PAPER • OPEN ACCESS

Static Load Tests Study of improved Anchors for CFRP Tendon

To cite this article: Wenhua Cai *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **490** 032008

IOP Conf. Series: Materials Science and Engineering **490** (2019) 032008 doi:10.1088/1757-899X/490/3/032008

Static Load Tests Study of improved Anchors for CFRP Tendon

Wenhua Cai[1], Bujun Yu[2,*], Jun Zhang [1]

[1]Civil Engineering, Yancheng institute of technology, Yancheng, 224003, China
[2]Infrastructure Office, Yancheng institute of technology, Yancheng, 224003, China

*Corresponding author e-mail: sunnydcai@163.com

Abstract. The original anchoring performance is not good enough, and the failure mode is not ideal. This paper improves and redesigns the clip anchor for CFRP tendon. The improved anchor has two-piece clips, eliminates the difference in taper angle between the anchor cup and the clip, and adjusts the slit on the clip. And then, through the uniaxial tensile static load tests of the anchorage assemblies, the failure modes and load-slip behaviour of CFRP tendon in the loading process are studied. The results showed that the improved anchor for CFRP tendon had a good anchoring performance, the CFRP tendons destructed outside the anchor that achieved an ideal breaking form. The treatment on the inner wall of the clip and the use of aluminum sheets can effectively reduce the slip of the anchor and enhance the anchoring performance. The research work done for clip anchorages of CFRP tendon had provided reliable basis for the wider application of CFRP tendons in civil engineering.

1. Introduction

Carbon Fiber Reinforced Plastics/Polymer (CFRP) is a new type of composite material, which is widely used in construction because of its prominent advantages, such as: light weight and high strength, good corrosion resistance, excellent fatigue performance, easily construction etc[1,2]. However, there is a great difference between the longitudinal properties and transverse properties, which makes the tradition anchors disabled, so the ultimate bearing capacity is more determined by anchor efficiency than the CFRP tendons' strength. it is a key factor and primary requirement to design secure, practical and economical anchor system.

Recently, all kinds of anchors have developed[3-5], while the clip anchors are widely concerned because of the convenient installation, reusability and ease of tensioning. At present, the researches of clip anchors are carried out around the parameters such as cone angle difference, anchor length, number of clips and internal processing methods. However, the anchoring efficiency is unstable, and problems such as shear failure caused by the "tip effect" of the clip still arise. In this paper, the clips are improved, cone angle difference between the clip and the anchor cup is cancelled, and the deep ridges on the inner wall of the clip are designed.

2. Anchor Design

There was a monolithic-clip anchor for CFRP tendon without casing, which failed due to the CFRP tendon being sheared inside the anchor(Figure 1). Based on the reference and summary of previous research results[6,7], the anchor specific system shown in Figure 2 was designed. In this anchor system, the anchor cup has the same taper angle as the clip, ie the cone angle difference of the original anchor

is eliminated. The clip is changed from a one-piece to a two-piece, and the slit on the clip is also redesigned. At the centre of the small end, each clip has a slit, whose length is from the small end to 20mm far away the large end. At the large end of the clip, a slit is also provided, whose length is half of the length of the clip, whose position lies at each of the two sides away 22.5°the semicircle.
The thinnest part of the clip is 1.5mm thick. To facilitate tensioning, threads and nuts are placed on the outside of the anchor cup. The real figure of the anchor system is shown in figure 3.

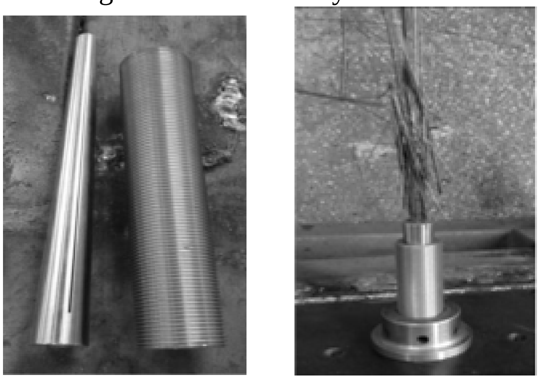


Figure 1. the anchor designed before

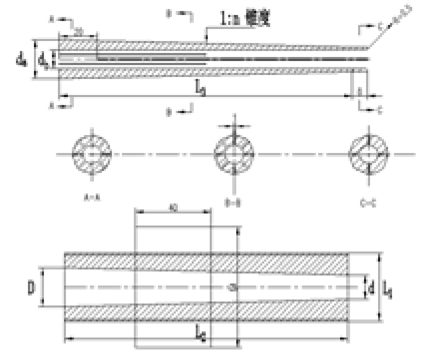


Figure 2. the anchor specific system

Figure 3. the real figure of anchor system

In order to compare and analyze the anchoring performance of this anchor, some parameters were changed, such as the length, cone angle, and the inner diameter of the clip. Table 1 shows the specific size of improved anchors for CFRP tendons.

Table 1. specific size of improved anchors for CFRP tendons

CFRP diameter/ mm	taper/ 1:n	d_a/mm	d_b/ mm	L_1/ mm	D/ mm	L_3/mm	L_2/mm	d/mm
10	1:20	10	20.75	36	20.5	153	150	13
10	1:15	10	23	36	22.67	158	145	13
10	1:10	10	27	36	27	163	140	13
12	1:20	12	23.5	38	23.25	168	165	15
12	1:15	12	26	38	25.67	173	160	15
12	1:10	12	30.5	38	30.5	178	155	15

3. Anchor Experiment

3.1. Test Content

The round CFRP tendons used in the tests are produced by domestic manufactures, and the specific parameters of them are shown in table 2, while there are two kinds of round CFRP tendons with diameter of 10 mm and 12 mm, as shown in figure 4.

Table 2. the parameters of CFRP tendons

CFRP diameter /mm	Measured diameter /mm	Tensile modulus /GPa	Poisson's ratio	Shear modulus /GPa	Poisson's ratio	ultimate tensile load /KN	ultimate tensile strength/MPa
10	9.8	125	0.27	10.3	0.02	141	1800
12	11.7	125	0.27	10.3	0.02	204	1800

Figure 4. surface shape of CFRP tendons

The uniaxial tensile static load tests of anchorage system for anchorage performance were carried out in the structural engineering laboratory of Yancheng Institute of Technology. During the test, in order to measure the strain development of CFRP tendon, several strain gauges were pasted on the surface of each CFRP tendon. Through dial indicators，the relative slip between the CFRP tendon and anchorage can be measured, and by hydraulic jacks the axial tension is provided. Test device and instruments are shown in figure 5 and table 3 shows the details of each anchorage specimen.

Considering the influence of the precision of the anchor manufacturing process, two thicknesses of aluminium sheets were used between the CFRP tendons and the clips, which were 0.04 mm and 0.06 mm, respectively.

Figure 5. test device and instruments

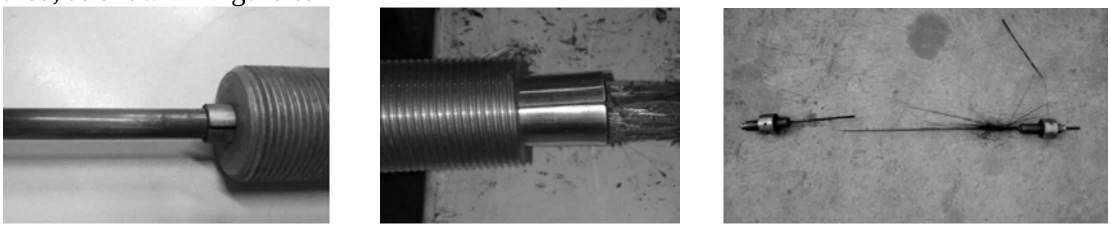
Table 3. Improved anchor system specimens

Specimen No.	diameter（measured：mm）	the length of anchor cup（mm）	Taper（1:n）	preload（KN）	Thickness of aluminum tube（mm）
1	9.6	150	1:20	0	
2	9.7	150	1:20	60	0.4
3	9.8	150	1:20	80	0.4
4	9.6	145	1:15	60	0.4
5	9.7	145	1:15	100	0.4
6	9.5	145	1:15	80	0.6
7	9.6	140	1:10	100	0.4
8	9.5	140	1:10	80	0.6
9	11.5	165	1:20	80	0.4
10	11.7	165	1:20	100	0.6
11	11.5	165	1:20	120	0.4
12	11.7	160	1:15	120	0.6
13	11.6	160	1:15	100	0.4
14	11.6	155	1:10	120	0.6
15	11.7	155	1:10	100	0.4

IOP Conf. Series: Materials Science and Engineering **490** (2019) 032008 doi:10.1088/1757-899X/490/3/032008

3.2. Test Results and Analysis

3.2.1. Failure modes The clip anchors for CFRP tendon have three typical failure modes: CFRP tendon pull-out failure, the CFRP tendon damaged just in front of anchorage, and tensile breakage of CFRP tendon. The first two failure modes may occur separately or simultaneously. In this uniaxial tensile static load test of clip anchorage for CFRP tendon, the above three failure modes have appeared, as shown in figure 6.



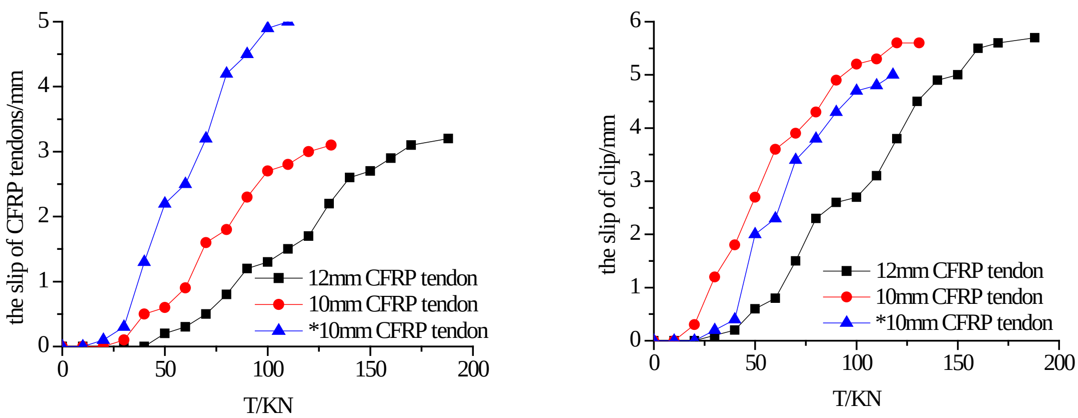
(a) CFRP tendon pull-out failure (b) CFRP tendon damaged (c) tensile breakage of CFRP tendon

Figure 6. failure modes of anchorage assembly

The failure modes shown in figure 6(a)(b) have an advise effect on the bearing capacity of the anchor assembly, and these two failure modes should be avoided. The reasons for these failure modes may be that the processing precision of the clip is not enough and no measures are taken, and in some anchor system specimens, the inner wall of the clip is not treated. Therefore, the contact between the clip and the CFRP tendons is not tight enough to produce a large friction force, so the CFRP tendons is slipped out.

The anchor system specimens with tooth pattern inside the clip and aluminium sheets between the clips and CFRP tendons mainly manifested as normal damage, the CFRP tendons burst open in the middle, as shown in figure 6(c).

3.2.2 Load-slip curve Load-slip curve is an important index to evaluate anchorage performance of anchor. In this experiment, tension-side is equipped with a loading device, so from the fixed-side the slip of CFRP tendon and clips were easier to be measured. The load-slip curves of CFRP tendons and clips are shown in figure 6 (For safety, the dial indicators were retreated in advance, as the load add to the setting value, so a complete load-slip curve can't be given. Since the number of test pieces is a bit large, only the results of several sets, such as fifth, twelfth (in table 3) and original anchor specimen (the diameter of CFRP is 10mm, and there is on aluminium))



(a) the slip of CFRP tendons (b) the slip of clips

Figure 7. load-slip curve

It can be seen from figure 7 that the entire load-slip curves of anchor specimens exhibited nonlinearity as the load increased. In figure 7(a), the CFRP tendons hardly slips under the initial load. Because the contact between the various components in the anchor system was tight after the preload was applied.

Then, the slip of CFRP tendons tended to increase with the increase of tensile force. When the CFRP tendon was close to breaking, the slip of the CFRP tendon became slower because the deformation of the clip and aluminium sheet had no more space. It can also be seen from the figure 7 that the slip growth of the 10mm CFRP tendon with star is very significant, probably because the contact pressure between the CFRP tendon and the clip is not large, when the load slightly increased, the CFRP tendon produced a large slip.

Comparing the data of 10mm and 12mm diameter CFRP tendons in Fig. 7 (a)(b), it is found that under the same tension, the slip of the anchors for 10 mm CFRP tendon was larger than that of the anchors for 12 mm tendon. Because the corresponding pre-tightening force of the large diameter anchor was large, and then the contact stress between the components in the anchor was also large, and the close contact increased the frictional force, so that the anchor for the small diameter tendon had a relatively small slippage.

Comparing the two figures in Fig. 7(a) and (b), the slip value of the CFRP tendons was not much different from the clips', indicating that the CFRP tendons followed the heel of the clips during the loading process until the clips were wedged and anchored, then commonly withstood external loads until the CFRP tendon was broken. These indicated that the improved anchor had good anchoring properties.

4. Conclusions

Through the experiment of the improved anchor for CFRP tendon, the conclusions were as follows:

Based on the proper modification of the original anchor, the failure modes were changed from the non-ideal failure of the CFRP tendons being cut to the normal rupture outside the anchor. So the improved anchor assembly of CFRP tendon was destroyed in typical failure modes. Thus showed its good anchoring performance.

The difference between the slips of CFRP tendons and the clips' was very small, indicating that the slips of CFRP tendons and clips were basically synchronous.

Acknowledgments

This work was supported by the Chinese National Natural Science Foundation (No. 51508491), and also funded by Yancheng Institute of Technology.

References

[1] Gu qian. Zhang Xiangshun. Summary of research and application of new material FRP[J]. Journal of Huazhong University of Science and Technology, 2003, 20(1):88-92.
[2] Xu Xinsheng. Zheng Yongfeng. Experimental study on the mechanical properties of FRP bars and analysis of mixed effects[J]. Journal of Building Materials, 2007,10(6):705-710.
[3] Cai Wen-hua. Zhang Jiwen. Analysis of mechanical behavior of bonding anchorages for CFRP tendons. International Conference on Modeling and Simulation, 2009,6, 423-426.
[4] Cai Wen-hua. Zhang Jiwen. Study of Static Load Tests of Bond-type Anchors for CFRP Tendons. International Conference on FRP Composites in Civil Engineering,2010, 313-316.
[5] Bu-jun Yu. Wen-hua Cai. Study on Static Load Tests of Bond Type Anchors for CFRP Tendons. Journal of Yancheng Institute of Technology, 2014,(4):89-91+96.
[6] Jiang Tianyong. Fang Zhi. Experimental investigation of wedge-type anchors for CFRP tendons[J]. Journal of Civil Engineering, 2008, 41(2):60-69.
[7] Zhu Geping. Guo Shufeng. Zhang Zihua. Design and Experimental Study of Clip Anchors for Light Round FRP. The 9th National Construction Engineering FRP Application Academic Exchange Conference, Chongqing，2015:134-140.