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RC beam strengthened with pre-stressed CFP under the secondary load

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Abstract: Feasibility of using pre-stressed carbon fiber plates to strengthen reinforced concrete beams was studied. Based on the characteristics of carbon fiber plates, we developed a pre-stress clamp and a device for applying the pre-stress. Contrast tests were conducted between ordinary carbon fiber plates and a pre-stressed carbon fiber plate and between secondary loaded carbon fiber plates and a concrete beam strengthened with a secondary loaded carbon fiber plate. On this basis, we analyzed the failure pattern, the width of cracks and their distribution, the cracking load, the yield load, the limit load and the relation between load and deflection. The results indicate that using pre-stressed carbon fiber plates to strengthen concrete beams is feasible and effective.

Key words: pre-stress; CFP; secondary load; strengthening; RC beam

1 Introduction

At present a great number of buildings need to be reinforced in China because 1) they have already reached or exceeded their service life, 2) their functional use has changed, 3) their design was unsuitable and 4) the quality of their construction was quite low. Some commonly used reinforcement methods have a number of shortcomings[1]. As a result, effective, suitable, and economic methods and materials for reinforcing these structures have become popular subjects for scientists in the realm of civil engineering. The technology of carbon reinforced plastics (CRP) has been extensively applied in practical use because of its good performance. Carbon plastics are classified as sheet, stick, and section material, etc according to its shape[2]. The sheet material includes carbon fiber sheets (CFS) and plates (CFP)[3]. The strength utilization ratio of CFP is higher than that of CFS but its modulus of elasticity is much smaller with respect to its strength. Only after the main rebar of concrete beams has reached its yield strength, will the high tensile performance of CFP become effective. In the case where the CFP works together with the rebar, when the rebar reaches the limit of its intensity, the CFP reaches only 20% or so of the limit of its intensity[4]. Before being stuck to the surface of the beam, the CFP should be pre-stressed to exert its intensity fully, which is called the pre-stressed carbon fiber plate (PCFP). The pre-stress can balance the dead weight of the beam and some live load to reduce the effect of early loading on the beam. The CFP can also enhance the transfer capacity on the finite boundary surface[5].

2 Experimental

There are five beams referred to as L-1 to L-5 in our experiment; their performance parameters are shown in Table 1. The dimensions of the section of each beam, attached by 2Φ14 to the bottom, are 150 mm × 250 mm × 3300 mm and the yield strength of the rebar and its ultimate strength are 362.4 MPa and 525.7 MPa, respectively. The concrete strength grade of each beam is C30 and the actual compressive strength of each of the five concrete cubes are 39.4, 38.8, 38.1, 42.0 and 40.8 MPa, respectively. The CFP used in this experiment is CFUP130 with a tensile strength of 2830 MPa, a modulus of elasticity of 1.47×105 MPa. The adhesive colophony, Lica, has a shear strength of 18 MPa. The CFUP is catena material of T700 and 12K carbon fiber (made in Japan) and special resin. The CFUP has the advantage of steady mechanical performance, high tensile strength, eminent endurance and good resistance to fatigue.

The freely supported beams are forced in place, 1300 mm apart from the steadier of load distributing beam. The experimental device is shown in Fig. 1. In the experiment, the pre-stress is loaded with a loading device, designed and manufactured by ourselves,

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which is soldered with band steel, of which the clamp can be operated easily. The pre-stress in the device is loaded by a bolt and the direction of the force is changed by a pulley. The pre-stress in the device is measured accurately by load sensors, which can reduce load losses.

The fundamental purpose of this experiment is to measure the following strains and stresses: the concrete strain along the section in the middle span of the beam, the strain of the lengthways rebar, the strain of CFP, the displacement of the steadier, the middle point of the beam, the width of the crack and the cracking development.

Table 1 Specimen

No.	Length of CFP (mm)	Initial load	Pre-tension (kN)
L-1	0		
L-2	2800		
L-3	2800	0.5 P_u	
L-4	2800		15
L-5	2800	0.5 P_u	15

Note: P_u is the ultimate bearing capacity of common RC beams (kN).

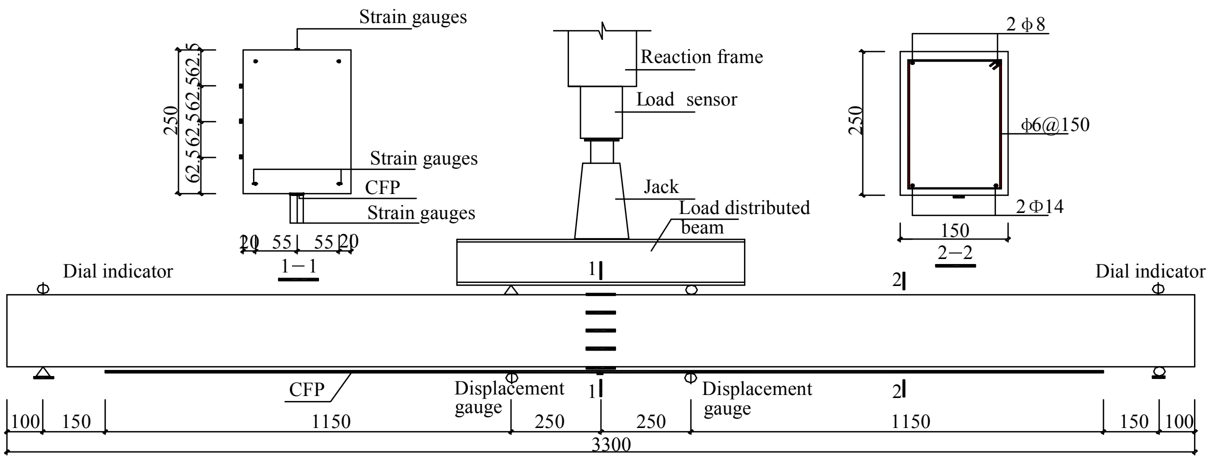

Fig. 1 Schematic diagram of loading device, strain gauge allocation and rebar arrangement (mm)

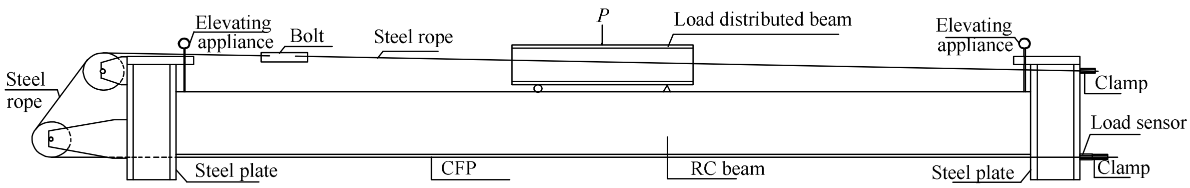

Fig. 2 Schematic diagram of pre-stress application

3 Results

3.1 Cracking process of the tested beams

L-1 denotes a non-reinforced beam. The properties of the other four beams are contrasted with L-1. The cracking process of L-1 is the same as that of a common beam which is known. When the beam is forced to its ultimate load, the vertical crack is perforated in the middle of the beam and the concrete in the compression zone loses its carrying capacity. The characteristic of cracking is similar to that of the rebar arranged suitable beams.

L-2 denotes the beam which is directly reinforced by CFP. The process of loading is almost the same as the loading characteristic of the rebar, arranged as a suitable beam. The first turning point in the relationship chart of load and deflection is a little higher than that in L-1, showing that the beam reinforced by CFP has a higher cracking load. In this experiment with L-2, we have not completely achieved the expected result because the arranged CFP is not large enough.

L-3 denotes the beam reinforced by CFP and pressed. Its initial load P_i is 20 kN. The comparison shows that the cracking load of L-3 is the same as that of L-1, while the ultimate load and the yield load is a little higher than that of L-1. The crack is also the same as that of L-1, but the cracking in L-3 is a little slower than that in L-1. When the beam is pressed to its ultimate load, the interface of concrete and CFP appears as a horizontal crack extending to both ends. There is a destructive symbol with a crack over 1.54 mm which stops to press the beam.

L-4 denotes the beam pressed by PCFP. The amount of pre-stress is 15 kN and the amount of strain is 5200 με. The beam is almost macroscopically unchangeable in the process of pressing. Compared with L-1, the cracking load of L-4 increases by 47%, the yield load increases by 22% and the ultimate load increases by 48%, showing that the