FEM Analysis of Improved Anchor Structure for CFRP Tendon

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Abstract: The structural composition of the improved CFRP tendon bonded anchor is introduced. Based on the improved finite element model of anchorage structure, relevant elasticity analysis is carried out. At different loading levels, the distribution and changes of axial stress and surface bonding stress of CFRP tendons show obvious regularity. CFRP tendons at the ends of steel pipes are easy to break, which is the disadvantage of this type of anchor. A buffer zone is still to be set at this location to reduce local stress.

1. Introduction

With the well-known advantages of high strength, low specific gravity, fatigue resistance, corrosion resistance, Carbon Fibr Reinforced Polymer (CFRP) has gained extensive attention over the past decade[1, 2, 3]. CFRP has been widely used in civil engineering, long span bridges and aircraft. In 1996, the Stork Bridge used two CFRP stay cables and tapered filling anchors. In 1999, the DSI developed the Dywidag anchor system for CFRP cables. In 2005, China's first CFRP cable-stayed bridge was completed, and its CFRP cables used cohesive anchor[4, 5, 6]. In 2012, the Jishou Aizhai Large Suspension Bridge in Hunan province of China adopted 2 Carbon Fiber strands as pre-stressed anchor cables[7].

In the cohesive anchor, CFRP tendons only contact the bonding medium, which reduces the shear stress of CFRP tendons and facilitates the axial strength of CFRP tendons. However, the existing cohesive anchors also face some problems. CFRP tends will break due to uneven distribution of the shear stress between the adhesive and the CFRP tendon. It is necessary to improve the structural form of the cohesive anchors. Figure 1 shows the improved cohesive anchor, the position of clamping can adjust along the steel pipe. In the improved cohesive anchor, the clip will not contact with CFRP, which is very important to the new system. This paper analysis the structure of the new anchor system under different load by FEM method.

2. FEM Model and Analysis of the Improved Anchor Structure

Considering the symmetry of the structure, the 2D-FEM model of the improved anchor established with Abaqus 6.14.

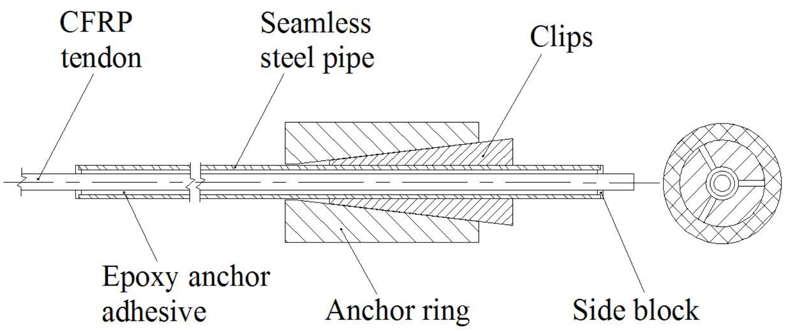


Figure 1: Structure of the improved anchor.

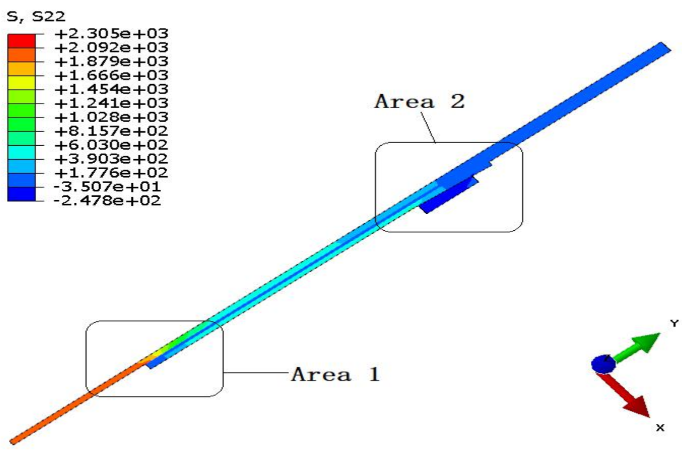


Figure 2: 2D-FEM of the improved anchorage.

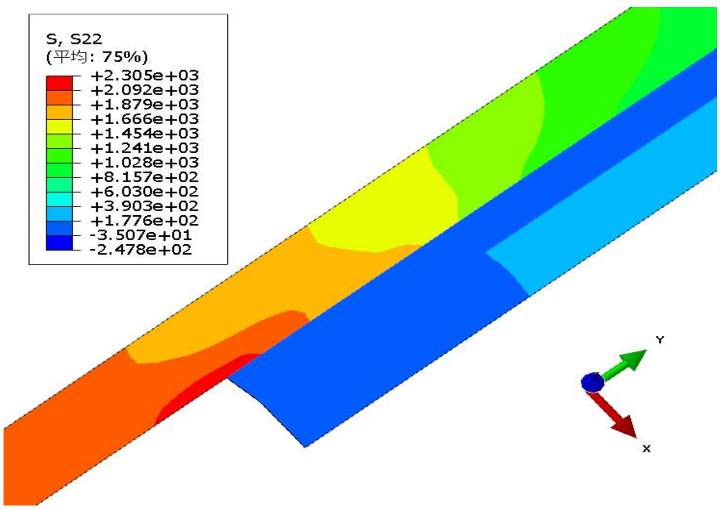


Figure 3: Stress distribution of Area 1.

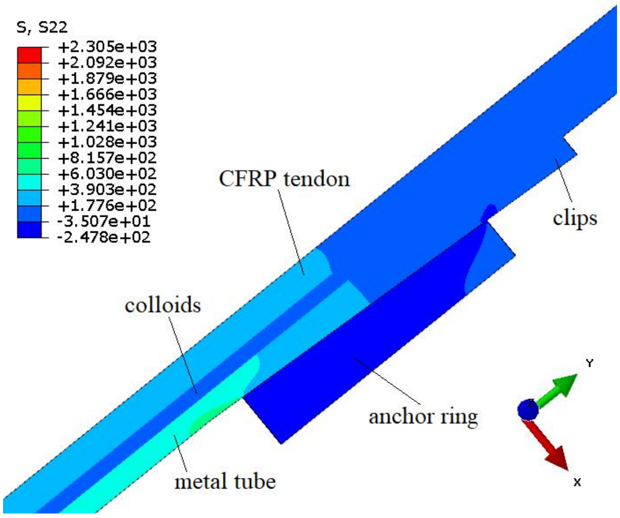


Figure 4: Stress distribution of Area 2.

2.1.Material Type and Parameter

The improved anchor has five components: the anchor ring, clips, metal tube, colloids and CFRP tendons. In the FEM model, CFRP tendon is selected bi-linear elastic material, while other parts of FEM model are selected elastic line materials.

2.2.Design Parameters and Boundary Conditions

2.2.1. Structural Parameters

Based on the previous research of this research group, the clip inclination is 4°, the difference angle of anchor ring and the jaw taper is 0.1°. The diameter of CFRP tendon is 8mm. All the interface of different components coupled.

2.2.2. Boundary Conditions

Three displacement constraints apply to the side surface of the anchor ring. The load apply in the axial end of CFRP tendons.

2.3. FEM Analysis of the Improved Anchor

2.3.1. FEM Model

The 2D-FEM model of the improved anchor as shown in Figure 2. The stress distribution of area 1 and area 2 as shown in Figure 3 and Figure 4.

According to Figure 2, the axial stress of the loading side of CFRP tendon is consistent with the loading level. The stress decreases with distance from the loading side. According to Figure 3, it is obviously to find that the stress of CFRP tendon is higher than the loading level in the initial contact region of the CFRP tendon and the colloids.

The basic reasons are as follow: the colloid is constrained by the steel pipe and the elastic modulus of the steel pipe is much higher than CFRP and colloid. In fact, a similar phenomenon exists in the contact area of the anchor ring with the steel pipe, as shown in Figure 4. However, because the elastic modulus of the steel pipe and anchor ring is close, as long as the thickness of the steel pipe is not too small, it will not cause damage to the steel pipe.

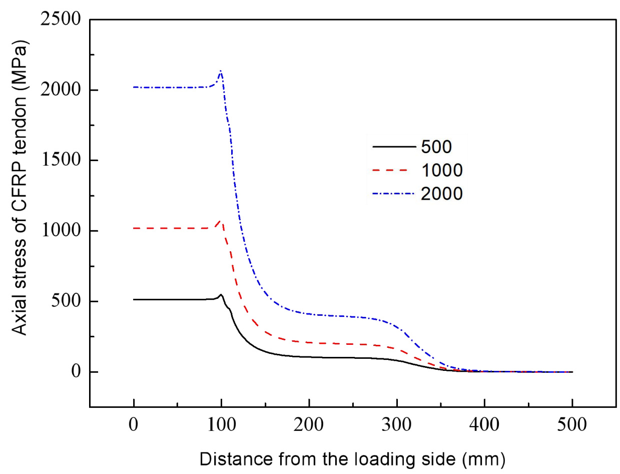
2.3.2. Axial Stress Distribution of the CFRP Tendon

After extracting the strain on the surface of CFRP bars in the finite element model, the surface stress of the bars can calculate by Hooke's law. In different loading level (500MPa, 1000MPa, 2000MPa), the stress of external surface of the CFRP tendon along the axial direction are shown in Figure 5(a). According to the Figure 5(a), the peak stress of the CFRP tendon is located in 100mm from the loading side. The stress of CFRP tendon increases with the increase of axial load.

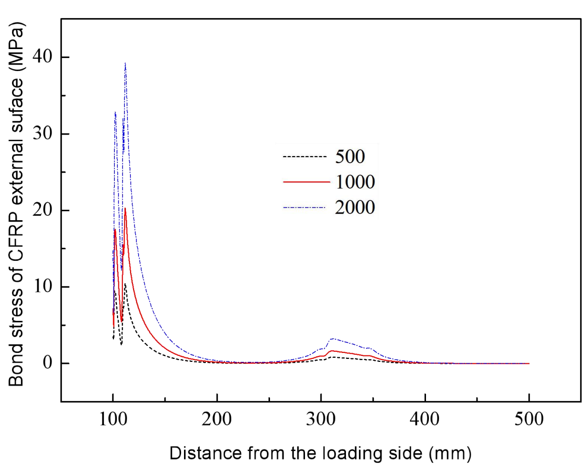
2.3.3. Bond Stress Distribution of External Surface of the CFRP Tendon

The bond stress of the external surface of the CFRP tendon is an important factor to the anchoring structure. This factor determines the failure of the adhesive colloid. When the bond stress is more than the bond stress of the adhesive colloid, the adhesive stress provided by the corresponding part of the colloid will be zero. This phenomenon usually means failure of anchoring. According to the Figure 5(b), the length of the improved anchor is 400mm, but about half of length of the steel tube will not provide bong stress to the CFRP tendon.

The result of above is based in elastic analyze, the adhesive colloid will come to the plastic stage during the test. In this condition, the rest part of adhesive colloid will provide bond stress. From the above analysis, it can be known that in the improved anchor structure, the length of the steel pipe is larger because part of it belongs to the reserve part. The bonding stress at the position of the anchor ring is larger than the beside area.



(a):Axial stress.



(b) Bond stress.

Figure 5: Stress distributions of the CFRP tendon in different loads(MPa).

3. Conclusions

Based on the above analysis, the conclusions are as the following:

- The FEM model of the improved anchor structure can provide qualitative analysis. The structural parameters of the anchorage are relatively reasonable;
- CFRP tendons and adhesive colloids at the ends of steel pipes are the most prone to failure. This conclusion is consistent with related experimental tests;

- The anchor structure can optimize further. In the improved anchor structure, it is necessary to set a buffer zone in this area to reduce the local stress of CFRP tendons. The length of the anchor ring can increase, which will be inherently beneficial to the anchor.

Acknowledgments

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References

[1] Lv Zhitao, Mei Kuihua. First application of CFRP cables for a cable-stayed bridge in China[J]. China Civil Engineering Journal, 2007 (1): 54-58.

[2] U. Meier, Carbon fiber reinforced polymer cables: why? why not? what if?, Arab J. Sci. Eng., 2012,37 (2): 399–411.

[3] K.H. Mei, R. Seracino, Z.T. Lv, An experimental study on bond-type anchorages for carbon fiber-reinforced polymer cables, Constr. Build. Mater., 2016 (106): 584–591.

[4] G. Xie, Y. Tang, C.M. Wang, S. Li, R. Liu, Experimental study on fatigue performance of adhesively bonded anchorage system for CFRP tendons, Compos. B, 2018(150): 47–59.

[5] G. Xie, Q. Feng, C.M. Wang, Y. Tang, R. Liu, Prediction and optimization of stress distribution in bonded anchors for CFRP tendons, Eng. Struct., 2019 (180): 50– 66.

[6] D. Cai, J. Yin, R. Liu, Experimental and analytical investigation into the stress performance of composite anchors for CFRP tendons, Compos. B, 2015 (79): 530–534.

[7] Yang Xinxiang． Construction technology of CFCC pre-stressed anchor cable for Aizhai bridge [J]. Construction Technology, 2013, 42 (5):12-14. (in Chinese).