Differences between hollow slab Grillage model and single beam model in design and analysis

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Abstract. Hollow slab girder bridge has the advantages of factory prefabrication, fast construction speed, small girder height and low cost. It is one of the main types of small and medium span bridges in China. In this paper, a hollow slab bridge with an effective span of 10.22m is taken as the research object. The Grillage method and single girder method of MIDAS/Civil finite element software are used to model and calculate the bridge, and comparing the difference between the results of two models in design analysis. The calculated value of single beam model is larger than that of Grillage model, and more insecure. The difference of stress calculation between the two models can be up to 1.2 MPa. For safety reasons, two kinds of modeling methods can be used for analogy in design, but when the structure is more complex, the model of the Grillage model should be closer to the actual situation.

1. Introduction
The history of fabricated hollow slab girder bridges dates back to the 1950s in the United States, the initial form of TT section is gradually becoming the closed box section after decades of development and improvement, as shown in Figure 1-1[1,3]. Hollow slab girder bridge has the advantages of factory prefabrication, fast construction speed, small girder height and low cost. It is one of the main types of small and medium span bridges in China, especially in urban bridges with high clearance requirements and the proportion is larger. The Ministry of Communications of the People's Republic of China promulgated the standard drawings of hollow slab girder bridges in 1993 and 2008, which greatly promoted the development and application of hollow slab girder bridges.

2. General situation of Engineering
The bridge structure analysis software MIDAS/Civil is widely used. The commonly used methods for calculating bridge model are Grillage method and single beam method. The single beam method uses the single beam model for discrete analysis, and calculates the internal force based on the transverse distribution theory. Because of the different values of transverse distribution coefficient, the results of internal force calculation are quite different.

The core idea of Grillage method is to replace the superstructure of bridge with equivalent grillage. The flexural and torsional stiffness scattered in each section of the beam is concentrated in the adjacent equivalent Grillage. The longitudinal and transverse stiffness of the actual structure are concentrated in the longitudinal and transverse grillage.

This paper taking a hollow slab girder bridge as an example, compares and analyses the differences between the two models in design and calculation, and the advantages and disadvantages
of the two models. The length of the hollow slab girder bridge is 10.22m. Fig. 1 is its elevation layout, and Fig. 2 is its cross-section layout. The width of the bridge is 9m, and 2% of the cross slope is set up. The calculation is based on the highway-Tan load.

![Figure 1 Section form of hollow slab](image1)

![Figure 2. Bridge elevation](image2)

![Figure 3. Bridge elevation](image3)

In the structural design, the concrete is C50, the elastic model is 34500 MPa, and the bulk density is 25kN/m3. HRB400 elastic modulus is 200 000 MPa, bulk density is 76.98 kN/m³, FSK is 400 MPa, FSD is 330 MPa. Prestressed strand, elastic modulus 195000MPa, tension control stress 1395MPa, strand relaxation coefficient 0.3.

3. Single beam model calculation
When designing a single beam model, it is necessary to calculate the transverse distribution coefficient. There are five methods for calculating the transverse distribution coefficient. In order to compare with
the Grillage method comprehensively and effectively, the rigid cross beam method, which is closest to the Grillage model, is used to calculate the transverse distribution coefficient of the girder bridge.

Figure 4. Single beam model

According to the information of the bridge: the spacing of beams = 1m, the span = 10.22m, the number of beams = 8 and the number of lanes = 2, the transverse distribution coefficients of beams 1, 2, 3 and 4 are calculated to be 0.185, 0.168, 0.151 and 0.134, respectively. The side beams are selected for calculation and compared with the side beams in the Grillage model, the basic combination cLCB2:1.2 constant load+1.2 installation load+1.0 steel bundle secondary+1.0 creep secondary+1.4 moving load is selected. The calculation results of the single beam model with side beams subjected to basic combinations are shown in Fig. 5-7.

Figure 5. Deflection of single beam model side beam under basic combination action

(a) Upper edge stress of side beam

(b) Lower edge stress of side beam

Figure 6. Stress of single beam model side beam under basic combination action
4. Calculation of Grillage model
The Grillage is an approximate method for spatial calculation. The core idea of Grillage is to use equivalent longitudinal and transverse Grillage to replace the superstructure of bridge, and to concentrate the flexural and torsional stiffness scattered in each section of slab and beam in the nearest equivalent Grillage. The longitudinal stiffness of the actual structure is concentrated in the longitudinal Grillage members, while the transverse stiffness is concentrated in the transverse Grillage.

Number of nodes in Grillage: 181; Number of units: 234; Quantity of Construction Stage: 5.

Vehicle load is grade I of highway; for the longitudinal overall impact coefficient $\mu$ of vehicle load, according to Article 4.3.2 of the <General Code for Design of Highway Bridges and Culverts>, according to the code, the calculated fundamental frequency $f = 1.95 \text{Hz}$, the impact coefficient $u = 0.102$. 

Figure 7. Bending moment of side beam under moving load

Figure 8. The Grillage calculation model

Because the object of single beam model is the side beam, the side beam of the two models is selected to compare with the single beam model. The calculation results of the side beam of the Grillage model under the basic combination action are shown in Figure 9-11.
5. Conclusion

There are some differences between Grillage model and single beam model in calculation, 1) For the maximum deflection in the span of side beam, the calculated values of Grillage model and single beam model are 3.84 mm and 4.78 mm respectively; 2) For the upper Edge Stress of Mid-span Section, the calculated values of Grillage model and single beam model are 9.1 MPa and 10.3 MPa respectively; 3) For the lower Edge Stress of Mid-span Section, The calculated value of Grillage model is -7.4 MPa, and that of single beam model is -8.1 MPa.

Generally speaking, in the design calculation, the calculated value of single beam model is larger than that of Grillage model, which is more unsafe. This difference may come from the accuracy of the calculation method of the lateral distribution coefficient, or from the accuracy of the lateral connection simulation of the two models. The difference of stress calculation between the two models can be up to 1.2 MPa. For safety reasons, two kinds of modeling methods can be used for analogy in design, but when the structure is more complex, the model of the Grillage model should be closer to the actual situation.

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