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Construction Process Numerical Analysis Method of Assembled Steel Truss-concrete Composite Continuously Ridged Bridge

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Abstract: This paper is aimed at exploring finite element modeling (FEM) method by reasonable structure discrete and boundary constraint choose, which can be suit for analyzing assembled steel truss-concrete composite continuously ridged bridge and reflect the characteristic of this kind of bridge, and using this method to analyze a bridge, the analysis results qualitatively agree well with the characteristic of the bridge, which means this method can be used to analyze this kind of bridge and worthy of expanding.

Keywords: Assembled steel truss-concrete composite bridge; Finite element modeling; structure discrete; Boundary constraint

1. Introduction

Analyzing bridge structure firstly needs to select the appropriate numerical analysis model and the corresponding analysis program according to the analysis object and requirements, then abstract, simplify and discrete the structure with corresponding mechanical method. After that, using the corresponding data file of the discrete structure to describe and recognize the structure behavior. So, reasonable structure modeling and numerical simulation is the key to the success of bridge structure analysis.

At the same time, the analysis of bridge structure should be connected closely with its construction method, construction process. Any bridge has its special construction process. And the typical bridge construction methods includes: the full bore stents methods; span by span construction method; incremental launching method; cast-in-place cantilever method and rotation construction, etc. In the construction process, on the one hand, the load such as gravity, construction machines and tools, prestressing are applied step by step in each construction stage, and each construction stage is likely to be associated with concrete creep, shrinkage, boundary constraint change, the prestressed tensioning and system conversion, etc. Late structure stress and mechanical properties have a close contact with the construction of the early stage of the structure. On the other hands, because of the erection construction technology application and development, pre-determining position of the pieces assembled becomes the important condition which is needed by reasonable design state. Therefore, construction method appears to be the same importance with structure internal force analysis in bridge structure analysis.

This paper intends to explore the finite element modeling method of assembled steel truss-concrete composite continuously ridged bridge, and establish the numerical analysis method which can reflect characteristics of this kind of bridge.

2. Project Overview

2.1. Structure designs

A bridge as a pilot project of the large assembled steel truss-concrete composite continuously ridged bridge, its designed main span is 70m, and the span arrangement is consisted of 41m+70m+41m three spans, as shown in Fig.1.

2.2. Construction method

Compared with conventional concrete continuous rigid-frame and steel truss girders, assembled steel truss-concrete composite continuously ridged bridge has certain different construction characteristic, so traditional construction methods can not be fit for this kind of bridge. This project, combined with long-design philosophy of assembled steel truss-concrete composite continuously ridged bridge, preliminarily draws up the construction method of this bridge, and subdivide construction process into the following three steps:

- Two-times integral hoisting of steel truss in completed piers, then connecting the piers and substructure;
- To complete the closure of steel truss, then demolish the temporary pier located in the midspan;
- To install the prefabricated bridge deck by batches according to the reasonable construction process,

then complete the reliable connection through the welding between the deck and steel truss.

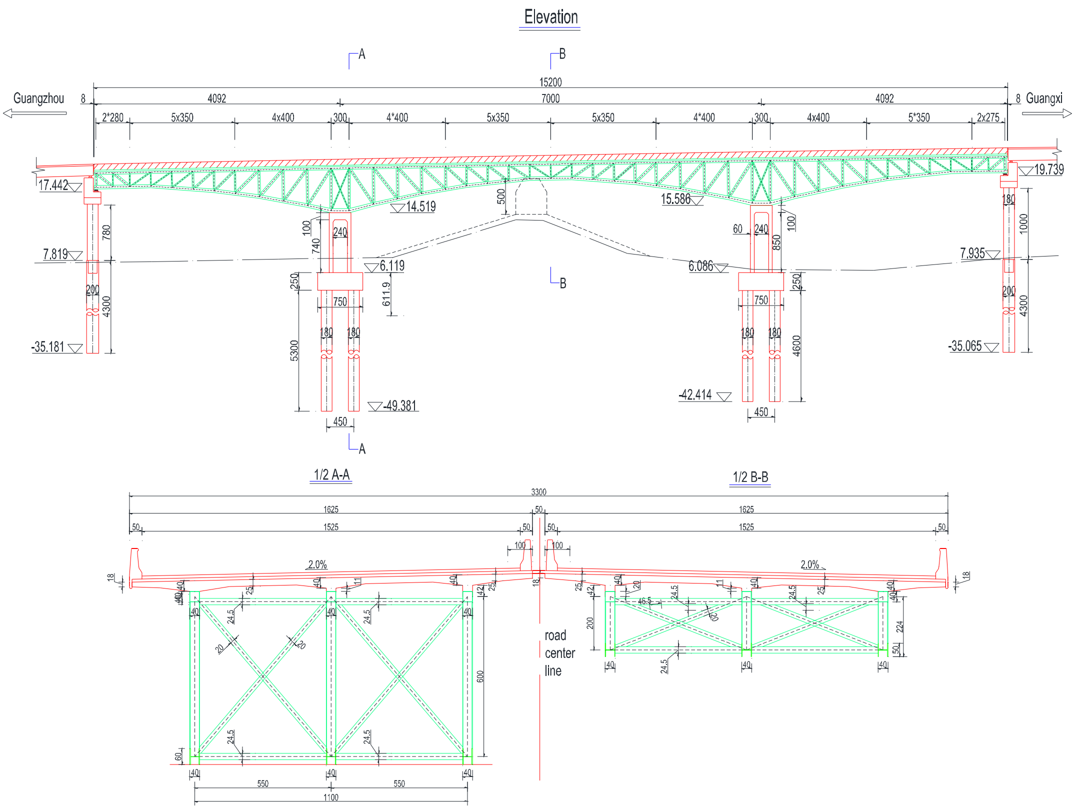

Figure 1. The overall arrangement of a bridge (cm)

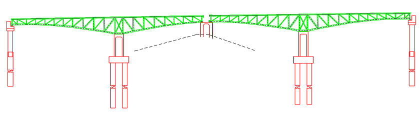

Figure 2. Integral lifting of steel truss

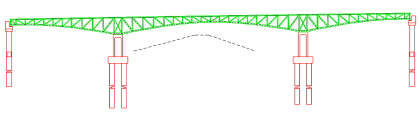

Figure 3. Closure the steel truss and demolishing the temporary pier

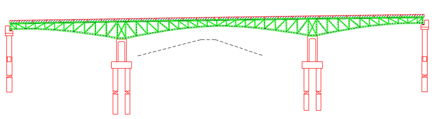

Figure 4. Installation of the bridge deck

3. Finite Element Module Method

3.1. The structure model and discrete

The process of structure modeling is a logical process. The first step of modeling is to choose the reasonable simplified model. In concept design phase, the main research of the structure is the design parameters, which is in order to obtain ideal structure arrangement, and because the structure accuracy on the internal forces is not high, the plane truss model can be used; In technology design stage, it just need to calculate the internal force of the overall structure under the influence of the constant and live load, so the plane truss model can be still chosen, and in this moment, the spatial effects of live load on load need to use the transverse distribution coefficient or partial coefficient to express.

The second step of modeling is to discrete the structure-reasonable.In finite element analysis, the reasonable structure discretization of the model is the key to the economic and reliable structure analysis. Bridge model discretization must first deal with the relationship between the structure construction and the discrete model, for truss structures, the node and cell division should follow the following principles:

(1) The anchor point of the structure should be set node;

(2) According to the construction process, the natural block points which apply to the construction by stages should be set node;

(3) For longer natural block, it should be appropriate subdivided.

(4) Cross section of prestressed cable endpoint should be set node;

(5) Part with support should be set node.

The third step of modeling is to choose the reasonable discrete model. This model chooses to use general practical grillage method, which has the clear basic concept, can be easily understood and used. This method uses equivalent grillage bridge to replace the upper structure to analyze the stress of beam, which can obtain real bridge bearing state, and this method is not only applied to the upper structure of the plate, beam-slab and box girder cross section, but also became the effective analysis of curved and skew girder bridge.

The analysis of bridge structure choose the relatively outstanding general spatial finite element analysis software Midas Civil, and in view of the whole bridge, the main beam element is chosed to simulate the whole bridge components. Model can be divided into the infrastructure, which includes piers and caps,the upper structure, including three same pieces of steel truss and relevant decks. The model is established according to the real size of the structure and the principle of establishing node and cell, and because of the large span, it chooses to set camberin across the bridge, whose value is 130 mm (mid-span deflection value under dead load + 1/2 mid-span deflection value underlive load). Finite element model are shown in figure 1.3 below. The node number is 1359, cell number is 2078.

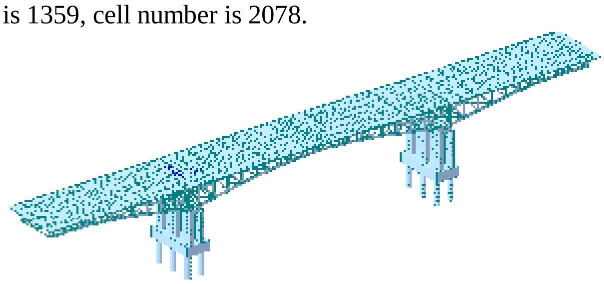

Figure 5. Qingqiyong bridge FEM

3.2. Boundary condition imitation

Another key step of successful structure analysis is to correctly describe boundary conditions system of the structure. In simulating the boundary conditions, the boundary of pier or abutment in point (or ground) must be ensured, and should be added to the model correctly. It must be based on some assumptions and construction method in engineering.

The FEM for the bridge adopts three kinds of boundary conditions:

(1) General support: used to simulate the whole structure of external constraints, which is as shown in figure 6.

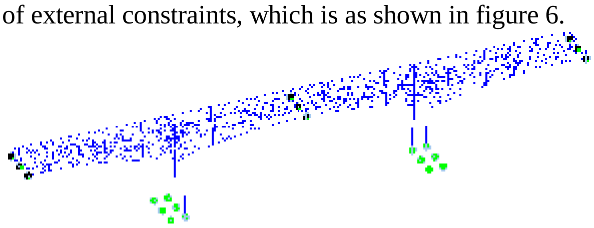

Figure 6. Structure boundary constraints

In this model, the pillar bottom adopts the constrained degrees of freedom; The beam end of three pieces of steel truss adopts Dz direction constraints, which is used to curb beam on the vertical displacement, and at the same time, Dy direction freedom of the middle steel truss needs to be restrained for restricting the movement of structure in the Y direction; Across a set of Dz direction constraints used to simulate the early stage of the construction of temporary support across.

(2) Rigid coupling: used to simulate the lower bearing platform, and through the rigid connection link bottom pile and pier with the expectant deformation, to simulate the effect of pile caps, as shown in figure 7.

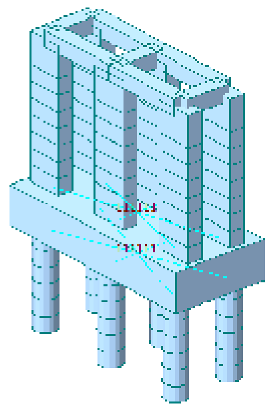

Figure 7. Pile caps rigid coupling

(3) Elastic connection: elastic connection can be subdivided into three types of connections, respectively is general connection, only compression connection and rigid connection.

General connection is used to simulate prefabricated decks temporary assembly process, through giving SDx, SDy and SDz three degrees of freedom stiffness value to complete temporary connection between decks and upper chord; Only compression connection is used to simulated the pier-beam temporary connection in front of pier-beam consolidation; Rigid connection is used to simulate the welding work after the tension of the prestressed, through which the decks and steel truss can participate in the structure as a whole. As shown in figure 8.

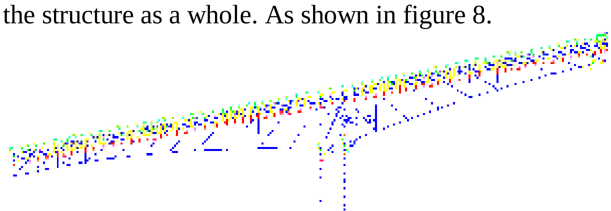

Figure 8. Elastic connection lay-out

3. Simulation Analyses of the Construction Process

3.1. Construction process simulation

This bridge is a steel girder - concrete composite structure, whose construction method chooses the different way according respectively to steel truss and prefabricated decks. For the installation of the steel truss, steel truss, as a whole, can be divided into two fabrication, following complete the installation of the steel truss by integral lifting; For prefabricated decks, because of its fabrication in factory, it chooses the construction way from the pier top to cross mid-span and symmetric piecewise constructing. In FEM, the construction process simulation is indispensability, and this process can come true through the real-timely activating and passivating relevant structure sets, boundary sets and load sets.

Structure sets:

Steel truss part is divided into left and right two structure sets and closure section of steel truss, such as steel truss 1, steel truss 2 and closure section of steel truss. Steel truss 1and 2 are set for integral lifting; and closure section of steel truss is set for folding aforementioned two steel trusses according to the construction error.

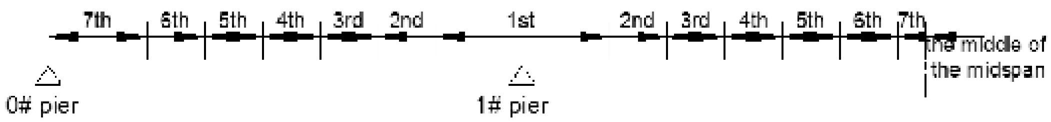

Figure 9. Arrangement lay-out of deck sets

Table 1. The main construction stage simulation

NO.	Construction Process	Sets	Activation	Passivation	Simulation Process	Description
1	pier	S-S	pier	X	the stress of the infrastructure	
		B-S	pile elastic support	X		
		L-S	dead load	X		
2	steel truss	S-S	steel truss 1 steel truss 2	X	stress of the steel truss	temporary connection activated in this stage for making decks assembled according to the steel truss,which has deformation under the dead load
		B-S	side-span support1 side-span support 2	X		
			pier-beam temporary connection	X		
			temporary connection 1~7	X		
			temporary pier	X		
			closure section temporary connection	X		
		L-S	X	X		
3	temporary pier dismantlement	S-S	X	X	removing the temporary pier	
		B-S	X	X		
		L-S	X	temporary pier		
4	decks assembly	S-S	decks	X	decks assembly	
		B-S	X	X		
		L-S	X	X		
5	tension prestress	S-S	X	X	tension relevant prestress	deck1~deck7 do the same process
		B-S	X	X		
		L-S	prstress	X		
6	deck-steel truss rigid connetion	S-S	X	X	welding the relevant deck and steel truss	
		B-S	X	X		
		L-S	rigid connection	temporary connection		
7	pier-beam consolidation	S-S	X	X	opretion stage of a bridge	
		B-S	pier-beam consolidation	pier-beam temporary connection		
		L-S	X	X		

Note:
1) S-S is the abbreviation of structure sets; B-S is the abbreviation of boundary sets; L-S is the abbreviation of load sets;
2) X:representneed not to add anything.

Boundary sets:

For the integral boundary constraints of bridge structure, it includesside-span support 1, side-span support 2, pile elastic support and temporary pier;

For pier-beam connection constraints, according to the construction process, it usually defines two boundary sets respectively, namely ofpier-beam temporary connection and pier-beam consolidation;

For the connection constraintsbetween steel truss and decks, according to the deck sets shown in Fig.9, it respectively defines temporary connection 1~ temporary connection 7, rigid connection 1~ rigid connection 7, closure sectiontemporary connection and rigid connection.

Table 1 for construction process simulation in FEM is shown below.

3.2. The shape change of structure in construction stage

Fig.10 shows the shape change of structure in some key construction procedure, Steel girder and concrete decks assembled one by one batch show a good shape and deformation coordination of structure. It is similar to the actual construction process.

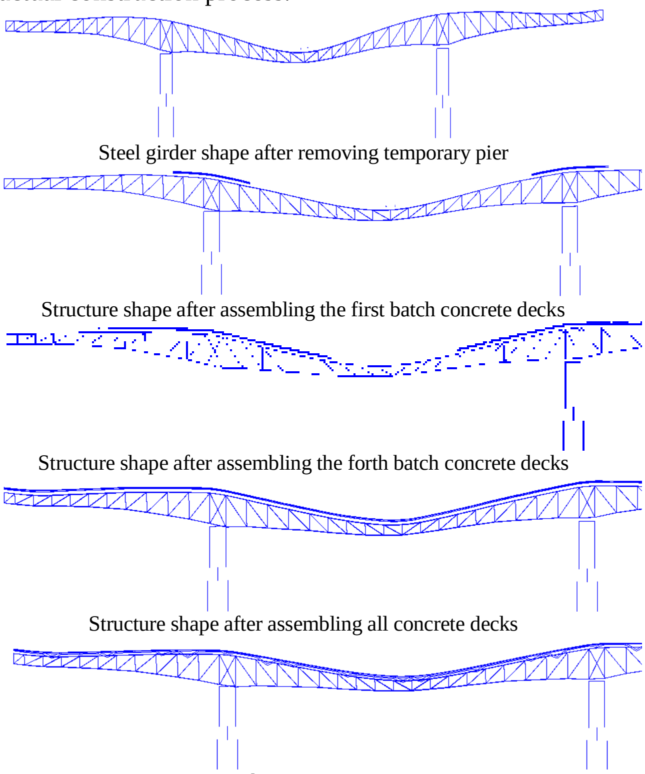

Figure 10. The linear change of structure in construction stage

Fig.11 draws out the deflection change of the mid-span node with construction progress, and looking from the trend of the curve, the deflection value increases smoothlyby construction progress, with the maximum value appearing in the pier-beam consolidation stage, namely operation stage, and the value is -87 mm, compared with 70m-span, it shows the better deformation performance.

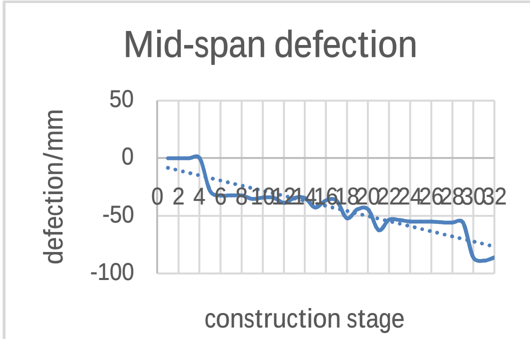

Figure 11. Deflection of middle span in the construction stage

3.3. The stress change of structure in construction stage

Fig.12 is the stress of upper chord in operation stage. From the figure we can find out that, the stress distributes evenly along the span length except the top of pier, at the same time, it is always the pressure stress under the dead load in construction stage. Because of the prestress tensioning in construction stage and decks welding with upper chord, the stress of upper chord which is affected greatly by the prestress presents the pressure stress, especially in the top of pier, the pressure stress reaches the highlight for the prestress focus.

Figure 12. The upper chord stress in construction stage

Fig.13 draws out the stress of decks in operation stage, and the stress presents the waveform moves, with the peak of wave in the top of pier, and symmetrically decreasing smoothly across both half-spans. As previously mentioned, in the top of pier, the stress reaches the highlight, and the stress decreases gradually because of the prestress density decreasing along the both sides of the pier. The results qualitatively agrees with the theoretical result.

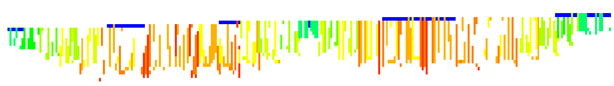

Figure 13. The concrete deck stress in construction stage

The stress of bottom chord is presented in Fig.14, from which we can see the even pressure stress in the top of pier and tensile stress in the mid-span. For steel truss-concrete composite bridge, cross section in top of pier bears hogging moment, so the bottom chord, which locals in the lower edgeof cross section neutral line, will produce pressure stress, and at the same time, the bottom chord in the mid-span as the same as the top of pier presents the tensile pressure under the sagging moment, which has been drawn out by blue line in this figure.

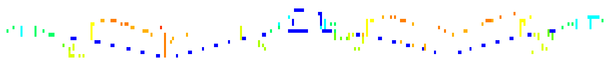

Figure 14. The bottom chord stress in construction stage

4. Conclusion

This paper is aimed at exploring finite element modeling method which can be suit for analyzingassembled steel truss-concrete composite continuously ridged bridge and reflect the characteristic of this kind of bridge.Through the finite element analysis of construction process, getting the following conclusion:

1)In the construction process analysis,steel truss and the subsequent assembly decks all show a good linear and deformation coordination, which are similar to thedeformation in the actual construction process;

2)deflection value of steel truss in mid-span increases smoothly by construction progress, and the maximum value is only -87 mm, which is small relative to thebig span, and that means the structure shows better deformation performance;

3) In operation stage, the stress of upper chord distributes evenly along the span length, and in the construction stage, it is always the pressure stress under dead load of structure and prestress focus.

4) In operation stage, the stress of decks presents the waveform moves, with the peak of wave in the top of pier, and symmetrically decreasing smoothly across both half-spans, at the same time, the stress in the top of pier is also affected aloud by the prestress focus.

5) In operation stage, the stress of bottom chord presents evenly pressure stress in the top of pier and tensile stress in the mid-span, which qualitatively agrees with the characteristic of continuous rigid frame bridge.

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