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CONSTRUCTION PROCEDURE OPTIMIZATION ANALYSIS OF ASSEMBLED STEEL TRUSS-CONCRETE COMPOSITE CONTINUOUSLY RIDGED BRIDGE

Wang Ming, Wen Dong
Chongqing Jiaotong University
Chongqing, China
2005-070104@163.com, wendong262@vip.qq.cpm

***Abstract*—A bridge is one kind of assembled steel truss-concrete composite continuously ridged bridge [1], and the prefabricated bridge deck is connected with steel truss through the reliable welding between the steel truss and the shear connector, which has been pre-buried in the bridge deck. For finding the bridge construction process to install the prefabricated bridge deck, which can make the steel truss and the deck in uniform and reasonable stress, initially putting forward three connection ways: one-time connection; three batches connection; the whole batches connection. Using Midas Civil to create a whole bridge finite element model of space, and analyze these three kinds of coupling methods, obtaining that different connection ways have significant influence on mechanical property of the bridge. The results of the study show that, the bridge deck connected with the steel truss in whole batch connection way can make combination structure in most reasonable stress, more uniform deformation, and can effectively improve the bridge structure stiffness, besides, this connection way will be beneficial to later welding work. In this paper, the calculation results have been used in Guangdong Qing Qi Yong bridge design, at the same time, the calculation results can provide reference for similar bridge design and construction.**

***Keywords*—Assembled steel truss-concrete composite, construction procedure optimization, precast deck.**

Steel truss-concrete composite continuously ridged bridge is a kind of extension in combination truss beam bridge foundation, which can be a reasonable application of the two kinds of materials, concrete and steel, and can give full play to the performance of them. Especially the completely prefabricated concept used in the concrete bridge deck, can weaken the adverse effect to the long term reliability of bridge structures which caused by the uncertainty of the concrete shrinkage and creep, and it also can shorten the construction period, which conforms to the overall trend of the world bridge construction development. For the indeterminate statically bridge, the construction method and the process often determine the internal force of a bridge, and bridge specification in our country is carried out according to the internal force of the bridge, so the analysis in construction phase is important. According to the construction characteristics of steel truss-concrete composite continuously ridged bridge, this paper conducts optimized analysis about the bridge deck installation, attempting to get the process which can make steel truss and bridge deck have the uniform, reasonable stress and deformation.

I. PROJECT OVERVIEW

A. Structure design

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.

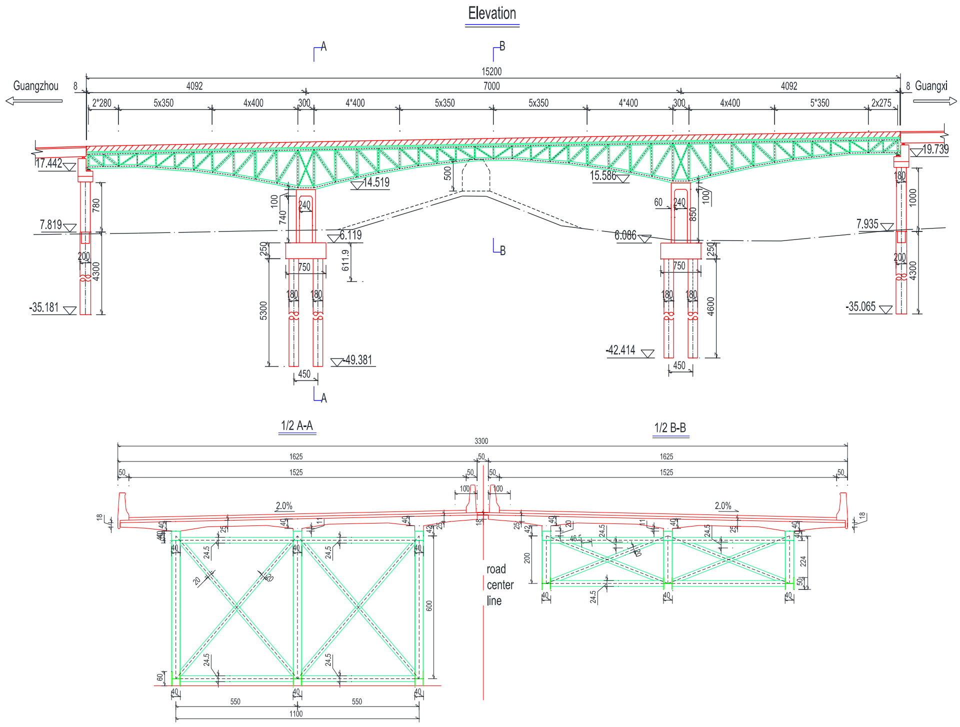

Fig.1 The overall arrangement of a bridge（cm）

The main bridge is composed of an upper, lower parallel two bridge, each bridge using one-way two-lane layout, with single deck width 16.25m; each bridge steel truss is composed of three pieces of parallel variable cross-section steel truss structure, which are contacted cross slope using upper, lower flat link and bracing; bridge deck crosses slope by 2%, and the bridge horizontal curve is 4500m, the bridge vertical curve 25000m; Bridge deck adopts the precast segmental segmental method, connected well with the steel truss through welding between the steel truss and the shear connector, which has been pre-buried in the bridge deck. Fig. 2 is a prefabricated bridge deck tectonic map, each bridge deck, as shown in this map, embedded with shear connectors in the full length deck ribs, which used for connecting with the steel truss upper chord.

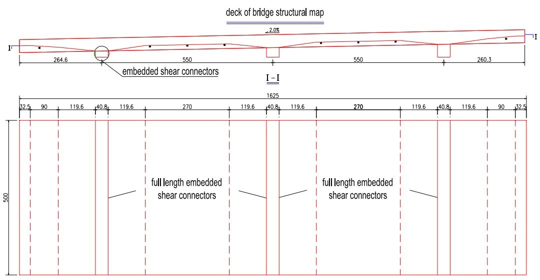

Fig.2 deck of bridge structural map（mm）

Figure.3 is a map of the distribution of Bridge deck along the longitudinal direction, and the deck is 16.25m width, with usual 5m length except individual deck, which adopt 3.5m length in the side span end, such as 1st deck, and two pieces of Bridge deck 3.3m length in the middle span of this Bridge, such as No.15, No. 16 deck. At the same time, pouring cast-in-situ section concrete reserved for 1.8m length in the middle place for closure of bridge deck.

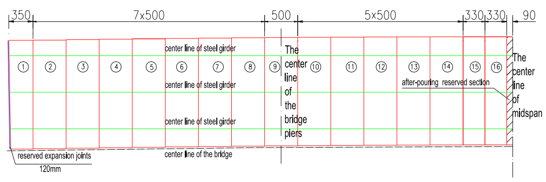

Fig.3 The bridge deck distribution（cm）

B. Construction Method

Based on the structure features of this bridge and according to the construction method, subdivide construction process into the following three steps:

1) Two-times integral hoisting of steel truss in completed piers, then connecting the piers and substructure;

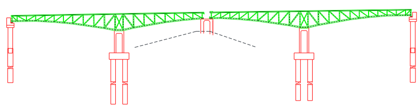

Fig.4 Integral lifting of steel truss

2) To complete the closure of steel truss, then demolish the temporary pier located in the midspan;

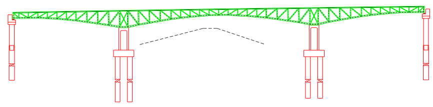

Fig.5 Closure the steel truss and demolishing the temporary pier

3) 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.

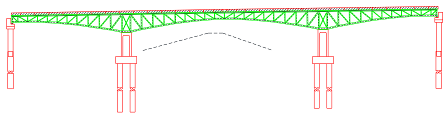

Fig.6 Installation of the bridge deck

In order to meet the requirement of construction process, the bridge consists of seven batches of the bridge deck and seven batches of prestressed. At the same time, in order to make the bridge deck to obtain sufficient compressive prestress, and to prevent the prestress to be excessive consumed by steel truss, selecting bridge deck connected with the steel truss rigidly after tensioned prestressed reinforcement. Process is as follows: first installing the bridge decks, then tensioning prestressed reinforcement; after finishing the 7th prefabricated deck installation, pouring cast-in-situ section concrete reserved in the middle section for closure of bridge deck. The bridge deck prestress layout is shown in Fig.7.

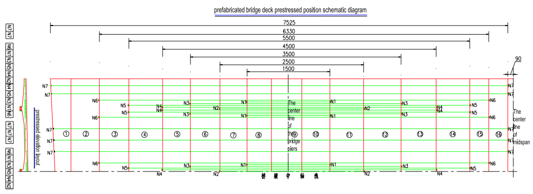

Fig.7 Deck and prestress layout

II. CONSTRUCTION PROCEDURE

According to the third step in above-mentioned construction process, initially putting forward three connection ways: one-time connection after tensioning all the deck prestress; three batches connection; the whole batches connection.

A. One-time connection

After completing the closure of steel truss and demolishing the temporary pier, installing the prefabricated bridge deck to a predetermined position, then tensioning the prestress. The next step is to finish the connection through welding between the steel truss and the shear connector, which has been pre-buried in the bridge deck, then pouring cast-in-situ section concrete reserved in the middle place for closure of bridge deck. So far, complete the installation work of bridge deck, as shown in Fig.8 a);

B. Three batches connection

The difference between three batches connection with one-time connection is the welding time. For one-time connection, it chooses beginning the welding after completing the deck assembly and prestress tensioning, while three batches connection chooses assembling the deck by the batches order in Fig.8 b), then completing the current batch welding work;

C. The whole batches connection

Whole batches connection is actually to complete the current batch of welding work after per symmetrical decks assembly and the relevant prestress tensioning, as shown in Fig.8 c);

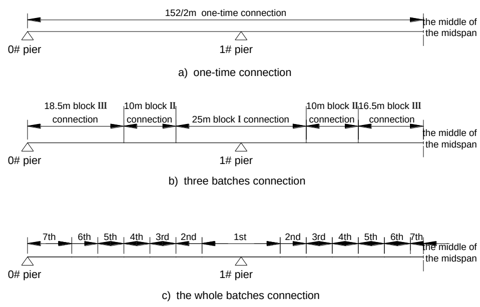

Fig.8 construction procedure

III. ANALYSIS OF THE EFFECT OF CONSTRUCTION PROCEDURE ON MECHANICAL BEHAVIOR OF COMPOSITE BRIDGE

A. Establishment of finite element model

The finite element analysis of real bridge is carried out by the Midas Civil, a finite element analysis software dedicated to bridge. Steel trusses and concrete decks are simulated by beam element. For simulating the decks installation process according to the different construction procedure, We define different structural sets and boundary condition sets, then activate and passivate relevant sets in time. On concrete decks assembling stage, all of deck elements and steel truss top chord elements connect with a kind of temporary and compression elastic connections, which allow decks to move freely on other directions. After the prestressing is completed, then we replace these temporary and compression elastic connections with rigid connections, in order to simulate the welding process of concrete decks and steel truss top chords.Fig.9 shows the finite element model.

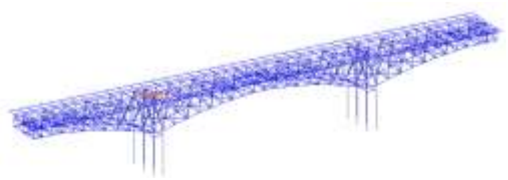

Fig. 9 FEM Qingqiyong bridge

B. The stress influence on composite bridge

The following figures show the most unfavorable truss stress. In these figures, 0m position indicates the middle of mid-span, -35m position indicates the 1# pier, and 35m position indicates the 2# pier.

Figure.10 is used for comparing the top chords stress among three different kinds of connection ways. The stress influence on composite bridge is significant due to different kinds of connection ways. On the top of 2# pier, the maximum value of top chords stress with the one-time connection is 181MPa, while the maximum value with the three batches connection is -33.4MPa, and the maximum value with the whole batches connection is -54.7MPa.Due to concrete decks and top chords do not get together to sustain the forces before they connect by one-time connection, the top chords make large tensile stress, but other connection ways make compression stress. Fig.12 shows peak stress of concrete decks on the top of bridge piers, early prestress which applied to concrete decks in batches do not reserve enough compression stress in top chords, as a result, concrete deck weight and live loads easily make the top chords cause a big tensile stress, which exceeds the material allowable stress, then lead truss to the truss buckling failure and reduce construction safety. While the concrete decks and steel truss top chords can get together to sustain the forces with other two connection ways, therefore stress of top chords show good uniformity along the bridge span, as shown as the red line and blue line in Fig10.

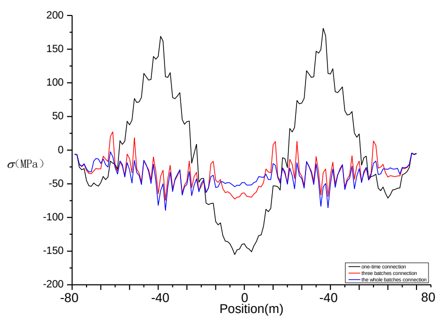

Fig.10 top chord stress

The top chords stress change of three batches connection and the whole batches connection almost are the same tendency by compared, in addition to stress variance in individual positions become more obvious. Fig.11 shows the stress amplitude difference of these two connection ways, as shown in this figure, the arrows which means stress peak point are mostly located to concrete decks batch boundaries with the maximum value 37.11MPa, which means top chords stress with the three batches connection are easy to change suddenly at decks batch boundaries. In contrast, top chords stress with the whole batches connection changes more evenly. The reason is that, with three batches connection, structure will produce the stiffness mutation at concrete decks batch boundaries, which leads to stress mutation.

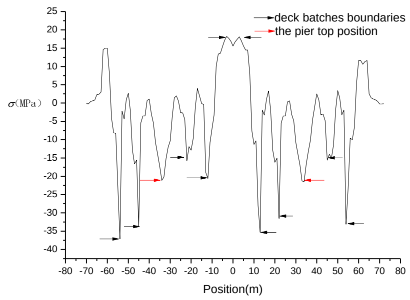

Fig.11 stress amplitude difference of top chord

Figure.12 shows the concrete decks stress curve with different connection ways, from which we can see that stress on the top of pier raise heavily with one-time connection, and stress tendency is nearly the same in other position with these three connection ways. The stress variation range is about -7MPa~-2MPa. Because of prestress do not assign along bridge span, and then there is no prestress in the relevant position, compression stress of concrete decks in the middle of mid-span decreases sharply. Due to concrete decks and composite girder don't get together to sustain the forces before they connect with each other by one-time connection, the stress on the top of pier raises heavily.

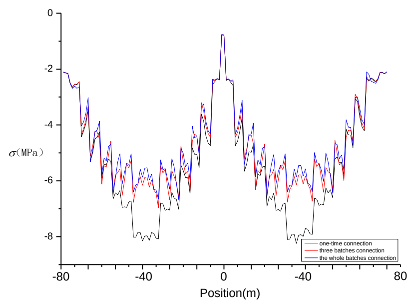

Fig.12 stress of concrete decks

Figure.13 shows that stress of steel truss bottom chords with different connection ways, the stress of bottom chords with one-time connection is commonly greater than that with other connection ways. Stress in the middle span changes more obvious, with the maximum stress amplitude difference 61.6MPa, and the tensile stress of bottom chords in the middle span 142MPa, which may cause stress reserve deficiency in these positions. Compared with the one-time connection, stress tendency of bottom chords is nearly the same with other two connection ways.

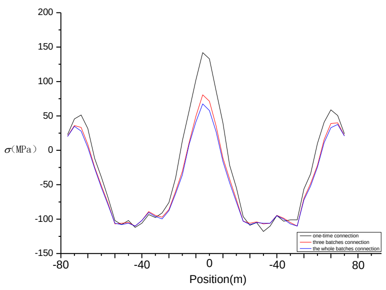

Fig.13 stress of bottom chords

C. *The deflection deformation influence on composite bridge*

Figure.14 shows that deflection deformation of the most unfavorable truss with different connection ways, and the deflection deformation of bottom chords in the middle of mid-span with one-time connection is much greater than that with other connection ways, with rates of rise are 73.4% and 89.2% respectively, and deflection deformation in the middle span reaches 168.2mm, which has exceeded the limit deflection deformation value of the composite bridge standard. Due to concrete decks and steel truss don't get together to sustain the forces before they connect each other by one-time connection, structure stiffness is less than other connection ways in early stage, therefore structure has large deflection deformation under the dead weight effect of concrete decks and steel truss. Unlike the one-time connection, concrete decks and steel truss partly get together to sustain the forces with the three batches connection and the whole batches connection, so deflection deformation decreases largely in bridge finished stage.

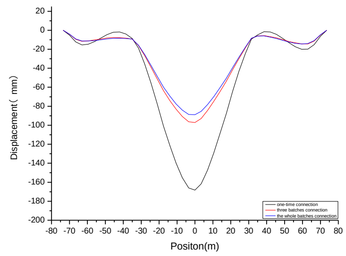

Fig.14 deflection deformation of bottom chords

We can also find that the deflection deformation of bottom chords in the middle span with the three batches connection is slightly greater than constructing with the whole batches connection, although distribution of these deflection deformation with these two connection ways are similar. That is because bridge span is small, which lead to the small difference between the batches partition of these two connection ways. In a conclusion, the finished bridge stiffness is proportional to the number of batches partition. In order to make composite bridge have better deformability, we recommend to use the whole batches connection.

IV. CONCLUSION

Steel truss-concrete composite continuously ridged bridge can give full play to the advantages of two kinds of steel and concrete materials, and the main steel girder segment and prefabricated bridge deck are produced by the factory, which can weaken the influence caused by the shrinkage and creep of concrete, thereby make the structural behavior more clear, avoid the disease caused by crack and down warping deformation due to factors, such as creep and shrinkage of concrete in long-term affecting conventional prestressed concrete composite bridge. The above mentioned advantage makes the prefabricated steel girder - concrete composite bridge has greatly promoted. In order to obtain a uniform connection procedure which can make composite stress and deformation more even and reasonable, this paper based on the Guangdong Qingqiyong extra-large bridge, analyzes effect on mechanical behavior of composite bridges with these three connection way, and come to the following conclusions:

1) Bridge decks obtain the maximum compressive stress through connecting with the steel truss by one-time connection after tensioning prestress, but because the bridge decks in the early do not participate in the combined force structure, all the loads are borne by the steel truss. Only in the bridge stage, the pier top position of steel truss chords tensile stress reaches 181MPa, at the

same time, the tensile stress of bottom chord in the middle of mid-span also reaches 142MPa, which will produce surplus value is insufficient stress in the late operation stage under live load action, and this is not recommended to use; in addition, using one-time connection, the clearance between top chords and decks will accumulate to expand with the decks assembling and prestress tensioning, which may lead to inconvenience of the welding work.

2) The bottom chord stress under three batches connection and the whole batches connection have unconspicuous difference except the deck batches boundaries, at the same time, the deck stress and bottom chord stress converge very well in the relevant position with these two connection ways; for the top chord stress outstanding phenomenon at the deck batches boundaries under three batches connection, the reason is the stiffness mutation at the relevant position ,which due to the construction process.

3) The deflection deformation of bottom chords in the middle of mid-span with one-time connection is much greater than that with other connection ways, with rates of rise are 73.4% and 89.2% respectively; at the same time influenced by the bridge span, the difference between the batches partition of these two connection ways are not significant ,which results in bottom chord deflection is almost the same, but the deflection deflection with three batches connection is bigger on the whole than the whole batches connection. We may safely draw that, for large span assembled composite bridge, bridge deck batches partition has great effect on the stiffness of composite structure, and the stiffness is proportional to the number of deck batches.

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