Design of Continuous Girder Bridge Inclined Support System

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Abstract. This paper takes the continuous girder bridge with inclined support as the object and establishes the finite element model with Midas for calculation and analysis. Combined with the engineering practice, the support system with stiffness is used to ensure the pier in a good working state. The support system with stiffness consists of brake piers with plate-spring bearings installed in both the axial and transverse directions, and the rest of the piers with plate-spring bearings installed in the transverse direction.

1. Introduction
The bridge project is located in an ecological wetland park. According to the landscape requirements, a V-shaped pier without a girder is adopted. The bridge support is placed at an incline of 15°, and the pier top and beam bottom are parallel to the support, as shown in Figure 1. This kind of structural system is relatively rare in the industry [1]. How to ensure the reasonable stress state of the pier is the key point of the design [2].

2. Design objective
The single pier column was taken as an isolator for force analysis, as shown in Figure 2. For the center O of the bottom of the pier:

\[ N_0 = G \cos 15° + F_z \]

\[ M_0 = G \sin 15° \cdot \frac{H}{2 \cos 15°} + F_x \cdot \frac{H}{\cos 15°} \]


$e_0 = \frac{G \sin 15^\circ (H/2 \cos 15^\circ) + F_x (H/\cos 15^\circ)}{G \cos 15^\circ + F_z}$  \hspace{1cm} (3)

According to the force analysis, when the size of superstructure and pier column is determined, \(F_z\), \(G\) and \(H\) basically remain unchanged. The eccentricity of pier bottom section is controlled by \(F_x\), and the smaller the \(F_x\) value is, the more ideal the stress state of pier is. This paper will take reducing \(F_x\) as the goal to analyze the bearing constraint system, and ensure that the beam displacement meets the requirements [3].

3. **Selection of supporting system**

Three kinds of support systems are proposed in this paper. The first one is arranged according to the conventional support [4]. The longitudinal restraint of the support is only set on the brake pier, while the lateral restraint is carried out on the unilateral side of all pier columns, as shown in Figure 3.

![Figure 3. The first constraint diagram](image)

The difference between the second support system and the first one is that the lateral constraint with stiffness is used, as shown in Figure 4.

![Figure 4. The second constraint diagram](image)
The third support system consists of a brake pier with longitudinal stiffness support, and all piers with lateral stiffness support, as shown in Figure 5.

![Figure 5. The third constraint diagram](image)

The support with stiffness is achieved by extending the distance between the steel plate and the lower steel plate on the ordinary bearing, and installing a plate spring between the gaps. The maximum effective stiffness of the plate spring provided by the support manufacturer is 10000 kN*m.

![Figure 6. Support diagram](image)

According to the above three kinds of support systems combined with different values of spring stiffness, the four constraint models in Table 1 are proposed to be used for calculation and analysis.

| Model   | Model 1 | Model 2 | Model 3 | Model 4 |
|---------|---------|---------|---------|---------|
| Constraint System | The first | The second | The third | The third |
| Stiffness (kN*m) | -       | -       | 10000   | 5000    |

4. **Support reaction force analysis**

The brake pier was selected as the analysis object to extract the lateral and longitudinal support reaction forces under live load without considering the braking force [5]. The analysis results are shown in the Figure 7.
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It can be seen from the figure that, in the case of lateral unilateral complete constraint, the constraint bearing will bear a large lateral force in the off-balance load condition under live load in the first model. When the lateral constraint is adjusted to the spring stiffness constraint on both sides, the lateral force of the bearing is significantly reduced. In the second model, the lack of global constraints leads to the larger longitudinal force borne by the brake pier under live load, while in the other models, the longitudinal force borne by the brake pier can be ignored. To sum up, the third support system can effectively reduce the support reaction force when the support is inclined.

5. Displacement analysis
The beam is selected as the object of analysis, and the longitudinal displacement results under three working conditions of overall temperature, concrete shrinkage and creep and braking force are analyzed, as shown in Figure 8.

It can be seen from the figure that the longitudinal displacement of the upper beam is the same under the effect of overall temperature and concrete shrinkage creep in the four models. When the longitudinal restraint of the brake pier is adopted, there is basically no longitudinal displacement of the beam under braking force. When the brake pier is constrained longitudinally by the stiffness, the longitudinal displacement of the beam under the braking force is proportional to the spring stiffness. In order to control the movement of the beam, it is more advantageous to select a larger spring stiffness.
6. Conclusion
According to the calculation and analysis, when the support is tilted, the lateral component force of the bearing can be effectively reduced by using the longitudinal stiffness constraint of the brake pier and the lateral stiffness constraint of all the piers. When the stiffness of the support is large, the longitudinal displacement of the continuous beam is small, so Model 3 is used in practical engineering. I hope this case can be helpful for the following similar projects.

References
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