Force Analysis of Long-Span Oblique Steel-Concrete Composite Beams

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Abstract. At present, scholars at home and abroad have conducted more research on conventional steel-concrete composite bridges and conventional oblique bridge, but there is relatively little research on long-span diagonal steel-concrete composite beams that appear in engineering. The article combines specific engineering examples and uses the finite element analysis software Midas Civil to establish a single beam model and a beam grid model for calculation. Through comparative analysis of the two calculation results, it is concluded that using a single beam model to simplify the calculation is biased towards safety, and due to the action of the diaphragm and crossbeam, the torque in the calculation results of the beam grid model is greater than that of a single beam. For structures with long oblique angles, the beam grid model should be used for inspection.

Keywords: Long-Span; Oblique Bridge; Steel-Concrete Composite Beams; Single beam model; Beam grid model.

1 Introduction

The steel-concrete composite beam is composed of the concrete bridge panel and the steel beam through the connection of shear nails. It is characterized by making full use of the tensile properties of the lower edge of the steel beam and the compressive properties of the upper edge of the concrete slab, so that the mechanical properties of the upper and lower edges of the material can be fully utilized[1]. Steel-concrete composite beams have the advantages of strong bearing capacity, small section size and large stiffness in terms of mechanical performance. At the same time, it can be assembled for construction, making construction convenient. Therefore, steel-concrete composite beams are increasingly being applied in engineering practice, and their application scope has developed to various bridge types.

In the design of urban bridge, it is inevitable to encounter some restrictive factors that make it difficult to adjust the position and angle of the bridge. This leads to situations where the angle of intersection between the bridge and the river channel is relatively large in actual engineering[2].

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At present, scholars at home and abroad have conducted more research on conventional steel-concrete composite bridges and conventional oblique bridge. For example, Hongwei Chen has studied the transverse distribution coefficient of load on multi beam composite beams[1]. Hongtao Mao has designed and studied diagonal small box beams[3], and Wenjiang Ma have studied the stress characteristics of oblique steel box beams. However, there is relatively little research on large-span diagonal steel-concrete composite beams[4]. Both theoretical analysis methods and numerical analysis have not formed a complete theoretical system, and there are still many shortcomings in their research. This article is based on previous research and takes the temporary bridge in the on-ramp project of Line 6-3 of Xin Zhuang Interchange of S20 Highway in Shanghai as an example and uses Midas software to establish single beam model and beam grid model respectively. By analyzing and comparing the calculation results of the two models, it is hoped to provide reference for the theoretical research and engineering design calculation of large-span oblique composite beams.

2 Project Overview

In the on-ramp project of Line 6-3 of Xin Zhuang Interchange of S20 Highway in Shanghai, the superstructure of the temporary bridge adopts composite steel beam. The composite steel beam adopts the whole prefabricated, and the structure is simply supported, and the bridge floor is continuous system. The bridge panel is 250mm thick and connected to two I-beams by welding nails to form π beams, which are prefabricated in the factory and transported to the construction site for hoisting together. Wet joints are arranged between the bridge panels, and the wet joints are poured on construction site for transverse connection.

The bridge crosses the railway at Pb5#~Pb6#, with span arrangement of 48m, bridge width of 13.84m and oblique angle of 30.7°. The superstructure is composed of four π-beams with a beam height of 2.0m in the middle span and 1.6m in the fulcrum range. π beams are connected with I-shaped transverse partitions, and the transverse partition spacing is 8m, and the vertical stiffening ribs of the web are arranged between the adjacent beams. The plan and cross section are shown in Fig 1 and Fig 2.

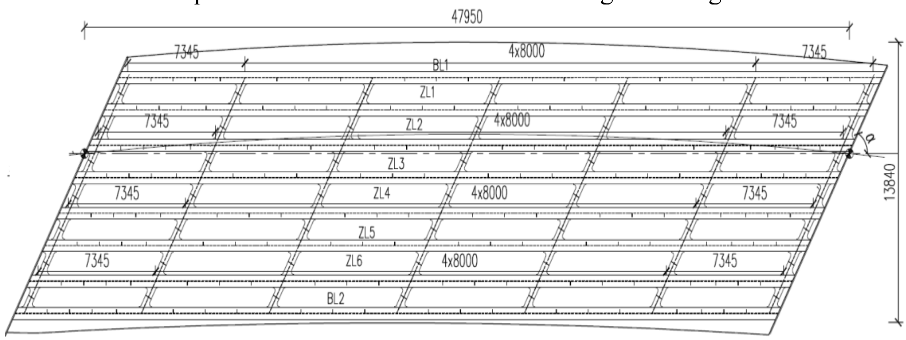

Fig. 1. Floor plan layout(Unit: mm)

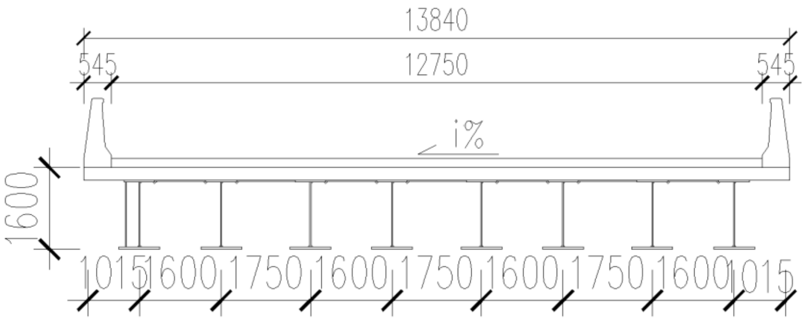

Fig. 2. Cross-sectional layout (Unit: mm)

3 Structure Calculation

3.1 Computational Modeling

Using the finite element analysis software Midas Civil, a single beam model and a beam grid model were established for structural analysis and calculation.

1. Beam Grid Mode

When using Midas Civil to establish a beam grid model, each I-beam is treated as a longitudinal beam[5], and each longitudinal beam is connected by the bridge deck beam grid, diaphragm, and crossbeam according to the actual position. Each longitudinal beam is orthogonal to the bridge deck beam grid and diagonally intersects with the crossbeam at an angle of 30.7 °. The entire bridge is divided into 899 units and 656 nodes. The specific model is shown in Fig 3.

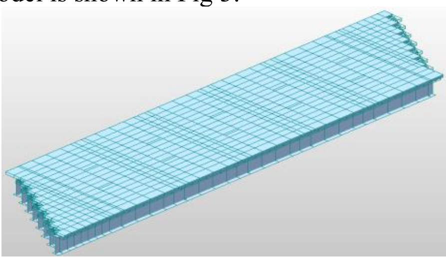

Fig. 3. Midas Civil beam grid mode

2. Single Beam Model

At present, the single beam model is widely used in the calculation and design of composite beams, which is characterized by simple modeling and can directly calculate the internal force and deformation of single beam section.

Using Midas Civil to establish a single beam model, the entire bridge is divided into 20 units and 21 nodes. The lateral distribution coefficient is calculated using the rigid beam method, and the single beam model takes the edge beam and middle beam with the highest lateral distribution coefficient for calculation. The model is shown in Fig 4.

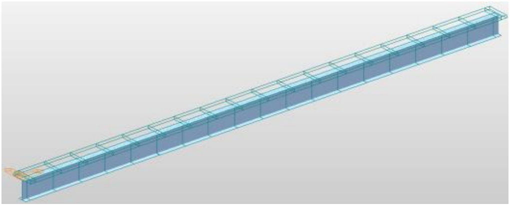

Fig. 4. Midas Civil single beam model

3.2 Calculation Comparison of Beam Grid Model and Single Beam Model Calculation

By comparing the internal force and stress of the two models under the basic combination, the deflection under the action of dead load and live load, and the support and reaction force under the standard combination to analyze the reasons for the difference.

(1) Internal force, Stress

Because the bridge oblique Angle is relatively large, the torque of each beam can not be ignored, and the internal forces are compared by the mid-span section bending moment and torque. The comparison results of internal force and stress are shown in Table 1 and Table 2.

Table 1. Internal Forces under Basic Combination (kN · m)

Project		Single beam model	Beam grid model	Difference/beam grid mode
middle beam	Bending moment	13839.7	12938.8	6.96%
	torque	0	127.9	-
side beam	bending moment	15268.5	14397.2	6.05%
	torque	0	150.3	-

Table 2. Stress under Basic Combination (Mpa)

Project		single beam model	beam grid model	Difference/beam grid mode
middle beam	Upper edge	-192.8	-167.7	14.96%
	Lower edge	194.9	180.4	8.04%
side beam	Upper edge	-185.7	-162.4	14.34%
	Lower edge	209.8	189.5	10.95%

From Table 1 and Table 2 above, it can be concluded that the bending moment and stress calculated by the single-beam model are larger than that of the beam grid model, in which the bending moment of the mid-span section is about 6% larger, the stress on the upper edge of the structure is about 15% larger, and the stress on the lower edge is about 10% larger. However, the beam grid model can reflect the torque, while the single-beam model can not reflect the torque.

Because the beam grid model is equipped with a transverse partition and a beam, each beam is acted on separately by other beams, so the bending moment of each beam is smaller than that of the single beam model, and the torque is larger than that of the single beam model[6]. In engineering design, the single beam model can be used as a simplified model to calculate the internal force and stress, but for the large Angle oblique beam, it is also necessary to use the beam grid model to calculate and check.

(2) Support reaction

The support force distribution of oblique bridge supports is not uniform, and the single beam model can not reflect the reaction of each support, while the beam lattice model can reflect the stress characteristics of oblique bridge well. Fig.5 shows the support reaction force of the beam grid model in standard combination.

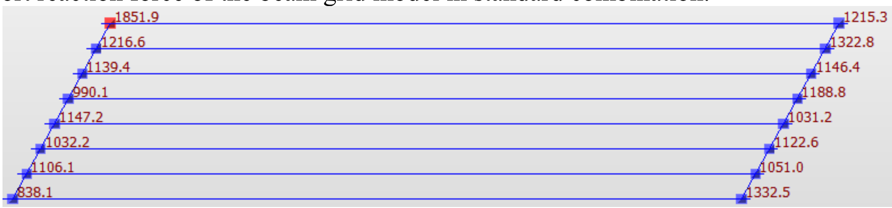

Fig. 5. Support reaction of beam grid model（kN）

It can be concluded from the above figure that due to the spatial stress characteristics of the oblique bridge, the support reaction of each beam is not evenly distributed, and the support reaction at the acute angle of the side beam is less than that at the obtuse angle[7].

(3) Displacement comparison

When designing composite beams, it is necessary to calculate the structural deformation under both dead and live loads, and set the camber according to the actual situation. The results of vertical displacement comparison are shown in Table 3.

Table 3. Vertical displacement comparison (mm)

Project		Single beam model	beam grid model
middle beam	Dead load displacement	193.1	160.3
	Live load displacement	55.3	45.7
	camber	220.8	183.2
side beam	Dead load displacement	189	158.6
	Live load displacement	65.1	53.2
	camber	221.6	185.2

From Table 3, it can be concluded that for the vertical displacement under live and dead loads, the calculation results of the beam grid model are smaller than those of the single beam model due to the consideration of the influence of lateral stiffness. Therefore, if the calculation results of the single beam model are used to set the pre camber, the value will be too large, which will cause deviations between the bridge's completed line shape and the road route shape.

4 Conclusion

This article combines specific engineering examples to establish single beam models and beam grid models for stress analysis of steel-concrete composite beams. Through comparative analysis of structural internal forces, stresses, displacements, and support reactions, the following conclusions are drawn:

(1) Both single beam model and beam grid model can be used for the design and calculation of steel-concrete composite beams.

(2) The structural modeling of the single beam model is simple and the displacement, internal force and stress are larger than the calculation results of the beam grid model, so it is safe to use the single beam model in engineering design.

(3) The single beam model can reflect the stress characteristics of large angle oblique beams, and its structural internal forces and section stress are not significantly different from the beam grid model, but the torque effect is relatively different from the beam grid model. For structures with large oblique angles, the beam grid method needs to be used for testing.

(4) The beam grid model can well reflect the spatial force characteristics of uneven distribution of support reactions in diagonal bridges, that is, the support reactions at acute angles are smaller than those at obtuse angles. Therefore, using a single beam model to calculate large-span diagonal composite beams has certain limitations, and the beam grid model should be used for calculation to avoid significant errors in the design results.

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