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Study on Anchoring Effect of Different CFRP Anchors

Weifeng Li

Nanjing Vocational Institute of Transport Technology, Nanjing, China
jobfrank0330@gmail.com

Abstract: *Prestressed carbon fiber plate (CFRP) is widely used in the field of bridge reinforcement, but the anchoring ways of CFRP are various, and the anchoring performance of different anchoring forms is also different. In this paper, the anchorage performance, failure form and tension control stress of several common anchorage are studied by experiments, the results show that the anchorage effect is the best when the end of the anchor bearing only tension and no other stresses, which can provide some construction guidance for the selection of anchorage in the future.*

Keywords: *CFRP; Anchorage form; Anchorage performance; Tension control; Limit test; Tlastic modulus*

1. Introduction

In "code for design of concrete structure reinforcement" GB 50367-2013, the anchorage in the method of strengthening prestressed CFRP composite plate is divided into plate anchorage and corrugated anchorage (toothed anchorage), and the coefficient of prestress loss caused by deformation of each anchor and shrinkage of CFRP plate is given, as shown in Figure 1, Figure 2 and Figure 3.

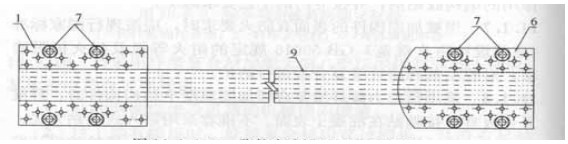

Figure 1: Plate anchor

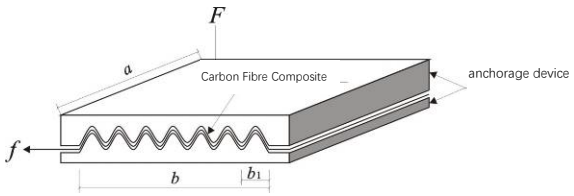

Figure 2: Serrated anchor (cusp)

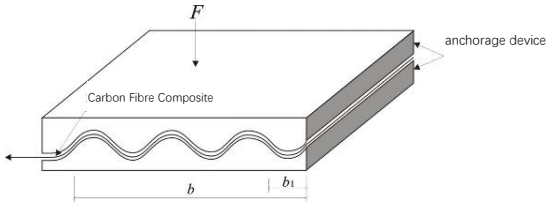

Figure 3: Serrated anchor (crenate)

At present, the prestressed CFRP anchorage can be purchased in the domestic market, mainly including the sika-stresshead prestressed anchorage system, as shown in Figure 4 and Figure 5. American Simpson prestressed CFRP plate reinforcement system; Liuzhou OVM anchoring system; Nanjing lika anchoring system, etc. All kinds of anchors have successful cases, but their anchoring performance, failure form, tension control stress, and other relevant data are less published[1-2].

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Figure 4: Sika-stressed prestressed CFRP plate anchorage system

Figure 5: Simpson prestressed CFRP plate reinforcement system

2. Anchor system selection

After detailed market research, the rika anchoring system developed by Nanjing haituo composite materials co., ltd. has a high market share and a certain degree of popularity and representativeness. The rigid self-locking anchoring system developed by Jiangsu expressway engineering maintenance co., ltd. has its characteristics, and adopts mechanical self-locking to facilitate on-site unloading. After comprehensive consideration, the two anchor systems were used as matching anchor systems to study their respective performance and reinforcement effect, as shown in Figure 6 and Figure 7. The two anchors are wedge plate anchors, but they are slightly different in anchoring process details, as shown in table 1.

Table 1: Technical performance characteristics of the two anchoring systems

	Force card anchorage system	Rigid self - locking anchorage system
Anchorage characteristics	End wedges with CFRP plates are required in the factory Glue into a whole; There is no need to slot the concrete surface.	End wedges with CFRP plates are available in Field assembly; The concrete surface needs to be grooved.
Form a complete set of CFRP plate	CFRP plate brand: nanjing haituo; CFRP plate size: 1.4-50mm and 3.0-50mm.	CFRP plate brand: Shanghai hummer; CFRP plate size: 1.4-50mm and 3.0-50mm.

Note: the size of the CFRP plate is 1.4-50mm, indicating that the section thickness of the CFRP plate is 1.4mm and the width is 50mm.

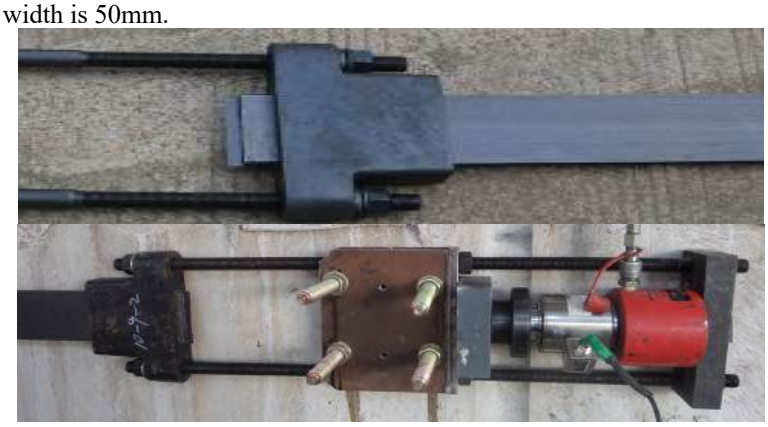

Figure 6: Force card anchoring system

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Figure 7: Rigid self-locking anchorage system

3. Limit test of anchorage system

To test the tensile strength of two kinds of anchorage system, the elastic modulus of CFRP board, failure when CFRP plate failure pattern, failure location information, such as the sea of Nanjing Billiton composite materials co., LTD., the anchoring force card system (hereinafter referred to as "the anchoring force card system") and Jiangsu expressway engineering maintenance rigid self-locking type anchorage system co., LTD. (hereinafter referred to as "self-locking type anchorage system") limit damage experiment was carried out[3-4].

In this ultimate failure test, the sizes of CFRP plates of two kinds of anchorage systems are 3.0-50mm (i.e., the section thickness of CFRP plates is 3.0mm, and the width is 50mm). Hydraulic jack is used for loading, and resistive strain gauges are pasted on the surface of CFRP plates to obtain load-strain curves, and then the elastic modulus of CFRP plates can be obtained.

(a) *(b)*

Figure 8: Ultimate test tensioning device

Table 2: Summary of limit test data

CFRP plate brand	CFRP plate size	failure load(kN)	elasticity modulus(GPa)	strength of extension(MPa)
Nanjing sea Billiton	3.0-50mm	378	165.7	2520
Shanghai hummer	3.0-50mm	>320	161.7	--
Shanghai hummer	1.4-50mm	168	----	2400

According to the field situation, the CFRP plate of the force card anchoring system has a slight "crack" sound when it is stretched to 378kN. After unloading, it is found that there are small cracks on the surface of the CFRP plate at the mid-span position, so it can be considered that the CFRP plate is damaged and the load is regarded as the failure load. For the self-locking anchorage system, when the tension reaches 200kN, the CFRP plate appears slight torsion, so the test is terminated, and the failure load cannot be measured. Instead, when the real bridge is strengthened, the tensioning block and the anchoring block of the self-locking anchorage system are placed in the slot to limit the position. The self-locking anchoring

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system is installed on the side of the reinforced concrete beam, as shown in Fig. 8(b). The test is conducted when the tension reaches 365KN.

Jiangsu expressway engineering maintenance co., ltd. has done the ultimate tensile test on the self-locking anchorage system with the size of the CFRP plate 1.4-50mm. The failure load is 168kN, and the carbon plate appears when the failure occurs[5-7].

In the process of limit failure test, when the tension reaches 160kN, the resistance strain gauge slips and the strain data cannot be collected further. According to the previous data, the load - is obtained.

The strain curve is shown in figure 9 ~10. The elastic modulus of the CFRP plate is calculated as shown in table 2.

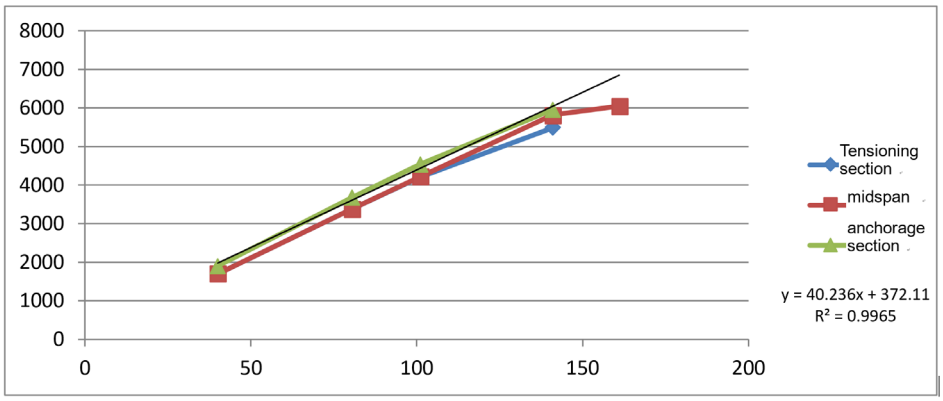

Figure 9: Load-strain curve of force card anchoring system (kN, uε)

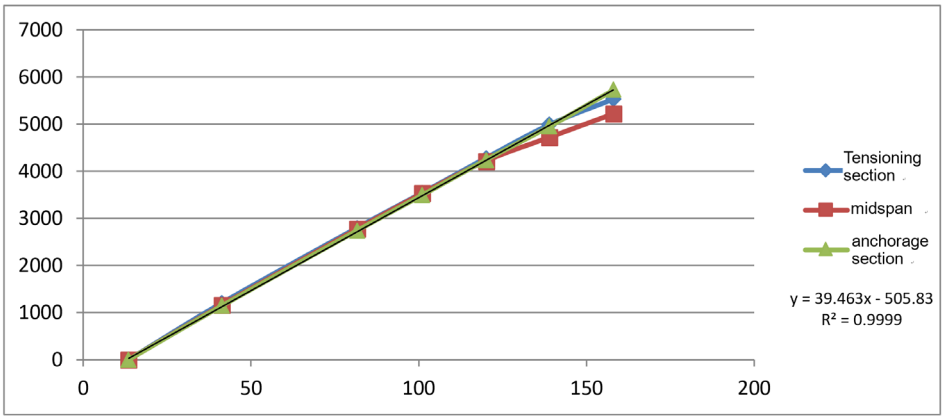

Figure 10: Load-strain curve of self-locking anchorage system (kN, uε)

To further understand the limit failure of the CFRP plate, the corresponding material test was carried out for the CFRP plate. According to the fabrication and loading requirements of GBT 3354-1999, the elastic modulus of two brands of CFRP plate was measured, as shown in table 3.

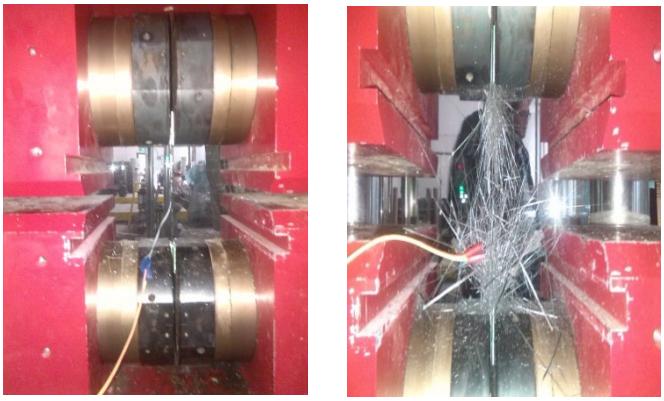

Figure 11: Test photo of CFRP plate

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Table 3: Elastic modulus of CFRP plate

parameter	Specimen size	Nanjing sea Billiton	Shanghai hummer
Measured value of elastic mold	3mm*25mm	163 GPa	161 GPa

There are two failure modes in tensile failure: one is an explosive failure, with a certain degree of suddenness, accompanied by a "bang" violent sound, CFRP plate completely disintegrated, the carbon fiber was blasted open. Another kind of failure occurs in the local wire cracking of the CFRP plate, and finally breaks in the place, mostly in the vicinity of the fixture. This is because the CFRP plate at the clamping position is in a state of multiple stresses. The shear stress of the section of the CFRP plate is too high due to the large pressure exerted by the tester chuck on the CFRP plate, and finally the weak part is destroyed first, as shown in Figure 11, Figure 12 and Figure 13.

Figure 12: CFRP plate being exploded FIG.

Figure 13: Local fracture of CFRP plate

4. Conclusion

Through the ultimate tensile test of the rika anchorage system of Nanjing haitou composite material co., LTD., it is found that the failure load is up to 378kN, the surface of CFRP plate appears slight cracks when the failure begins, the elastic modulus of CFRP plate is 165GPa, and the tensile strength reaches 2520MPa. The results show that the anchoring effect of the two kinds of anchors is similar, but it should be avoided that the CFRP plate is in a state of complex stress in engineering practice. When the prestressed CFRP plate is pasted to reinforce the reinforced concrete structural members, the stress mode of the CFRP plate should be designed to only bear the tensile stress, to ensure the integrity of the CFRP plate near the anchorage side.

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