Improved Incremental Launching Method for Steel Box Girder

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***Abstract*—During the traditional incremental launching method for steel box girder, high-performance launching equipment, more accuracy and stronger temporary piers are needed because of the exaggerated gravity caused by upper plate, which leads to the cost increasing. It can even cause damages at the support points due to the enormous gravity for the thin wall steel box girder. In order to prevent above failure, an improved incremental launching method is proposed for steel box girder. Five pushing cases, stresses distribution, buckling at the mid-span and so on are analyzed by software ABAQUS. The result shows that this improvement method can meet the requirement of incremental launching construction; the deformation and stress in the pushing process meet the requirement.**

Keywords- incremental launching method; steel box girder without upper plate; ABAQUS; post buckling

I. INTRODUCTION

In recent years, rapid development of the economy put forward new requirements for smooth traffic. In order to meet this demand, the design and construction of bridges are constantly developing; New calculation method, new materials and new structures are constantly emerging; facing the design and construction of modern, designers and builders are more concerned about the construction cost, the efficiency and the safety of construction design, which is the purpose of modern bridge construction. Incremental launching method is an economic and safe construction method. Its advantages are as follows[1]-[3]: (1) its equipment can be used repeatedly, so it can save the construction investment and reduce the construction cost; (2) segmental box girder is produced in prefabrication field or in factory production and assembled in the spot field, thus the quality of the product can be greatly improved; (3) compared with other methods, incremental launching method is safer because its less aerial work; (4) Incremental launching method can not block the traffic below the construction site, and it can reduce the environmental effect on the construction site. Based on the above reasons, incremental lunching method occupies an important position in modern bridge construction.

In the traditional girder construction, box usually builds incremental launching together with upper plate. In the process of pushing, great dead weight of upper plate brings about a negative impact on the construction.

① Great dead weight of full bridge requires that incremental launching equipment has higher ability, which will not only increase the construction cost, but also require the pushing process's higher accuracy.

② Incremental launching of the bridge with huge dead weight also increases security risks, and it requires that temporary piers have higher bearing capacity, and bending rigidity, thus the investment is increased and the construction period is extended.

③ Because the foundation treatment of temporary pier can't be compared with permanent pier, there will increase the possibility of uneven settlement, it is likely to worsen the beam body's load bearing behavior, and even damaged the beam body by the action of the beam body with great dead weight.

④ The beam body with great dead weight is also facing difficulties in falling girder.

This paper proposes a new incremental launching method for box girder. In order to reduce the structure dead weight in pushing construction, there doesn't contain upper plate in the process of pushing construction, and construct upper plate after the push is completed.

In order to study the walking jacking construction technology, Houdingxiang No. 1 Bridge on Shenyang is analyzed, shown as Fig .1. The bridge length is 137m, it is composed of three spans (38m+61m+38m), guide girder length is 25m, and the material used is Q345 steel. There will construct the model without upper plate, analyze the girder's mechanical performances such as stress distribution, deflection and so on to test this method. In view of possible failure by bending moment, mixed elements will be used for special analysis.

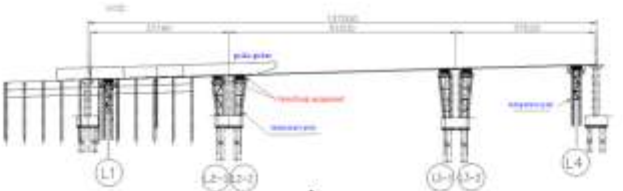

Figure 1. No.1 bridge

II. STRESS ANALYSIS OF PUSHING PROCESS

In the FEM analysis by ABAQUS[4]-[7], beam segment and guide girder modeling use the plane element S4R, shown as Fig .2. A cushion padding block is arranged in the lower part of the beam body, its length is 2.15 m, width is 0.5 m, and it uses rigid constraints. The padding block will move after horizontal displacement is applied on the reference point in simulating process. Contact element is adopted between the padding block and beam bottom.

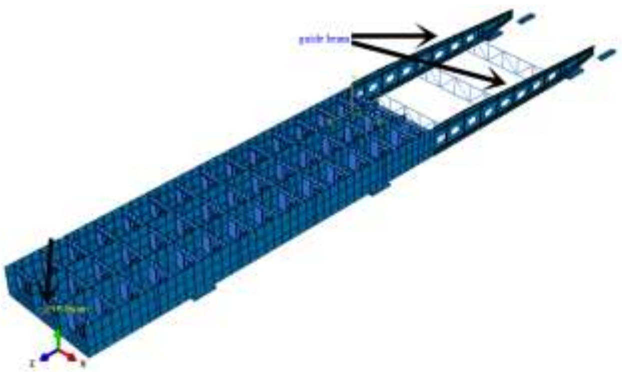

Figure 2. FEA model

A. Case study

In the case study, five cases were analyzed, shown as Fig .3.

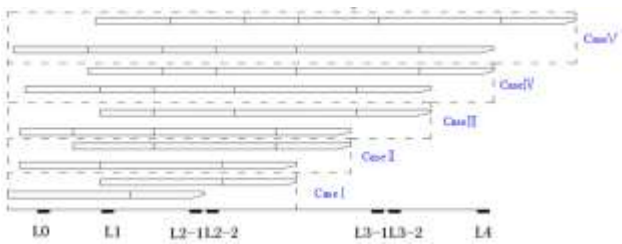

Figure 3. Five cases

The first pushing case: In this stage, the former 5 box bodies was assembled and welded in the assembly area, beam body length was 41 m (7 m+9*3 m+7 m). In this case, the beam body would move forward 31m. When the beam body was pushed to 13.89 m, the maximum Von-mises stress attained, and its value was 173.1 MPa, as shown in Fig .4. This stress was in the range of material bearing capacity, structure didn't failure. In this period, the maximum support force (the support force refers to the sum of two pieces of bearing pads' forces on the same support point) occurred on the block L1, and its value was 2006 kN. The displacement of guide beam's front end was shown in Fig .5. In the pushing early stage, guide girder didn't sling at the block L2-1 and it was in the state of cantilever state, so there would be a descent stage. Then, the guide beam slung the block L2-1, vertical displacement at the front of the guide beam began to rise under the action of incremental launching force, and the pushing continued. The deflection of central beam body made front end of the guide beam tilt, so vertical displacement of front end of the guide appeared positive value. After the block L2-2, the front end of the guide beam was in the state of cantilever state again, so that final pushing stage of this case was downward again. In this stage, the maximum vertical displacement was 0.048 m, the beam body and the guide beam were still in elastic state, and so the guide beam deflection was still recoverable elastic deformation.

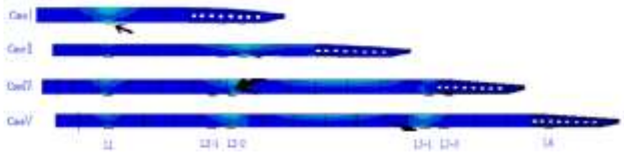

Figure 4. Distribution of stress

Figure 5. Displacement at the end of guide beam

The second pushing case: in this pushing case, the beam body would increase 3 segments; total length of the beam body was 68 m. in the pushing process, the beam body was pushed forward 18 m, the cantilever section constantly increasing, When the beam body was pushed to 14.85 m, the maximum Von-mises stress appeared on the block L2-2, the maximum support force appeared on the block L2-2 when the pushing completed in this stage, and its value was 2727 kN. The maximum Von-mises stress did not appear when the maximum support force attained. The reason was that there was a piece of transverse diaphragm near the support of the box girder, and it strengthened resistance ability of this section. In this construction process, continuous increase of the cantilever section of the beam caused vertical displacement of front end of the guide beam constantly increased. It was shown in Figure 10; vertical displacement of left guide beam was even up to -0.2 m. The calculation stress results showed that the structure still was in elastic state, and deflection occurred still was elastic deformation, so the structure is in safe state.

The third pushing case: in this pushing case, the beam body would attain 10 segments, and total length of the beam body was 86 m, pushing distance was 27 m. In this case, pushing construction would reach large cantilever state until the guide beam reached the support cushion block L3-1, and this cantilever state was the least favorable state. There were the largest support reaction force and the maximum Von-mises stress. the structure appeared the biggest cantilever when the beam body was pushed to 10.54 m, at this moment, the guide beam would sling the support L3-1, and the support reaction force of the cushion block L2-2 attained 3563 kN, as shown in Fig .6. Its Von-mises stress reached 443 MPa, far beyond the material's allowable stress, and the structure would produce unrecoverable plastic deformation. Further analysis found that the support force of the block L2-1 adjacent to block L2-2 was always 0.0 kN. The reason is that the cantilever segment caused the beam body arch camber and the connection failure between the support block L2-1 and the beam body, thus a lot of gravity was bore by the cushion block L2-2. The model showed that the distance between the cushion block L2-1 and the beam bottom reached 22 mm. in order to prevent above situation, the support cushion block L2-1 could be increased, the support L2-1 was blocked up, the block L2-2 could share the force of the block L2-1.

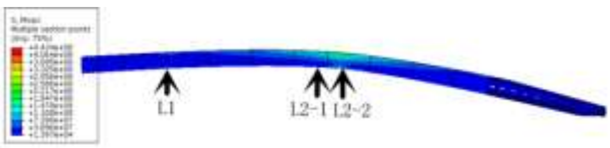

Figure 6. Distribution of stress in case III

In view of the above situation, the situation blocked up the support L2-1 was analyzed. When the support L2-1 was blocked up 30 mm by using the displacement load, the support reaction force of the block L2-2 effectively decreased, its maximum stress also effectively reduced, and reduced below the material's allowable stress. Based on the calculated results, the stress of the block L2-1 was almost same as that of L2-1 when the support L2-1 was blocked up 23 mm, and it was only 240 Mpa, the material was still in elastic state, so high stress could be prevented by blocking up the support block L2-1.

After the least favorable situation, guide beam has been slung on the block L3-1, the stress of beam body was still not high even if the block L2-1 was not elevated, and it could meet the requirements, the deflection of the guide beam was recoverable elastic deformation.

The fourth pushing case: in this pushing case, the beam body would attain 13 segments, and total length of the beam body was 111 m, pushing distance was 21 m. When the beam body was pushed to 9.01 m, the maximum Von-mises stress appeared on the block L2-2, its value was 239 MPa, at the same time, the maximum support force appeared on the block L2-2 and its value was 2491kN. In the whole case, the beam body's stress met the requirements.

The guide beam was always in cantilever state. Vertical displacement of the front end of the guide beam continuously increased along with the pushing construction. When the pushing stage completed, guide beam reached the cushion block L3-1, but it did not contact with the cushion block because the front section was arc-shaped. The maximum vertical displacement of the guide beam was -0.031 m., as shown in Fig .7. The deflection of central span made the front end of the guide beam to tilt, so vertical displacement of the guide girder was positive value. It became negative value again when the length of cantilever of the guide reached a certain value.

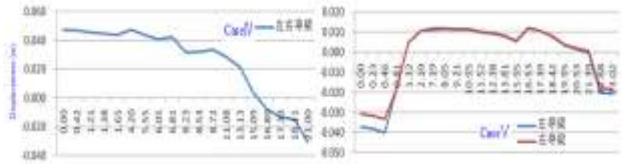
Figure 7. Displacement at the end of guide beam

When the box girder body reached the cushion block L3-1, the maximum positive bending moment would appear in the middle of the maximum span. It was easy to cause the local buckling even full failure because there was not upper plate in this kind of construction method. Therefore professional analysis was needed, and it would be carried out in the next section.

The fifth pushing case: in this pushing case, the beam body would attain 16 segments, and total length of the beam body was 137m, pushing distance was 27.5m. When the beam body was pushed to 16.5m, the maximum Von-mises stress appeared on the block L3-1, its value was 202MPa. It could be seen that the stress of the block L3-2 was small from the stress nephogram; it could be considered that the block L3-1 bore a lot of supporting force. This stress was in the scope of allowance, and the structure was in a safe state. The maximum support force appeared in the end period of the pushing and its value was 2527 kN. In the early period, the deflection between the block L3-2 and L4 caused the front end of the guide beam to tilt, and so vertical displacement of the guide girder was positive value. It became negative value again when the length of cantilever of the guide reached a certain value.

B. Bending analysis of the midspan

In the fourth case analysis of the section 2.1, the maximum positive bending moment appeared in the middle of the maximum span. It was easy to cause the local buckling even full failure because there was not upper plate in this kind of construction method[8]-[11]. Therefore separate analysis was needed.

Mixing element was adopted because the stress condition on the midspan was only concerned. The beam segment used shell element, two ends used beam element with the length of 14.5 m. There were 3 beam sections with the length of 9 m in the middle box girder, their web thickness were 16 mm, and they were the minimum thicknesses in the whole beam sections. The spacing of transverse diaphragm of these beam sections was the largest. If these beam sections could meet the force requirement, incremental launching method could meet requirements. The model was shown as Fig .8. The eigenvalue was analyzed, and ten eigenvalues were given in Table 1. After eigenvalues were obtained, the post buckling analysis was carried out with the addition of defective factor.

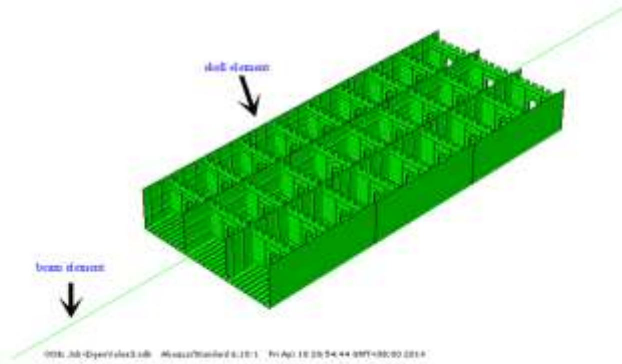

Figure 8. Mixing element model

TABLE 1. EIGENVALUE OF TEN

Mode No.	*Eigenvalue*
1	8.6480
2	8.8102
3	9.3442
4	10.106
5	10.202
6	10.604
7	10.976
8	11.263
9	11.487
10	11.853

The first-order mode was shown as Fig .9. There were not same standard scale factor in various countries, the defect of the plate should meet f/b≤1/250 (f is initial defect, b is the width of the plate) in Europe Specification; f/b<1/124 (flange: f/b≤1/113; Web: f/b≤135) in Canada specification; flange: f/b ≤ 1/127, Web: f/b ≤ 106 in Germany specification. Initial defect was 0.012mm (according to Europe specification), 0.024mm (Canada specification) and 0.025mm (Germany specification), respectively. The maximum initial defect 0.025mm was used. The load was gravity load, its acceleration adopted 1.0 in the analysis of eigenvalue and9.8 in the analysis of the post buckling.

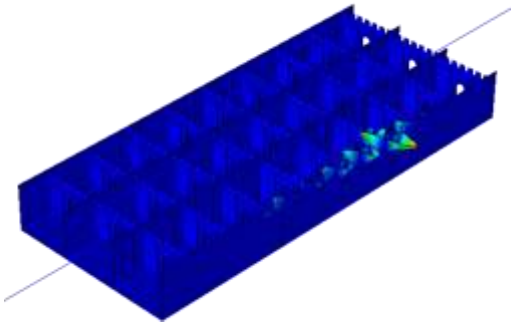

Figure 9. The first-order mode

The stress nephogram obtained from the post buckling analysis was shown in Figure 10, the maximum Von-mises stress was 160MPa, it was in the range of material elastics, and the structure is in a safe state. The maximum deformation was 0.01m shown as Figure 11. Equivalent plastic strain was 0.0 shown as Figure 12. It showed that structural deformation was recoverable elastic deformation.

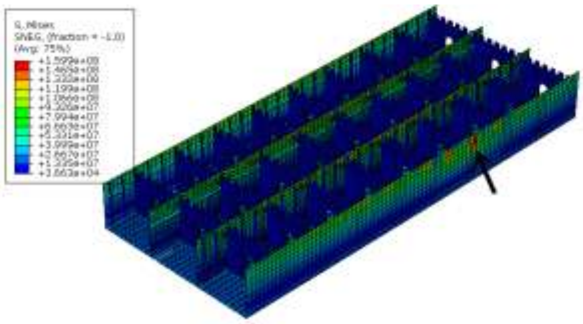

Figure 10. The maximum Von-mises stress

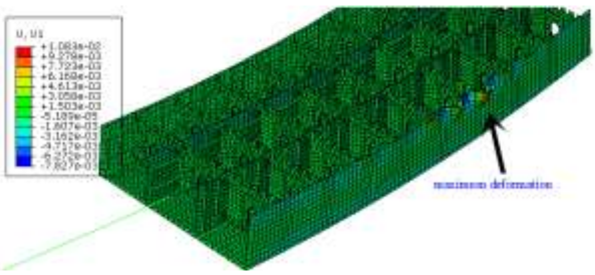

Figure 11. Deformation in post buckling

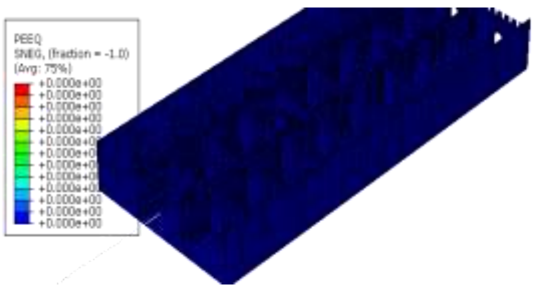

Figure 12. The Equivalent plastic strain

III. CONCLUSION

(1) This method can meet the requirement of incremental launching construction, the deformation and stress in the pushing process meet the requirement (in addition to the third case 3 carried out special treatments).

(2) The structure will appear the arching phenomenon in the process of pushing; it can lead to supporting conditions change and internal stress of the structure increase. These problems can be effectively solved by adjusting the height of adjacent support cushion block. For example, in the third pushing case, adjusting the height of adjacent block effectively reduces the maximum stress, prevents structural failure.

(3) The middle part of beam body can resist the maximum positive bending moment when the beam segment without upper plate strode across the middle maximum span, and the structure will not lose stability. Deformation caused by the maximum positive bending moment is still elastic deformation, so the structures will not failure.

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