cracks. The reinforcement beams with two arched CFRP slats embedded on the sides are particularly noticeable. After the cracks pass through the slats, they become noticeably thinner or even stop developing. The maximum crack width and the average distance between the main cracks were significantly reduced, and the number of main cracks increased.

(5) After the reinforcement of the components, the stiffness is obviously improved. Under the same load, the mid-span deflection of the reinforcement beams is smaller than that of the strengthened beams, and this difference increases with the increase of the load.

(6) CFRP slat reinforcement also has an obvious effect on the mid-span deflection. According to the test data, the bigger the amount of reinforcement is, the greater degree of cross-middle deflection is.

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