Beam-Truss Model of Steel-Concrete Composite Box-Girder Bridges II: engineering application

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Abstract: This paper firstly presents the field tests of a straight and a curved composite continuous box girder bridges. Elaborate FE model and beam FE model are then built on the basis of achievements of the companion paper. According to the comparison of results among elaborate FE model, beam FE model and field test, testing coefficient of mid-span deflection is 0.5~0.8, and that of stress is 0.6~0.9 for the elaborate FE model. Also good correlation of the calculation results between elaborate FE model and beam FE model can be observed with the relative errors within the range of ±10%. This and the companion paper propose the beam-truss model of composite box-girder bridges, then accuracy and adaptability are fully verified by amounts of numerical analysis. Conclusions drawn in these papers are helpful for design analysis of steel-concrete composite box-girder bridge.

1. Introduction
Due to the insufficiency of the composite box beam bridge-truss numerical model data, it is necessary to introduce a new beam truss model for bridge design analysis. The theoretical basis of the beam-truss model is provided by the shear-flexible frame analysis model. Based on extensive numerical analysis, the calculation accuracy of the beam truss model is verified by comparison with the prediction of the accurate model. These models are ultimately considered to be accurate. Through the modeling and analysis work examples, it is found that the mechanical behavior of composite simply supported beam and continuous box girder bridge is calculated by using complex beam truss model. In addition, the alignment of both the simply supported bridge and the continuous bridge includes straight lines and curves to predict the beam truss model to increase the torsional effect due to the horizontal curvature of the curved bridge. Researchers can evaluate different horizontal curvatures by comparative analysis of straight and curved bridges. Finally, the beam truss model of the composite box girder bridge is applied to the field test analysis of composite continuous box girder bridges (including straight bridges and curved bridges) in two practical projects, in order to further verify and popularize the beam truss model.

2. Modeling Application
2.1. Description of Bridges
The engineering example in this paper is the overpass on the Jiqing Expressway in China. It is designed as a three-span straight steel-concrete composite continuous box girder bridge, as shown in Figure 1. The overpass spans 66+96+66=228m. Its bridge deck is read as 20m wide and consists of...
32cm to 40cm thick reinforced concrete with a concrete rating of C50. Its open double-box steel beam has a box spacing of 5.4m. The height of the supporting steel beam inside the steel-concrete composite beam is 5.4m, and the outer support height of the steel-concrete composite beam is 2.4m. After the parabola alignment, the height of the composite beam steel beam varies between 5.4m and 2.4m, as shown in Figure 1(a). C50 concrete with a height of 0.35m was cast into two boxes within 12m from the internal support. The thickness of the bottom flange of the steel beams in these areas is 40mm, and the thickness of the flanges in other areas is 32mm. The thickness of the steel beam web and the top flange are 24mm and 36mm, respectively. 21 transverse connecting beams are placed between the two steel box girders and 44 diaphragms are placed in each of the steel box girders. In addition, support is provided at each of the four positions of the steel box girder, and four pot-type rubber support members are respectively placed in the lateral direction at each support position, as shown in Fig. 1(b).

![Diagram of steel-concrete composite bridge](image)

**Fig. 1** Dimension of actual straight composite continuous box-girder bridge

The second engineering example of this paper is the B-bridge of the Zhuxi Minzu Road Interchange in China, designed as a four-span curved steel-concrete composite continuous box girder bridge, as shown in Figure 2. The interchange ramp bridge spans 30+45+28+28=131m. Its horizontal curve radius is 80.275m. Its bridge deck is 9.45m wide and consists of 28cm to 40cm thick reinforced concrete with a concrete rating of C50. The open steel beam of the steel-concrete composite beam consists of a single box and two chambers. The height of the supporting steel beam of the steel-concrete composite beam is 1.2m. The outer support height of the steel-concrete composite beam is 0.9m. The steel beam height of the steel-concrete composite beam varies between 1.2m and 0.9m after linear alignment, as shown in Fig. 2(a). The thickness of the top flange of the steel beam of the steel-concrete composite beam is 20mm to 30mm. In addition, the web and bottom flange thicknesses are 12mm and 30mm, respectively. As shown in Fig. 2(a), 41 diaphragms were placed in each steel box. In addition, support is provided at five locations of the steel box girder, and two basin rubber supports are placed at each support position. The horizontal rubber center of the basin rubber support is 250mm.
By offsetting the bracket outwardly by 200mm in the lateral direction, the negative reaction of the stent without the anti-lift bracket is eliminated, as shown in Fig. 2(b).

Fig. 2 Dimension of actual curved composite continuous box-girder bridge

2.2. Field Tests
In order to accurately evaluate the mechanical properties of both straight and curved continuous box girder bridges, two actual bridges were tested in the field, as shown in Figures 3 and 4. Fig. 5 illustrates the parameters of wheel load and wheel-line spacing of truck for field tests of straight and curved bridges. For field testing of two bridges, standard trucks typically weigh a total of 300kN.

Fig. 5 Parameters of wheel load and wheel-line spacing of truck
The truck is placed in three positions corresponding to the three load boxes in the longitudinal direction as shown in Fig. 6(a). In order to generate the maximum torque in the outer span, the area of the inner span and the internal supporting torque is used for field testing of two steel-concrete composite bridges. In the lateral direction, the truck is placed as close as possible to the guardrail. According to the field test of the straight bridge, the distance between the outer wheel of the truck and the edge of the guardrail is 0.5m; according to the field test of the curved bridge, the distance between the outer wheel of the truck and the edge of the guardrail is 0.6m. In addition, as shown in Fig. 6(b), in order to generate the most unfavorable force in the middle of the span of the two bridges, the bridge is divided into as many 3.1m wide lanes as possible to place the truck. Compared to the width of the lane, this truck is much more compact in the lateral direction and can produce the most unfavourable load conditions in the middle span of the two bridges.
2.3. Numerical Analysis

In order to facilitate the discussion and analysis, in the field test, the observed result was named FT. This method is very similar to the research method in the working example. It is further verified by comparison between the fine finite element model developed on the platform of the commercial FE package ANSYS12.0 (2009) and the prediction of the beam truss finite element model. The accuracy of the beam truss finite element model. At the same time, the application value of the beam truss finite element model is effectively evaluated by referring to the field test results of the bridges of the two engineering examples. In these two finite element models, the material properties are the same as those in the engineering instance. In order to simulate the full shear connection effect between the steel beam and the concrete slab interface, the nodes that normally work together represent the components of the concrete slab and the steel beam, respectively. Due to the prestressed load, the concrete does not crack under the plate. In addition, the upper part of the concrete is pressed and does not crack, so the cracking of the concrete can be ignored. In addition, since the prestressing tendons have little effect on the deck stiffness during the completion of the bridge, the prestressing tendons are not considered. In addition, the wheel load of the truck can be simplified to a concentrated load. When it is necessary to build a complex finite element model, the SHELL63 element can be used to simulate a steel beam composed of steel plates. However, concrete slabs should use SOLID45 components instead of the SHELL63 components used in the working examples. This element was chosen because it is more convenient to use a solid element instead of a shell element to simulate a board with a variable thickness. For the beam truss finite element model, the cross sections of the two actual bridges are conceptually cut in the middle between the webs, as shown in Figure 7, with a cross-member spacing of 0.5 m. Steel beams, concrete slabs and a part of the concrete poured into the box are made by using BEAM44 elements. simulation
3. Conclusions

Following conclusions can be drawn from this research in this paper:

1. By using the complex beam truss model, the prediction of the mechanical properties of the composite box girder bridge is compared. It is found that the beam truss model can accurately predict the mechanical properties of composite box girder bridges. The main research is on composite simply supported beams and continuous box girder bridges, whose alignment includes straight lines and curves. Good correlation between detailed prediction and beam truss model prediction. The modal analysis and static analysis of steel-concrete composite girder bridges under gravity loads, prestressed loads and driveway loads have a relative error of ±10%.

2. The study found that the established beam truss model is suitable for the design analysis of the actual composite box girder bridge. This paper presents field trials of two engineering example bridges, including straight and curved composite continuous box girder bridges. Detailed prediction and beam truss finite element model are applied to predict the mechanical performance of two actual bridges under load conditions in field tests. It was discovered by comparing the predictions of the two models with the results obtained in the field test. Both the deflection and the stress detection coefficient are within a reasonable range, which proves the applicability of the beam truss model in the design analysis of the actual composite box girder bridge.

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