Study on the quantitative determination of effective stress of steel strand based on anti-rafah

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Abstract. Effective stress of prestressed steel bars in bridge structures is very important, and there is no compulsory requirement to test the tensile force of prestressed steel bars in bridge codes of our country. However, the lack of tensile force and failure of prestressed reinforcement will bring significant security risks. In this paper, according to the structural characteristics and anchorage characteristics of prestressed steel bar, on the basis of theoretical analysis and experiment, the curve of tension F and elongation S of single prestressed steel strand is established, which lays a foundation for effective stress detection of bridge steel bar in China.

1. Introduction
Prestressed steel bars play an important role in bridge construction and have become an indispensable part of bridge construction. The failure of prestressed reinforcement will cause the bearing capacity of bridge structure to decline, and even serious accidents will happen. Considering the influence of environment, construction technology, operator level and other factors, the effective stress of prestressed steel bars is difficult to guarantee, and ultimately the bearing capacity of bridge structure is difficult to guarantee. [1].

The sensor testing the prestressed state of the steel strand in vivo can be realized through the distributed fiber Bragg sensor grating sensor flux sensor of resistance strain gauge. The relevant research and application are as follows[2]:
- Oil pressure gauge method: tension is read directly from the calibrated oil pressure gauge on the tension system.
- Sensor method: a pressure sensor is placed between the anchor head and the pad to measure the tension.
- Frequency method: the tension is calculated according to the relation between tension and natural vibration frequency.
- Magnetic flux method: an electromagnetic sensor is placed in a steel beam to measure the tension through changes in its magnetic flux.
- Reverse tensioning: a method of confirming the working load in a prestressed beam by tensioning a prestressed steel strand in service or without pipe grouting.

Among the above stress testing methods, anti-rafah is the most economical and practical method. This study also takes anti-rafah as the theoretical basis. Currently, there are two types of anti-rafah commonly being used, namely whole beam tension and single root tension.
2. Theoretical basis

2.1. Fundamentals of the whole bundle of Nanyanghe

The basic principle of the test is shown in Figure 1. The tool anchor is installed on the steel bar, and a jack, a displacement sensor and a force sensor are installed between the tool anchor and the working anchor. When the tensile force is less than the original value, the stretched strand is exposed length. When the reverse tension is greater than the original value, the strand also takes part in elongation thus under the same drawing force increment, steel strand elongation will increase significantly, namely F-S relationship inflection point, the position of the inflection point that reflects the original prestressed. The typical f-s relation curve of the whole bundle of tension steel strand is shown in figure 2.

![Figure 1. Steel strand stress measurement device.](image1)

![Figure 2. F-S relation curve of steel strand.](image2)

2.2. The basic principle of Tangen Changlafa

Single zhang rafa as shown in figure 3, the basic principle of the exposed tool installed on single steel strand anchor and anchor in the tool and the anchor head (anchor) between jack and displacement force sensor, displacement sensor for measuring the displacement of a jaw tension steel strand, when the tension is less than the original prestressed, clip has binding force to the steel strand, not happen prestressed, the displacement and the tension is greater than the original clip with steel strand elongation also there at this time, the displacement of clamping piece has increased dramatically, as a result, the measuring displacement trend of the clamping piece can determine effective prestress Theoretically, as long as the clamping piece produced relative to the displacement of the anchor head can determine effective prestressed tension is greater than the original Therefore, to reduce the measurement noise, improve signal-to-noise ratio is meaningful In addition, the clamping piece produced relative to the anchor head displacement and the pore free steel strand length have a close relationship A typical single F - S relation curve of the as shown in figure 4.

![Figure 3. F-S relation curve of a single strand.](image3)

![Figure 4. Steel strand stress measuring device](image4)
3. Testing solutions

With the increase of counter-tension, the displacement increment is the elastic deformation of the steel strand in the working section, and the slope of the curve tends to be stable, as shown in the figure of AB segment. At the end of the AB section, the tension is equal to the sum of the effective prestress and the static frictional force, and the anti-tension force acts continuously to overcome the frictional force. At this point, the prestressing system will be adjusted, as shown in BC section: the friction between the stranded wire clip and the stranded wire anchor disappears, the stranded wire clip moves outward until it is restricted; When clamping piece is loose, the tension continues to increase, the displacement increment for the work period of elastic deformation of steel strand anchor and anchor cable, obviously this unit back pull of displacement is much bigger, on the F ~ S curve slope is reduced, as shown in figure of the CD segment as a result, C point after the tension can be thought of have overcome a clip friction, therefore, can also will as a criterion of the prestressed C o’clock[3].

4. Etection scheme

The movement of a single piece of rafah on clamping piece is relatively easy to control, and the whole bunch of rafa is relatively difficult, especially the control of the steel strand tensioned prestressed large difference, the original prestressed strand wire first to enter the smaller force balance state (that is, the clamping piece are becoming loose and bring out), but as a result of other steel strand has not yet entered into a state of force balance, so jack went to work, and make the clip to be taken out, is likely to make it by the super to exceed the permitted limit retraction (1 mm) so, from the adverse effect of the prestressed structure, single tension has certain advantages in this study single tension steel strand as the research object[4-5].

Considering the impact of friction prestress loss, a curve model of the exposed section of a single prestressed steel strand in ym15-5 group-anchor system was established to quantitatively detect the permanent stress of the steel strand after fastening. The test results are shown in table 1, and the fitting curve is shown in figure 5

| No. | F  (kN) | S  (mm) | No. | F  (kN) | S  (mm) |
|-----|---------|---------|-----|---------|---------|
| 1   | 15      | 0.00    | 11  | 916     | 9.19    |
| 2   | 142     | 2.47    | 12  | 934     | 9.29    |
| 3   | 260     | 3.62    | 13  | 942     | 9.42    |
| 4   | 350     | 4.40    | 14  | 949     | 9.71    |
| 5   | 445     | 5.20    | 15  | 960     | 9.81    |
| 6   | 552     | 6.06    | 16  | 945     | 10.03   |
| 7   | 638     | 6.80    | 17  | 937     | 10.22   |
| 8   | 738     | 7.63    | 18  | 955     | 10.36   |
| 9   | 831     | 8.42    | 19  | 963     | 10.52   |
| 10  | 875     | 8.86    | 20  | 971     | 10.68   |
Inflection point C in this stage, the anchoring steel strand tension and exposed section of the steel strand tension are equal, then jack provide pulling force $F = A \sigma$ if continue to tensioning, the prestress of the leakage and work is no longer regarded as an independent but participation by stretching long but in practice, because the clip from instantaneous jacks, hydraulic supply is insufficient, lead to tension suddenly become smaller, so the tensioning inflection point appears on the load - displacement curve, the moment corresponding tension prestressed steel strand that is equal to the work of internal force, the force value size is 934.0 kN, and the tension control stress, the size of 969.5 KN, the stress measurement error is 3.6%

5. Conclusions

The reverse tension method is applicable to the detection of effective stress of prestressed steel strand, and the reverse pulling method has almost no damage to steel strand. The anti pull method has the advantages of high efficiency, low cost and accuracy over 3%:

- The detection accuracy is high, and the sensitivity of the pressure sensor through the heart is 1N.
- High testing efficiency, single strand test can be completed in about 3 minutes, without affecting the construction progress.
- The detection system is simple, the self-developed wireless test system is simple to install.
- The anti pulling method is very safe and can effectively control tension force.

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