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Study on the Connecting Length of CFRP

Xiongfei Liu^{1,a*}, Yue Li^{2,b}, Zhanguo Li^{3,c}

1 The Key Laboratory of Urban Security and Disaster Engineering, MOE, Beijing Key Lab of Earthquake Engineering and Structural Retrofit, Beijing University of Technology, Beijing 100124, China

E-mail: a:liuxfking@foxmail.com, b: liyue@bjut.edu.cn, c:lizg@bjut.edu.cn

Abstract. The paper studied the varying mode of shear stress in the connecting zone of CFRP. Using epoxy resin (EP) as bond material, performance of specimens with different connecting length of CFRP was tested to obtain the conclusion. CFRP-confined concrete column was tested subsequently to verify the conclusion. The results show that: (1) The binding properties of modified epoxy resin with CFRP is good; (2) As the connecting length increased, the ultimate tensile strength of CFRP increased as well in the range of the experiment parameters; (3) Tensile strength of CFRP can reach the ultimate strength when the connecting length is 90mm;(4) The connecting length of 90mm of CFRP meet the reinforcement requirements.

1. Introduction:

Reduction in the useful service-life of the modern reinforced concrete construction, a major problem confronting the construction industry worldwide, was affected by many factors. Rather than damaging the buildings and rebuilding, using corresponding repair materials which possesses superior adhesion, fracture toughness and compatibility with a concrete substrate to repair and reinforce the reinforcement concrete structure is a more cost-effective and easily achieved method to improve the service life of the building[1]. Choosing the proper repair materials is one of the key technology to ensure the quality of the repair of cement concrete construction[2]. Epoxy resin has become one of the most commonly used repair materials for repairing construction because of its excellent mechanical properties, interfacial adhesion and durability [3,4].

There are many kinds of repair materials commonly used for mending the building construction, such as cement, epoxy resin, polyester resin, polymer latex and polyvinyl acetate, of which epoxy resin is most widely used^[5-7], and it has attracted considerable research attention. To improve the performance of epoxy resin^[8], polymer such as epoxy emulsion, dispersible adhesive powder and water soluble copolymer have been developed by using emulsification and particle redispersion technology.

In order to enrich the research of fiber composite material reinforced concrete columns and save the reinforcement material under the same strengthening effect, in this paper, experiments were conducted



to research the varying mode of shear stress in the location of CFRP connecting zone. To verify the conclusion obtained by above experiment, a reinforced concrete column (size $\Phi 100 \times 200$ (mm)) with CRFP was tested.

2. Experiment

2.1 Raw materials

CFRP and C30 concrete were used in this research. The adhesive was modified epoxy resin (EP), which included epoxy resin, curing agent, diluent, filler, coupling agent, anti-forming agent. The main properties of the CFRP, EP and concrete are shown in Table 1.

Table 1. The main properties of the CFRP, modified epoxy resin and concrete

Materials	f /MPa	f_{\max} /MPa	Δ /%	E /GPa	t /mm
Concrete	19.36	—	—	28.9	—
EP	—	48.03	1.74	98.1	—
CFRP	—	1290.32	1.80	210	0.19

Note: f is compressive strength of core of concrete column $\Phi 100 \times 200$ (mm); f_{\max} is the ultimate strength; Δ is the elongation; E is the elasticity modulus; t is the thickness of the CFRP.

2.2 Design of experiment

The tensile strength of CFRP with 30mm wide and 0/15/30/60/90mm long were tested according to “Technical specimen for strengthening concrete structures with carbon fiber reinforced polymer laminate” (CECS146 : 2003). To avoid the end cracking, aluminum sheet was bonded at two ends of the CFRP in the range of 35mm, as shown in Figure1. The concrete column was reinforced and compressed based on the results of the CFRP connecting test. The sketches of the reinforced columns which were sized $\Phi 100$ by 200 millimeters were shown in Figure 2.

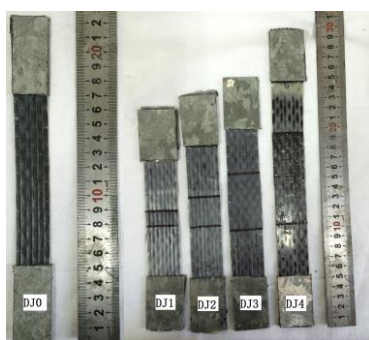


Figure 1. The specimens of CFRP

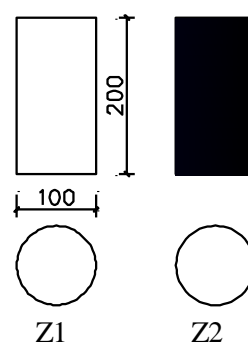


Figure 2. The dimension of the reinforced columns

3. Results and discussions

3.1 The test of CFRP

The final failure mode of specimens was shown in Figure 3.

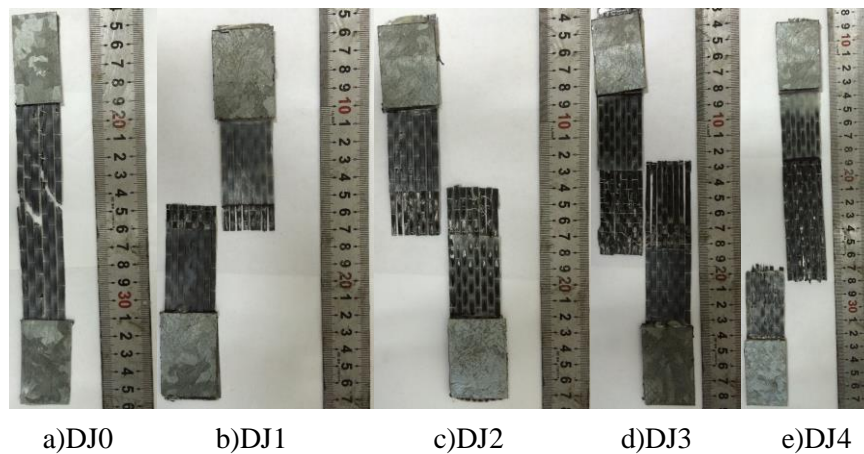


Figure 3. Failure models of CFRP

From the observation of Figure 3, the appearance of CFRP had no obvious changes at the preliminary stage of loading. As the load increased, cracks occurred in the EP connecting zone. When subjected to ultimate load, specimens of DJ 1~3 damaged due to shear stress at the bottom of CFRP. DJ4 and DJ0 cracked and failed suddenly. The test results of the connecting CFRP were shown in Table 2. Where, CFRP-The failure of the CFRP; Middle-The failure in the lapping zone of CFRP.

Table 2. Summary of the experimental results of the connecting CFRP

Code	f_u/MPa	Failure
DJ0	1290.32	CFRP
DJ1	622.58	Middle
DJ2	896.77	Middle
DJ3	1143.55	Middle
DJ4	1295.16	CFRP

Based on Table 2, the following conclusion can be obtained:

There is a linear growth relationship between the ultimate load value and the length of connecting zone of CFRP. When the connecting length is shorter than 90mm, the failure of CFRP always starts from the shear force in the connecting zone, which means the CFRP can't reach its tensile strength before failure. When the connecting length is longer than 90mm, the failure of CFRP starts from the tension fracture of its middle region, which means CFRP reaches its tensile strength before failure, and therefore can be fully used.

3.2 The test of the reinforced columns

The final failure of specimen was shown in Figure 4.



Figure 4. Failure models of columns

From the observation of Figure 4, the appearance of unconfined columns had no obvious changes at the preliminary stage of loading. As the load increased, the vertical micro-cracks developed accordingly. Under the ultimate bearing capacity of the columns, the width of the cracks got larger and the bearing capacity decreased rapidly. The failure of unconfined column was sudden and showed an obvious brittleness destruction. The appearance of entirely wrapped columns also had no obvious changes at the preliminary stage of loading. As the load increased, the axial compression deformation of the column was obvious and many micro-cracks occurred in the concrete. The sections of columns were restrained by CFRP uniformly, and all the cross sections of concrete were under the three-dimensional compressive stress. The columns stored a large deformation energy under the ultimate bearing capacity of the entire wrapping columns, and the carbon fiber at the middle position broke abruptly with a huge detonation

The compressive strength of reinforced column increased by 107.2% with a thick layer of concrete in the fracture section of CFRP, which indicated that the bond properties of CFRP and the concrete were good. The failure mode of the confined column is tear failure of the CFRP, and the connecting zone kept intact, which indicated that CFRP can reach the ultimate tensile strength meet the requirement to reinforce structure when the connecting length is over 90mm.

3.3 Micro-Analysis

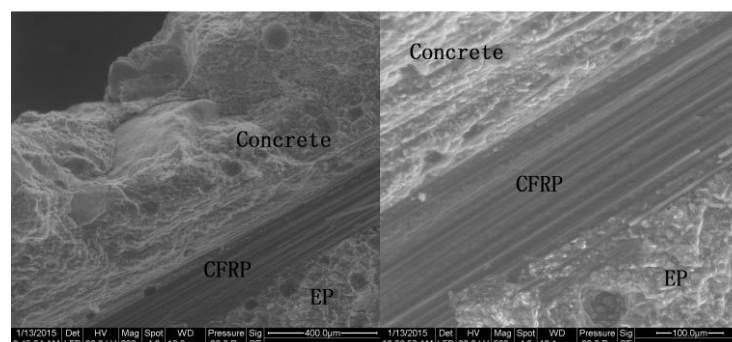


Figure 5. The fracture section images of sample

The fracture morphology analysis in Figure 5 shows that the binding properties of modified epoxy resin with CFRP was good and the interface of CFRP、concrete and CFRP was dense. Penetrating into the concrete and CFRP, EP jointed CFRP and concrete to form a structure and improved the bearing capacity of column greatly, so there is a thick layer of concrete in the fracture section of CFRP.

4. Conclusions

- 1) The binding properties of modified epoxy resin with CFRP is good. With EP penetrating into the concrete and CFRP, EP joints CFRP and concrete to form a structure and improve the bearing capacity of column greatly.
- 2) As the connecting length increased, the ultimate tensile strength of CFRP increased as well, and the tensile strength of CFRP can reach the ultimate strength with the connecting length of CFRP over 90mm.
- 3) The compressive strength of reinforced concrete column increased by 107.2% with 90mm connecting length, and failure didn't result from the connecting zone, which indicated the connecting length of 90mm met the requirements to reinforce structure.

5. Reference

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