Study of Bearing Model on the Internal Forces of the Wide Bearing Continuous Beam

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Abstract. The standing pile has been applied quite extensive in our country, which is one of the three major structure forms of the quay. Take the internal force calculation of wharf track beam in Jiangsu Taizhou for example, this paper studied the bar system finite element method processing method of rigid support and elastic support. Using different bearing support mode to calculate the track beam internal force, the results show that the corresponding internal force of different models has big differences. The negative bending moment and shear force of point support model are large. The effect of support width and elastic support was considered in the continuous beam model of elastic distribution supporting and should be considered prior to other supporting. In the process of similar design, the bearing width can be increased. This is conducive to the uniform distribution of internal force, and make the structure more reasonable.

1. Introduction

With the rapid development of economy, the demand for shipping is constantly increasing, and the trend of large ships, deep-water berths and heavy loading and unloading machinery is becoming more and more obvious. In order to meet this need, the sections of pile foundation, beam and rail beam of high pile wharves are becoming larger and larger [1-4].

As an important wharf component, the track beam is generally supported on the lower beam and connected together at the support. It is a continuous beam structure. Due to the deformation of pile foundation and beam under the action of load, the actual support state at the bearing of rail beam is not rigid support. The width of the rail beam on the beam relative to the span of the rail beam can not be ignored, the actual support should be distributed support rather than point support constraints.

For the internal force calculation of the track beam, according to the different simplified methods of the support, it can be roughly calculated according to the rigid point support, elastic point support and elastic distributed support continuous beam. In this paper, the finite element model of elastic support
and rigid support is studied. Combined with the internal force analysis of track beam in specific engineering, some laws are found, which can be used for reference of related structures [5-8].

2. Project overview
A general wharf is of high pile girder plate structure, with two 70,000-ton general berths for outer gearing and three 1000-ton bulk cargo berths for inner gearing. The spacing between racks is 7.5m, the width of lower beam is 2m, and the length of typical structural section is 64.27m. There are 8 spans of track girders in this section, C50 concrete is used, and elastic modulus $E=3.45\times10^4\text{MPa}$. The cross-sectional area is $1.740\text{m}^2$, the moment of inertia is $0.625\text{m}^4$, and the load parameters of the gantry crane are: 40t-40m, gantry crane gauge 10.5m; Track width 0.8 m; Base from the 10.5 m; wheel pressure of 350 kN; The total number of rounds is 32, and the minimum interval between two parallel machines is 1.5 m. The structural diagram is shown in Figure 1.

![Figure 1. Typical structure section ——8 track beam](image)

3. Computational model
A Continuous beam belongs to statically indeterminate structure, so it is difficult to calculate the internal force manually. For continuous beam with equal stiffness and equal span rigid support, the internal force can be obtained by looking up the table in the relevant tables in the mechanics manual, and the common rod system finite element method is used to calculate the continuous beam with different span and elastic support [9-11].

The rail beam is simplified to a continuous beam model with single point rigid support. The model does not consider the width of the support, nor the elastic support action of pile foundation and beam on the rail beam. The model is a conventional model, relatively simple and easy to calculate. In the finite element method of rod system, the continuous beam is generally divided into several elements with nodes on the boundary of the element body, through which the discrete elements are connected as one. Taking the node displacement of each element as the basic unknown quantity, the displacement field on the element is represented by the displacement interpolation function, then the stress and strain of the element can be expressed by the node displacement by using the geometric equation and the physical equation, and the node force of the element can also be expressed by the node stiffness matrix and the node displacement. All discrete array element stiffness matrix and equivalent node set, respectively, of the whole stiffness matrix and equivalent nodal load of the whole, through the displacement constraint conditions according to the balance equation to establish the overall structure of the node displacement equations, so as to get the answer, rigid constraint, constraint direction displacement is zero.

Considering the bearing width of the track beam, and included in the elasticity of track beam support, pile foundation and beams can be used to calculate the distribution of elastic support continuous beam model track beam internal force, distribution of elastic support as shown in figure 3, the elastic support distribution within the scope of the support width, the equivalent of a beam on elastic foundation, the elastic support to replace the bearing by a number of points and elastic support form distribution, The stiffness coefficient of elastic support at each point is numerically equal to the force of pile foundation or beam under unit displacement divided by the number of supports. The calculation principle of internal force is the same as that of continuous beam with elastic support at point.

According to Code for Design and Construction of Pile Wharf, for the point support model, the negative bending moment and shear force should be "peak-clipped" to consider the influence of bearing width [12-15].
4. Results and analysis

Take the dead weight and 40t-40m portal crane parallel load of the track beam as an example to analyze the internal forces of the track beam under different supports. The schematic diagram of the track beam in the typical structural section is shown in Fig. 4.

Under the moving load of gantry crane, the envelope diagram of track beam shear force, positive bending moment and negative bending moment of point-rigid support, point-elastic support and distributed elastic support model is respectively calculated, as shown in Fig. 4 to Fig.9.

Figure 2. Distribution of the elastic support

Figure 3. Track beam stress diagram

Figure 4. Shear force envelope diagram of rigid support crane load (Maximum 1945.41kN)

Figure 5. Shear force envelope diagram of elastic support crane load (Maximum -1774.59kN)

Figure 6. Shear force envelope diagram of elastic distribution support crane load (Maximum 1368.38kN)
Figure 7. Bending moment envelope of rigid support crane load (Maximum 2242.84kN; Minimum 1368.38kN)

Figure 8. Bending moment envelope of elastic support crane load (Maximum 2991.98kN; Minimum -1477.66kN)

Figure 9. Bending moment envelope of elastic distribution support crane load (Maximum 2438.74kN; Minimum -1071.44kN)

Under the same gantry crane load, the maximum positive bending moment, the maximum negative bending moment and the maximum shear force of the three models are summarized in Table 1.

| No. | Method                | Maximum bending moment | Maximum negative bending moment | Maximum shear |
|-----|-----------------------|------------------------|---------------------------------|--------------|
| ①   | Rigid point support   | 2242                   | -2793                           | -1837        |
| ②   | Elastic point support | 2991                   | -1477                           | -1774        |
| ③   | Elastic distributed brace | 2427                | -1071                           | -1368        |
| ④   | (①-③)/③             | -7.6%                  | 160.8%                          | 34.3%        |
| ⑤   | (②-③)/③             | 23.2%                  | 37.9%                           | 29.7%        |

As can be seen from Table 1, among the maximum bending moment values, the elastic point support is the largest (conservative), which is 23.2% larger than the elastic distribution support. The overall difference of positive bending moment is acceptable within a certain range. For the maximum negative
bending moment, the result of rigid point support is the largest (conservative), which is 160.8% larger than that of elastic distribution support, which is a big difference. Therefore, the result of point support can not be used for design. In the maximum shear force, the result of rigid point support is the largest, which is 34.3% larger than that of elastic distributed support.

According to Code for Design and Construction of Pile Wharf (JTS 167-1-2010), the negative bending moment and shear force at elastic point support and rigid point support support are "peak-clipped". The bending moment and shear force are the values at 1/4 support width at the middle point of the support. The internal forces after "peak-clipped" are shown in Table 2:

| No  | Method                      | Maximum bending moment | Minimum bending moment | Maximum shear moment |
|-----|-----------------------------|------------------------|------------------------|----------------------|
| ①  | Rigid point support         | 2242                   | -1899                  | -1595                |
| ②  | Elastic point support       | 2991                   | -1411                  | -1445                |
| ③  | Elastic distributed brace   | 2427                   | -1071                  | -1276                |
| ④  | (①-③)/③                   | -7.6%                  | 77.3%                  | 25.0%                |
| ⑤  | (②-③)/③                   | 23.2%                  | 31.7%                  | 13.2%                |

By "peak-clipping" the negative bending moment and shear force of the bearing, the negative bending moment and shear force of the point support are reduced, and the result after "peak-clipping" is still larger than that of the elastic distribution support (conservative), especially the negative bending moment of the bearing, which is 77.3% larger than that of the elastic distribution support, and still cannot be used as an approximate calculation result.

The shear force, positive bending moment and negative bending moment of the track beam model of point rigid support, point elastic support and distributed elastic support are calculated respectively under the action of dead weight load.

![Figure 10. Schematic diagram of track beam weight](image)

The internal force results without "peak clipping" are shown in Table 3:

| No  | Method                      | Maximum bending moment | Minimum bending moment | Maximum shear moment |
|-----|-----------------------------|------------------------|------------------------|----------------------|
| ①  | Rigid point support         | 186                    | -262                   | 201                  |
| ②  | Elastic point support       | 242                    | -217                   | 183                  |
| ③  | Elastic distributed brace   | 203                    | -141                   | 144                  |
| ④  | (①-③)/③                   | -8.4%                  | 85.8%                  | 39.6%                |
| ⑤  | (②-③)/③                   | 19.2%                  | 53.9%                  | 27.1%                |

After "peak-clipping", the negative bending moment and shear force of point support are shown in Table 4.
Table 4. The internal force of three kinds model under dead-weight (After peak clipping)

| No. | Method                  | Maximum bending moment | Minimum bending moment | Maximum shear |
|-----|-------------------------|------------------------|------------------------|---------------|
| ①  | Rigid point support     | 186                    | -166                   | 178           |
| ②  | Elastic point support   | 242                    | -138                   | 161           |
| ③  | Elastic distributed brace | 203               | -141                   | 144           |
| ④  | (①-③)/③               | -8.4%                  | 18.7%                  | 23.6%         |
| ⑤  | (②-③)/③               | 19.2%                  | -2.1%                  | 11.8%         |

It can be seen from Table 4 and Table 5 that the internal force results of the three bearing models under dead weight are consistent with the internal force results of the moving load: the positive bending moment varies little within a certain range, while the negative bending moment and shear force of the point support are much larger than those of the elastic distribution support, that is, the point support results tend to be conservative. After peak clipping, the negative bending moment and shear force of the point bracing model are reduced to some degree. Compared with the result of elastic distribution bracing, the negative bending moment and shear force of the point bracing model are still larger and the result is conservative.

5. Conclusion
In this paper, the continuous beam models of rigid point braces, elastic point braces and distributed elastic braces are studied. By calculating the internal forces of actual engineering, the results show that: for the positive bending moment, the result of the point braces model is large and conservative, and the deviation is acceptable within a certain range; The negative bending moment and shear force of point braces deviate greatly from the results of distributed elastic braces before "peak clipping", which is too conservative. After "peak clipping", the deviation value is reduced and can be used as an approximate value. Because the continuous beam model with distributed elastic braces takes into account the influence of support width and elastic braces, it should be used first in the selection of the calculation model of track girder. In the design process of similar continuous beam, the width of support should be increased if possible, which is conducive to the uniform distribution of internal forces of continuous beam and makes the structure more reasonable.

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References
[1] Zhou Weicai. Study on Calculation Method and Model Test of Pile Cap Wharf Shelving[D]. Nanjing: Hohai University, 2016.
[2] Ji Ming. Study on model test and simplified calculation method of continuous beam with wide support[D]. Nanjing: Hohai University, 2016.
[3] Zhang Yanjiao, Zhao Cheng, Zhang Yanpeng, Li Yachao. Experiment study of the elastic support beams[J]. Sichuan Building Materials, 2012, 35(167): 24-25
[4] i Ming, Tao Guilan, Chen Fengqi. Influence of different support stiffness on mechanical characteristics of continuous beam with wide support[A]. Proceedings of the 12th China Coastal Engineering Symposium[C]. 2005.
[5] Tao Guilan, Bu Meifei. Force Analysis of Rail Beams with Big Pile Capping under Different Supporting Conditions[J]. China Harbour Engineering, 2013, 188(5): 17-20
[6] Shen Xuebin. The Solution Elastic Support Stiffness Beam Counterforce[J]. Journal of Hohai University, 1993, (4).
[7] Yin Yongxin. Internal Force Analysis of Different Bearing Continuous Beam[J]. Pearl River Water Transport, 2011, (06): 87-89
[8] Ling Xiaojun, Ding Yingpin, Peng Xuezhong. Explore the Design Method of Elastic Support Continuous Beam [J]. Pearl River Water Transport, 2004(08)
[9] Lu Wanfeng, Tao Guilan, Wen Tao, Sun Haiyan. Study on Calculation of Internal Force of Longitudinal Beam with Wide Pile Cap [A]. Port Engineering Branch of China Civil Engineering Society Technical Exchange Collection [C]. 2009: 144-150
[10] Yao Jianxiong, Li Ning, Xu Dong. The reaction force distribution of inner and outer supports of curved concrete box girder bridge is studied by different calculation models [A]. The 20th National Symposium on Bridges (Volume I) [C]. 2012
[11] Mao Weishuai. An Exact Method Research for Computing Internal Force Evelops of Bridge Space [D]. Harbin Institute of Technology, 2012.
[12] CCCC Third Harbor Consultants Co., Ltd. JTS167-1-2010, Code for design and construction of piled wharves [S]. Beijing: China Communication Press, 2010.
[13] Gu Minquan. Harbour Works Design Manual [M]. Beijing: China Communication Press, 2001.
[14] Chen Fengqi, Cheng Zekun. Revision of code for open-type wharf on piles [J]. Port & Waterway Engineering, 2013, 484(10): 114-117
[15] Han Li’an. Port Hydraulic Structures [M]. Beijing: China Communication Press, 2008