

# Analysis of cracking-moment calculation method of pre-stressed sheet pile

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**Abstract:** The two existing calculation methods of cracking moment for the pre-stressed high-strength concrete piles are analyzed in this paper. Through systematically calculation analysis of characteristics, sources, processes, errors in the two formulas, also the calculation results are compared with the field-tested data, the differences of the two methods and their advantages and disadvantages are pointed out. Results showed that the two calculation methods can be used in general engineering projects, also process of production and construction. The appropriate analysis methods can be chosen to calculate the cracking moments according to the characteristics and needs of the projects.

## 1. Introduction

In 1993, Japan developed a new type of pile and issued the industrial standard of JISA5334 "Concrete Sheet -Pile". This kind of concrete sheet-pile has good mechanical properties, steel savings, and good durability. It has the advantages of low overall construction cost and short construction period. It has been widely used in retaining walls, embankments, foundation pit enclosures, pier embankments and other engineering areas. At present, the new type of sheet pile has the advantages of various sections, large rigidity, good water stopping effect, low cost and high economic and social benefits[1].

As a new type of prestressed prefabricated retaining pile, the analysis and research of its mechanical properties is still lagging behind the production demand. In the process of production, assembly, transportation, application and use, sheet pile is inevitably subjected to tensile stress. However, the tensile strength of concrete is too small to bear the tensile force. In order to avoid the failure of the sheet pile, the calculation of the anti-crack moment of the sheet pile is very important. This paper compares and analyzes the method for calculating the crack bending moment (called Method 1) which adopted by each existing sheet pile manufacturing enterprise, and the calculation method for "Code for design of concrete structures" (GB50010-2010)[2] (called Method 2). The optimization analysis method is put forward for the calculation of the crack resistance of prestressed slab piles to meet the industrial production and popularization of prestressed sheet pile.

## 2. The analysis of two kind of anti-crack bending moment

### 2.1 Introduction to Calculation Methods of Crack bending moment



The calculation method of two kinds of crack bending moment is to calculate the prestress loss of the steel bar and then calculate the concrete prestressing stress at the edge of the bending member. Finally, the anti-crack bending moment is calculated by using the formula derived from the material mechanics formula. The difference between the two methods is that the calculation method of the prestress loss is different, and the prestressed concrete stress is different after the prestress loss is calculated.

In this paper, we introduce the derivation of the calculation formula of the anti-crack moment in the two methods, and then introduce the method of calculating the prestress loss respectively.

## 2.2 Introduction to the formula of cracking bending moment

The two existing methods for calculating the crack bending moment of slab piles are calculated as follows:

When calculating the crack moment of the normal section, the stress of the loading to the tensile edge of the component is zero, and the bending moment of the component is the anti-crack bending moment. Set the external bending moment is  $M_0$ , it has:

$$M_0 = \sigma_{peII} W_0 \quad (1)$$

When the concrete is about to crack, Set the external bending moment is  $M_{cr}$ . For prestressed concrete flexural members, there are two ways to determine  $M_{cr}$ .

(1) Calculated by elastic material.

Without considering the plasticity of the concrete in the tensile zone, the concrete stress is distributed in a straight line. When the stress of the loading to the tensile edge is equal to the standard value of the concrete axial tensile strength, it has:

$$M_{cr1} = (\sigma_{peII} + f_{tk}) W_0 \quad (2)$$

Here,  $\sigma_{peII}$  is tensile stress of prestressed reinforcement (N/mm<sup>2</sup>);  $f_{tk}$  is standard value of concrete axial tensile strength (N/mm<sup>2</sup>);  $W_0$  is the elastic resistance moment of the tensile edge of the reduced section (mm<sup>3</sup>).

(2) Consider the plasticity of the tensile concrete.

When considering the concrete plasticity in the tensile zone of the component section, the equivalent transformation is the linear distribution, stress on the tensile edge is  $\gamma f_{tk}$ . When the loading to the tensile edge is about to crack, following material mechanics formula:

$$M_{cr2} = (\sigma_{peII} + \gamma f_{tk}) W_0 \quad (3)$$

Equation (4) can be used to calculate the influence coefficient of the section resistance moment plasticity of concrete member.

$$\gamma = \left( 0.7 + \frac{120}{h} \right) \gamma_m \quad (4)$$

Here,  $\gamma$  is the influence coefficient of the section resistance moment plasticity of concrete member;  $\gamma_m$  is a basic value, which is 1.4.

## 2.3 Introduction of first calculation method to the tensile stress of prestressed reinforcement

This method is the calculation method that the enterprise is producing and using.  $\sigma_{peII}$  is the concrete prestress at the edge of the flexural member after the second batch of prestress loss is completed, the calculation process is as follows:

(1) Calculation of tensile stress of prestressed reinforcement after prestressing:

$$\sigma_{pt} = \frac{\sigma_{con}}{1 + n \frac{A_p}{A}} \quad (5)$$

Here  $\sigma_{pt}$  is tensile stress of prestressed reinforcement after prestressing(N/mm<sup>2</sup>);  $\sigma_{con}$  is initial tensile stress of prestressed reinforcement(N/mm<sup>2</sup>),  $\sigma_{con} = 0.70f_{ptk}$ ;  $f_{ptk}$  is tensile strength of prestressed reinforcement(N/mm<sup>2</sup>);  $A_p$  is Cross-sectional area of prestressed reinforcement(mm<sup>2</sup>);  $A$  is the cross-sectional area of sheet-pile(mm<sup>2</sup>);  $n$  is ratio of elastic modulus of prestressed reinforcement to elastic modulus of post-tensioned concrete.

(2) Calculation of tensile stress loss caused by concrete creep and shrinkage of concrete:

$$\sigma_{l5} = \frac{n \cdot \psi \cdot \sigma_{cpt} + E_p \cdot \delta_s}{1 + n \cdot \frac{\sigma_{cpt}}{\sigma_{pt}} \cdot \left(1 + \frac{\psi}{2}\right)} \quad (6)$$

Here,  $\sigma_{l5}$  is Prestress loss caused by concrete creep and shrinkage of concrete(N/mm<sup>2</sup>);  $\sigma_{cpt}$  is the preloading stress of the post-tensioned concrete(N/mm<sup>2</sup>),  $\sigma_{cpt} = \frac{\sigma_{pt} \cdot A_p}{A}$ ;  $\psi$  is the creep coefficient of concrete, value of 2.0;  $\delta_s$  is Shrinkage of concrete, value of  $1.5 \cdot 10^{-4}$ .  $E_p$  is elastic modulus of prestressed reinforcement(N/mm<sup>2</sup>);  $r_0$  is relaxation coefficient of prestressed reinforcement;

(3) Calculation of tensile stress loss due to relaxation of prestressed reinforcement:

$$\sigma_{l4} = r_0 (\sigma_{pt} - 2\sigma_{l5}) \quad (7)$$

Here  $\sigma_{l4}$  is tensile stress loss due to relaxation of prestressed reinforcement(N/mm<sup>2</sup>);  $r_0$  is relaxation coefficient of prestressed reinforcement.

(4) Calculation of effective tensile stress of prestressed reinforcement bars:

$$\sigma_{pe} = \sigma_{pt} - \sigma_{l5} - \sigma_{l4} \quad (8)$$

Here  $\sigma_{pe}$  is effective tensile stress of prestressed reinforcement bars.

(5) Finally, the ultimate tensile stress of prestressed reinforcement is calculated:

$$\sigma_{peII} = \frac{\sigma_{pe} A_p}{A} \quad (9)$$

#### 2.4 Introduction of second calculation method to the tensile stress of prestressed reinforcement

Using the method in "Code for design of concrete structures" (GB50010-2010), the calculation process is as follows:

(1) Calculation of tension control stress of reinforcement:

$$\sigma_{con} = 0.70f_{ptk} \quad (10)$$

Here  $\sigma_{con}$  is tension control stress of reinforcement.

(2) Calculation of prestress loss caused by stress relaxation of prestressed reinforcement bars:

$$\sigma_{l4} = 0.125 \left( \frac{\sigma_{con}}{f_{ptk}} - 0.5 \right) \sigma_{con} \quad (11)$$

(3) Calculation of tensile stress loss caused by concrete creep and shrinkage of concrete:

$$\sigma_{l5} = \frac{60 + 340 \frac{\sigma_{pc}}{f'_{cu}}}{1 + 15\rho} \quad (12)$$

$$\rho = \frac{A_p + A'_p}{A_0} \quad (13)$$

$$A_0 = \frac{E_p}{E_c} (A_p + A'_p) + A \quad (14)$$

$$\sigma_{pc} = \frac{N_p}{A_0} \pm \frac{N_p e_{p0}}{I} y_0 \quad (15)$$

$$N_p = (\sigma_{con} - \sigma_{l4}) A_p + (\sigma'_{con} - \sigma'_{l4}) A'_p \quad (16)$$

$$e_{p0} = \frac{(\sigma_{con} - \sigma_{l4}) A_p y_p - (\sigma'_{con} - \sigma'_{l4}) A'_p y'_p}{N_p} \quad (17)$$

Here  $A_0$  is total area of the concrete section and all the longitudinal prestressed reinforcement and non-prestressed reinforcement section area are converted into the section area of concrete(mm<sup>2</sup>);  $N_p$  is the stress of prestressed reinforcement and non-prestressed reinforcement only deduct the stress after the prestress loss(N);  $e_{p0}$  is the distance between the center of gravity of the conversion section and the joint point of prestressed reinforcement and non-prestressed reinforcement(mm);  $\sigma_{pc}$  is compressive stress of concrete which is applied to the joint of the prestressed reinforcement bars in the tensile zone(N/mm<sup>2</sup>);  $y_p$  and  $y'_p$  is the distance between the resultant points of the longitudinal prestressed reinforcement bars and the center of gravity in tensile zone and the compression zone(mm);  $A_p$  and  $A'_p$  is area of prestressed reinforcement section of tensile zone and compression zone(mm<sup>2</sup>);  $\sigma'_{l4}$  is prestress loss caused by stress relaxation of prestressed reinforcement bars in compression zone(N/mm<sup>2</sup>);  $\sigma_{con}$  and  $\sigma'_{con}$  is tension control stress of prestressed reinforcement bars in tension area and compression zone(N/mm<sup>2</sup>);  $f'_{cu}$  is according to the concrete compressive strength standard value(N/mm<sup>2</sup>);  $I$  is the sum of the moment of inertia of the net section and the moment of inertia of the conversion section(mm<sup>4</sup>)

(4) Finally, the ultimate tensile stress of prestressed reinforcement is calculated:

$$\sigma_{peII} = (\sigma_{con} - \sigma_{l5} - \sigma_{l4}) \frac{A_p}{A_0} \quad (18)$$

### 3. Comparative analysis of engineering examples

#### 3.1 Introduction to the engineering examples

The engineering example is the high strength prestressed slot sheet pile, the section shape of prestressed sheet pile is shown in FIG. 1. The connection of sheet pile is shown in figure 2, its calculation model is shown in figure 3. A symmetric cross section of 996mm is taken from two prestressed sheet piles. In the calculation process, the Angle force of the sheet pile is negligible, so the cross section of the sheet pile is equivalent to a T section. After the equivalent t-shaped section, the calculation model of bending coefficient is shown in FIG. 4.

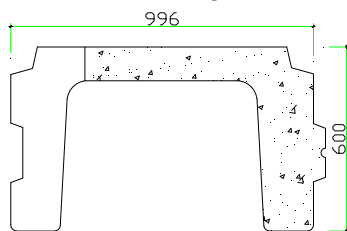


Figure 1. Calculation section diagram of prestressed sheet pile.

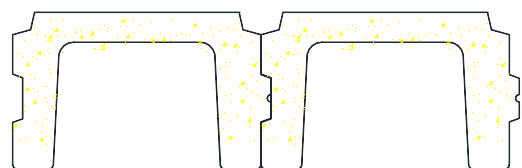


Figure 2. Row diagram of prestressed sheet piles.

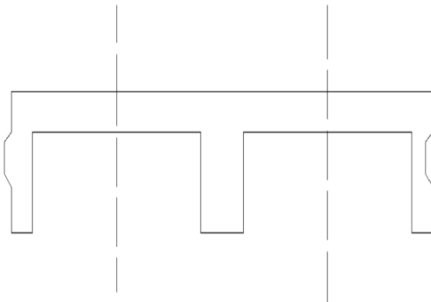


Figure 3. Calculation model of prestressed sheet piles.

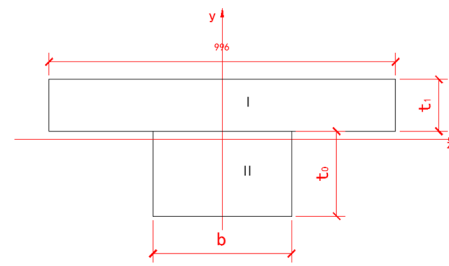


Figure 4. T-section Calculation diagram of prestressed sheet piles.

The section size of the calculation model of sheet pile is as follows:

Let  $t_1$  be the flange height, its value is 120mm; let  $l$  be the flange width, its value is 996mm; let  $t_0$  be the Web height, its value is 480mm; let  $b$  be the web width, its value is 320mm; let  $h$  be the overall depth of section, its value is 600mm; let  $y_c$  be the centroid position, its value is 382.89mm; let  $A$  be the cross-sectional area, its value is 250930mm<sup>2</sup>, let  $I_0$  be net section moment of inertia, its value is 8799691767mm<sup>3</sup>.

The steel reinforcement adopts 16 diameter 12.6mm prestressed steel wire, the nominal total area is 2000mm<sup>2</sup>. The 8 steel bars are arranged on the t-shaped flange, and another 8 bars are arranged in the lower web. The concrete grade is C60, Specific parameters of concrete and steel are shown in table 1 and table 2.

Table 1. Concrete parameters of strength and elastic modulus

| Strength grade of concrete | Standard value of compressive strength. $f_{ck}$ (kPa) | Design value of compressive strength. $f_c$ (kPa) | Standard value of tensile strength. $f_{tk}$ (kPa) | Design value of tensile strength. $f_t$ (kPa) | Elasticity modulus. $E_c$ (N/mm <sup>2</sup> ) |
|----------------------------|--------------------------------------------------------|---------------------------------------------------|----------------------------------------------------|-----------------------------------------------|------------------------------------------------|
| C60                        | 38.50                                                  | 27.50                                             | 2.85                                               | 2.04                                          | $3.60 \times 10^4$                             |

Table 2. Material parameters of PC stranded wire

| The number of prestressed bars. | Diameter of steel wire.(mm) | Nominal sectional area. (mm <sup>2</sup> ) | Standard value of tensile strength. $f_{ptk}$ (MPa) | Design value of tensile strength. $f_{pt}$ (MPa) | Design value of compressive strength $f_{pc}$ (MPa) | 1000h Relaxation value(%) |
|---------------------------------|-----------------------------|--------------------------------------------|-----------------------------------------------------|--------------------------------------------------|-----------------------------------------------------|---------------------------|
| 16                              | 12.6                        | 125                                        | $\geq 1420$                                         | 1005                                             | 386                                                 | $\leq 2.0$                |

### 3.2 The crack bending moment of sheet pile is calculated by first method

When the first method is used to calculate the crack bending moment of the above section, all 16 steel bars are used as tensile bars to calculate the crack bending moment.

Calculation of tensile stress of prestressed reinforcement after prestressing:

$$\sigma_{con} = 0.70 f_{ptk} = 1420 \times 0.7 = 994 \text{ N} \quad (19)$$

$$\sigma_{pt} = \frac{\sigma_{con}}{1 + n \frac{A_p}{A}} = \frac{994}{1 + 5.56 \times \frac{2000}{250930}} = 951.82 \text{ N/mm}^2 \quad (20)$$

Calculation of prestress loss of concrete shrinkage and creep:

$$\sigma_{l5} = \frac{n\psi\sigma_{cpt} + E_p\delta_s}{1 + n \frac{\sigma_{cpt}}{\sigma_{pt}} \left(1 + \frac{\psi}{2}\right)} = \frac{5.56 \times 2 \times 7.586 + 2.0 \times 10^5 \times 1.5 \times 10^{-4}}{1 + 5.56 \times \frac{7.586}{951.82} \times \left(1 + \frac{2}{2}\right)} = 105.05 \text{ N/mm}^2 \quad (21)$$

$$\sigma_{pt} = \frac{\sigma_{pt} \cdot A_p}{A} = \frac{951.82 \times 2000}{250930} = 7.586 \text{ N/mm}^2 \quad (22)$$

Calculation of prestress loss caused by stress relaxation of prestressed reinforcement bars:

$$\sigma_{l4} = r_0 (\sigma_{pt} - 2\sigma_{l5}) = 0.025 \times (951.82 - 2 \times 105.05) = 18.543 \text{ N/mm}^2 \quad (23)$$

Calculation of effective tensile stress of prestressed reinforcement bars:

$$\sigma_{pe} = (\sigma_{pt} - \sigma_{l5} - \sigma_{l4}) = 951.82 - 105.05 - 18.543 = 828.227 \text{ N/mm}^2 \quad (24)$$

After the second batch of prestress losses, the pre-compressive stress of the concrete subjected to the bending member is:

$$\sigma_{peII} = \frac{\sigma_{pe} \cdot A_p}{A} = \frac{828.227 \times 2000}{250930} = 6.60 \text{ N/mm}^2 \quad (25)$$

Calculation of the elastic resistance moment of the tensile edge of the section:

$$W_0 = \frac{I}{y_0} = \frac{I_0 + I_g}{y_0} \quad (26)$$

Calculation of the moment of inertia of prestressed reinforcement:

$$I_g = A_s \times (y_c - a_s)^2 \times \frac{E_p}{E_c} = 2000 \times (382.89 - 60)^2 \times \frac{20}{3.6} = 1158421690 \text{ mm}^4 \quad (27)$$

$$W_0 = \frac{8799691767 + 1158421690}{382.89} = 26007765.83 \text{ mm}^3 \quad (28)$$

Calculation of crack resistance moment:

$$\gamma = \left( 0.7 + \frac{120}{h} \right) \gamma_m = \left( 0.7 + \frac{120}{600} \right) \times 1.4 = 1.26 \quad (29)$$

$$M_{cr2} = (\sigma_{peII} + \gamma f_{tk}) W_0 = (6.60 + 1.26 \times 2.85) \times 26007765.83 = 265.08 \text{ kN} \cdot \text{m} \quad (30)$$

### 3.3 The crack bending moment of sheet pile is calculated by second method

Calculation of initial tensile stress of prestressed reinforcement:

$$\sigma_{con} = 0.70 f_{ptk} = 0.7 \times 1420 = 994 \text{ N/mm}^2 \quad (31)$$

Calculation of prestress loss caused by stress relaxation of prestressed reinforcement bars:

$$\sigma_{l4} = 0.125 \left( \frac{\sigma_{con}}{f_{ptk}} - 0.5 \right) \sigma_{con} = 0.125 \times (0.7 - 0.5) \times 994 = 24.85 \text{ N/mm}^2 \quad (32)$$

Calculation of prestress loss of concrete shrinkage and creep:

$$A_0 = \frac{E_p}{E_c} (A_p + A'_p) + A = \frac{200000}{36000} \times (1000 + 1000) + 250930 = 262041.11 \text{ mm}^2 \quad (33)$$

$$\rho = \frac{A_p + A'_p}{A_0} = \frac{2000}{262041.11} = 0.00763 \quad (34)$$

$$\begin{aligned} N_p &= (\sigma_{con} - \sigma_{l4}) A_p + (\sigma'_{con} - \sigma'_{l4}) A'_p \\ &= (994 - 24.85) \times 1000 + (994 - 24.85) \times 1000 = 1938300 \text{ N} \end{aligned} \quad (35)$$

$$e_{p0} = \frac{(\sigma_{con} - \sigma_{l4}) A_p y_p - (\sigma'_{con} - \sigma'_{l4}) A'_p y'_p}{N_p}$$

$$= \frac{969.15 \times 1000 \times 157.11 - 969.15 \times 1000 \times 322.89}{1938300} = -82.90 \text{ mm} \quad (36)$$

$$\sigma_{pc} = \frac{N_p}{A_0} \pm \frac{N_p e_{p0}}{I} y_0$$

$$= \left( \frac{1938300}{262041.11} + \frac{1938300 \times 82.90 \times 382.89}{9958113457} \right) = 13.58 \text{ N/mm}^2 \quad (37)$$

$$\sigma_{l5} = \frac{60 + 340 \frac{\sigma_{pc}}{f'_{cu}}}{1 + 15\rho} = \frac{60 + 340 \times \frac{13.58}{38.5}}{1 + 15 \times 0.00763} = 161.45 \text{ N/mm}^2 \quad (38)$$

After the second batch of prestress losses, the pre-compressive stress of the concrete subjected to the bending member is:

$$\sigma_{peII} = (\sigma_{con} - \sigma_{l5} - \sigma_{l4}) \frac{A_p}{A_0} = (994 - 161.45 - 24.85) \times \frac{1000}{262041.11} = 3.08 \text{ N/mm}^2 \quad (39)$$

Calculation of the elastic resistance moment of the tensile edge of the section:

$$W_0 = \frac{I_0 + I_g}{y_0} \quad (40)$$

Calculation of the relative compression zone of the section

$$x = \frac{E_p A_p}{E_c b} \left( \sqrt{1 + \frac{2bh_0 E_c}{E_p A_p}} - 1 \right)$$

$$= \frac{5.56 \times 1000}{320} \times \left( \sqrt{1 + \frac{2 \times 320 \times 540}{5.56 \times 1000}} - 1 \right) = 120.71 \text{ mm} \quad (41)$$

Here  $x$  is the relative compression zone of the section.

Calculation of the moment of inertia of prestressed reinforcement:

$$I_g = A_p (h_0 - x)^2 \frac{E_p}{E_c} = 2000 \times (540 - 120.71)^2 \times \frac{20}{3.6} = 1953378934 \text{ mm}^4 \quad (42)$$

Here  $I_g$  is the moment of inertia of prestressed reinforcement.

$$W_0 = \frac{I_0 + I_g}{y_c} = \frac{8799691767 + 1953378934}{382.89} = 28083968.51 \text{ mm}^3 \quad (43)$$

$$\gamma = \left( 0.7 + \frac{120}{h_0} \right) \gamma_m = \left( 0.7 + \frac{120}{600} \right) \times 1.4 = 1.26 \quad (44)$$

Calculation of crack bending moment:

$$M_{cr2} = (\sigma_{peII} + \gamma f_{tk}) W_0 = (3.08 + 1.26 \times 2.85) \times 28083968.51 = 187.35 \text{ kN} \cdot \text{m} \quad (45)$$

### 3.4 Comparison and analysis of two kinds of calculation results

Compared with the last calculation results of the two algorithms, it can be found that the crack bending moment calculated by the first method is about one third larger than the crack bending moment calculated by the second method. The difference is caused by the difference in  $\sigma_{peII}$  value calculated

by two algorithms. The calculation result of  $\sigma_{peII}$  by first method is 6.6N/mm<sup>2</sup>, and which is 3.08N/mm<sup>2</sup> by second method. The reasons for the difference between the two H values are as follows:

1)In the first calculation method, all 16 prestressed steel wires are treated as tensile steel bars in the tensile zone when calculating the crack bending moment, not considering the influence of the prestressed reinforcement in compressive zone to component to calculate crack bending moment. In this calculation, all 16 prestressed steel bars are used, and the total sectional area of steel is 2000mm<sup>2</sup>. In the first calculation method, only 8 prestressed bars in the tensile zone are used to calculate the anti-crack moment. In second method, the total sectional area of steel reinforcement is 1000mm<sup>2</sup>, and the sectional area of the reinforcement is one half of the first calculation method. Therefore, the second result of  $\sigma_{peII}$  is much smaller than the first result, which is the main reason for the anti-cracking moment of both.

2)The first calculation method used in the calculation process of area are not considering the conversion of prestressed reinforced concrete section area, and the second method considering the prestressed conversion sectional area, lead to small  $\sigma_{peII}$  results.

3)The first calculation method uses the formula of the international prestress association model (CEB-FIP) to calculate the prestress loss caused by creep, and the calculated  $\sigma_{is}$  is smaller, which makes the final  $\sigma_{peII}$  larger.

4)In the first calculation method, the moment of inertia of the steel bar conversion section is calculated by using the actual tensile zone. The second calculation method is calculated by using the steel bar conversion section, so that The total inertia moment of the cross section calculated is small. Finally, the calculated anti-crack bending moment value is small than the first calculation method result.

### 3.5 Comparison and analysis of two kinds of calculation results with the experimental results

Table 3. Calculation and experimental results

|                      | Height of section.<br>$h(m)$ | Number and diameter of prestressed reinforcement bars | Breadth of section.<br>$l(m)$ | Sectional area.(mm <sup>2</sup> ) | Cracking bending moment.<br>(kN·m) |
|----------------------|------------------------------|-------------------------------------------------------|-------------------------------|-----------------------------------|------------------------------------|
| First method         | 600                          | 16×12.6                                               | 996                           | 250930                            | 265.08                             |
| Secord method        | 600                          | 16×12.6                                               | 996                           | 250930                            | 187.35                             |
| Experiment al result | 600                          | 16×12.6                                               | 966                           | 250930                            | 454                                |

It can be found from the comparison of the three sets of data in the above table that the actual anti-crack bending moment is larger than that of the two calculation methods, and the reasons for the difference are as follows:

1)When calculating, the steel and concrete parameters used are design values, while the actual measurement is the ultimate anti-crack bending moment of the sheet pile, so the calculation results are relatively conservative.

2)When calculating, the unit cross section is used to calculate, while the actual measuring sheet pile is a 15m-long entity, and the actual situation is different from the assumption in our calculation, which is bound to produce a difference.

3)When the sheet pile is produced, four lumbar muscles are added at the center of the sheet pile, which is used as the anti-twist construction reinforcement. In the calculation, the effect of the lumbar tendon on the fracture bending moment is not considered.

#### 4. Conclusion

1)The two methods have their own characteristics in calculation, and the calculation method is more rigorous, and the method is more suitable for general working conditions. For example, the first method using all prestressed reinforcement bars while calculating the crack bending moment, and the other is calculated by prestressed reinforcement in the tensile zone. In the calculation of all prestressed reinforcement bars, the differences between the prestressed reinforcement bars and the compression zones are ignored, and the assumptions in this method under certain conditions are not in line with the actual situation, leading to the larger error of cracking bending moment. However, this method can meet the general engineering requirements. In the actual working conditions, all the prestressed bars exert pressure on the concrete members, so that the concrete does not bear the tension. Therefore, it is more useful to consider using the first method in general engineering.

2)The first calculation method is based on the old standard, there are many details in the calculation that are not considered, resulting in errors. The first calculation method has been used for a long time in the production and construction of the enterprise, which indicates that the error does not affect the application of the actual engineering. Process of the second method is detailed and comprehensive, and the formula is derived strictly according to the formula of material mechanics, but the calculation results are conservative and cannot fully reflect the use value of the components. In practical engineering application, it is necessary to further improve the algorithm and formula to meet the actual working condition demand, and to make the calculation result is more reasonable and effective. In the case of high environmental grade and demanding engineering quality, the more rigorous and thorough second method is applicable, and the calculation results of its anti-crack bending moment are more conservative, which can guarantee the engineering quality and safety.

3)In the process of production and construction, a suitable analytical method can be used to calculate the crack bending moment according to the engineering characteristics and requirements. From the point of comparison on the results of the experiment, the calculation results of two methods relative experimental results are relatively small, using these two kinds of calculation methods are relatively safe, which is able to meet the general engineering situation. Therefore, we can use the first method for calculation in general engineering design, which is beneficial for enterprises to reduce costs and save capital, which also helps to save building materials. And when the situation is more complicated or engineering quality requirement is high, we can use second method in the precision of design and calculation, in order to ensure the construction process to meet the more stringent quality, environmental requirements.

#### Acknowledgments

Fund program: Supported by the National Natural Science Foundation of China (51678153); Supported by the Science and Technology Planning Project of Fuzhou (No. 2017-G-69); Supported by the Industry Cooperative Development Fund Project of Fujian University of Technology (GY-Z17145).

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