ISSN:3007-9640 DOI: https://doi.org/10.70114/acmsr.2025.2.1.P1

Safety Analysis on Construction Supports for Long-Span Bridge Structures

Mingqi Lu [a]*, Shujun Li [b], Saifei Zhang [c]

School of Civil Engineering, Beijing Jiaotong University. Beijing. P.C100044, China.

[a] mqlu@bjtu.edu.cn, [b] 23121037@bjtu.edu.cn, [c] 23126027@bjtu.edu.cn

Abstract. Long-span bridges feature continuous box girders constructed through the cast-in-place method, necessitating a supporting structural system to withstand the loads imposed by upper construction activities. Ensuring the structural integrity of this supporting system throughout the construction phase is paramount. Traditionally, calculations for such supporting structures focused on individual members, neglecting a holistic view of both the overall structure and its component parts. In this study, a finite element analysis approach is introduced for comprehensive evaluation of the supporting structure in a real-world application to a long-span bridge. The practical engineering case study demonstrates that this method not only comprehensively assesses the overall stability of the supporting structure system, but also facilitates precise calculations of deformation and stress in specific members, affirming its practical feasibility.

Keywords: Switch Continuous Girder; finite element analysis; support system, stability; cast-in-place method.

1. Introduction

At present, with the rapid development of high-speed railway and large continuous box girder, the importance of cast-in-place method in construction is increasingly significant, which is convenient and low price. However, this method requires the support system to bear the upper concrete formwork and the corresponding construction load. Then comes the problem for the safety of the support system, which directly affects the success of cast-in-place construction. According to the construction scheme and load information provided by the construction unities, the 3D finite element model was proposed in this study, to decide whether the original construction scheme was secure. Liu et al[1],propose a method in Cast-in-place construction technology industrial,which helps to promote the sustainable development of human living environment. Xiao Yanting[2] concentrate on a large span steel truss continuous beam bridge in Xi ' an ,and propose the static analysis, linear control and error adjustment of the structure. Ma et al[3],analyzed the key design points of the continuous rigid bridge beam in the variable section and put forward the precautions for the force at the support. In the construction of the large-span bridge, researchers[4-5] compared the finite element analysis with other methods, and provided guidance for the future construction methods.

2. Project Overview

The analysis is based on an actual construction project of the 6×32 m Track Switch Continuous Girder of Pujiang Special Bridge (Piers 12 to 14), which is the Switch Continuous Girder between Pier 1 and Pier 7, and Pier 504 to Pier 510. The continuous girder features a single-box, single-cell prestressed concrete box girder section. with the width of the bridge deck 12.6 m, the width of the bottom deck 5.5 m. The lowest point of the section is 3.05 m, the roof thickness is 34 cm, the bottom thickness is 30 cm, and the web plate thickness varies from 50 to 80 cm.

ISSN:3007-9640 DOI: https://doi.org/10.70114/acmsr.2025.2.1.P1

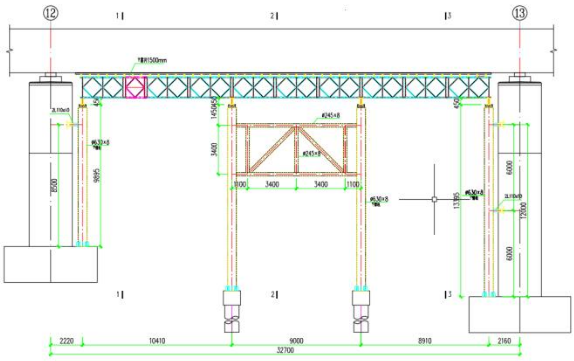

Fig. 1 Support scheme longitudinal layout of the bridge

The continuous girder was constructed by cast-in-place method, and the cast-in-place support was beam-column support with 630×8mm round steel tube column, with 4 rows of each span, and the longitudinal bridge spacing was 10.41m, 9m and 8.91m, respectively. On each pier cap, there were three steel pipe columns per row, evenly spaced transversely with a spacing of 4 meters. At the mid-span position, two rows of steel pipe columns were set up, with four columns per row, also evenly spaced transversely with a spacing of 3 meters. Above the steel pipe column, double-web I-beams of type I45a was used as the column top distribution beam, The Bailey beams on the upper of the column top distribution beams serve as the longitudinal load-bearing structure, 4 pieces were set under the side web, 2 pieces were set under the bottom plate of each chamber, and 4 pieces were arranged on the outside.

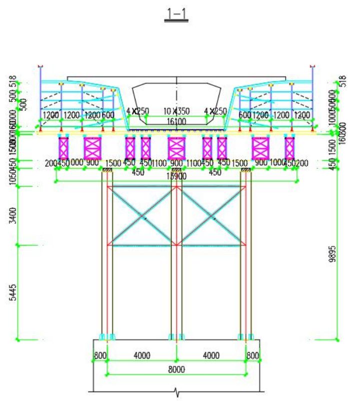

Fig. 2 Support scheme transverse layout of the bridge(side pier)

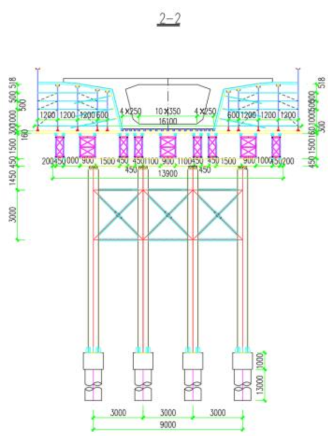

Fig. 3 mid-span

Steel I16 beam with a spacing of 600mm was set as 100 × 100 longitudinal square wood, the square wood web spacing 250mm, the bottom plate spacing 350mm, and the upper square wood

ISSN:3007-9640 DOI: https://doi.org/10.70114/acmsr.2025.2.1.P1
was set 15mm thick bamboo plywood as the bottom plate template panel. The Bailey beam was made of Q345 steel, and all other components were Q235 steel. Fig. 1~3 shows the arrangement of the support along and across the bridge.

3. Calculate Load

According to the relevant drawings and construction data of the Pujiang bridge turnout continuous girder provided by the construction unity, we can obtain dead load and live load

The dead weight of the newly poured concrete was G1, and the excess square coefficient of 1.05 was calculated according to the bulk density of 26 kN/m3. Template dead weight, press 150 kg/m2 consideration, G2=1.5kN/m2.

Standard value of load generated by construction personnel and equipment: Q1=2.5kN/m2

The load generated during the vibration of concrete: Q2=2.0kN/m2

Impact load generated during concrete pouring: Q3=2.5kN/m2

Wind load parameters: The wind pressure was at the maximum value of 26.78kg/m2=0.27kN/m2 according to the wind level, wind speed and wind pressure comparison table.The load combination value coefficient was 1.35, and coefficient of live load combination value was 1.4.

Additional horizontal load generated by pumping concrete or uneven stacking:The 2% of the standard value of the vertical permanent load in the calculation condition can be considered.

4. Finite Element Analysis Model

With the general finite element analysis software SAP2000, a 3D calculation model of the cast-in-place continuous box girder support system has been establlished. The model includes steel pipe column,vertical and horizontal column support, double work beam I45a distribution beam, Bailey beams, I16 beam, square timber and bamboo plywood. The frame element in SAP2000 software was used to simulate the steel pipe column, the brace, column top distribution beam, bailey beam, I16 beam and square wood. The bamboo plywood formwork was simulated by the shell elements. Because the bottom of the steel pipe column was supported on the concrete ground beam during the construction, so the hinge joint was used. To simplify the calculation, the 32.7m span was taken for analysis. Fig. 4, Fig. 5, and Fig.6shows the overall computational analysis of the model. The model consisted 7778 nodes, 7494 frame elements, and 1314 shell elements.

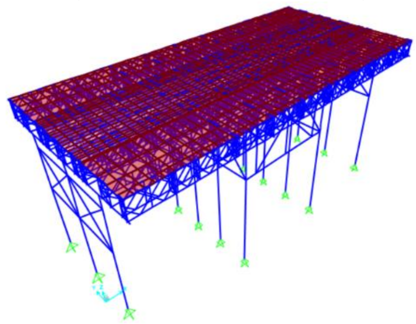

Fig. 4 The 6 x 32m Track Switch Continuous Girder of Pujiang Special Bridge (Piers 12 to 14) overall model of bracket

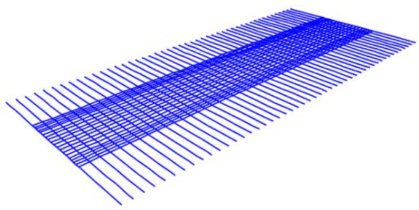

Fig. 5 Column top distribution beam and bailey beam

ISSN:3007-9640 DOI: https://doi.org/10.70114/acmsr.2025.2.1.P1

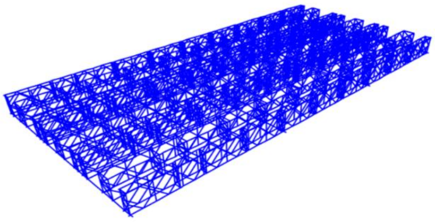

Fig. 6 I16 Horizontal beams and square timber

5. The Stability of the Cast-in-Place Support System

By calculating the stability of the support system through the above finite element model, the most unfavorable situation was the combination of the constant load and the load generated by the construction personnel and equipment, and the construction wind load. The calculated first order buckling coefficient was 2.49> 1, indicating that the bracket structure can meet the overall stability requirements, and the first order buckling mode was shown in the following figure.

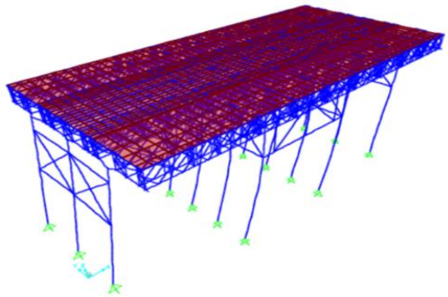

Fig. 7 The first overall buckling mode of the support structure

6. Deformation and Strength of Steel Pipe Column Structure

The verification of steel pipe columns is generally controlled by the stability of the steel pipe columns. For this project, a design verification is conducted for the steel pipe columns.

The design calculation results can be seen in Fig 13, the maximum stress ratio is 0.507, which meets the design requirements. The design calculation results for the column bracing are shown in Fig 14, the maximum stress ratio 0.573, which meets the design requirements.

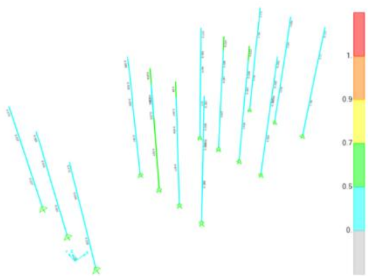

Fig. 8 Design stress ratio of steel tube column

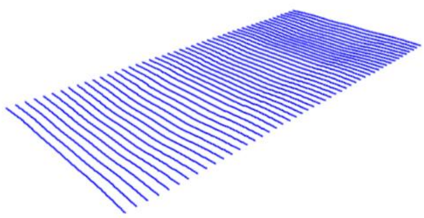

Fig. 9 I16 Deformation of the crossbeam

ISSN:3007-9640 DOI: https://doi.org/10.70114/acmsr.2025.2.1.P1

7. I16 Deformation and Strength of Crossbeam

In order to evaluate its strength requirements , the maximum stress of I16 beam is 12.58MPa <210MPa and its maximum deformation is 0.12mm<L/400=1.125mm, and its deformation is shown in Fig 10. From the results, its safety can be ensured.

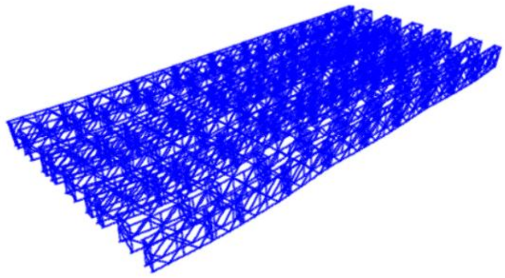

Fig. 10 Deformation of Beilei Beam

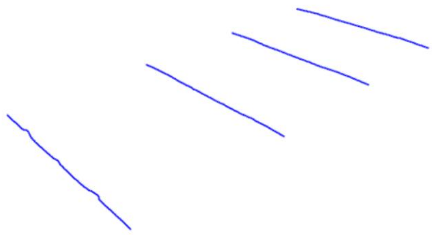

Fig. 11 Deformation of column top distribution beam

8. Deformation and Strength of Bailey Beam

Its maximum vertical displacement is 17.16mm<L/400=22.5mm, which meets the deformation requirements. The maximum axial force of chord (double 10 channel steel) is 238 kN <its axial force limit 560 kN, which also meets the deformation requirements. The maximum axial force of diagonal (I8 I-steel) 160.81kN < 170.5kN（its axial force limit）, which can satisfy the requirement. The maximum axial force（I8steel）is 210.46kN, which is slightly greater than its axial force limit of 210 kNand do not meet the requirements. Deformation and Strength of the Distribution Beam on the Top of the Column.

Fig. 11 shows the deformation of the distribution beam on the top of the column. Its maximum deformation 7.05mm<L/400 =10mm, which can satisfies the request: its maximum stress is 136.23MPa<215MPa, satisfies the requirement.

9. Conclusion

In the study, the stability analysis was conducted on the cast-in-place continuous box girder support structure for piers 12#-14# of the 6×32m turnout continuous beam of the Pujiang Grand Bridge. The research results indicate that if construction is carried out strictly according to the support design scheme provided by the contractor, the overall stability of the steel pipe supports,

The steel pipe columns, crossbeam, and the distribution beam on the top of the column are all satisfied the requirments. However, the maximum axial force of partial members of the Beilei beams is slightly greater than its secure limit. Some reinforcement measures in these parts are nessasary.

ISSN:3007-9640 DOI: https://doi.org/10.70114/acmsr.2025.2.1.P1

Acknowledgement

The authors would like to acknowledge the funding support from the National Natural Science Foundation of China (grant no. 51641802 and grant no. U1801254).

References

[1] Liu Cong, Fangqing Zhang, Hong Zhang*,. Comparative Analysis of Off-Site Precast Concrete and Cast-in-Place Concrete in Low-Carbon Built Environment[J]. Fresenius Environmental Bulletin. 2020, 29(3): 1804-1812.

[2] Yanting Xiao. Research on key technology of large span steel truss bridge construction monitoring based on stress-free state method [D]. Chang'an University, 2023, 6.

[3] Zhilong Ma, Jieliang Wu, Chunhui Pan. Design calculation analysis of long span prestressed continuous beam rigid frame bridge with variable section[J]. Shanxi Architecture, 2021,47(18):146-149.

[4] Kongling Chang. Simulation and verification of long-span Bridge Structure Based on Finite Element Analysis.[J]. Road construction machinery and construction mechanization, 2020,37(8):61-65.

[5] Xiaoju Xiang, Hou Xu, Zhixiang Zhou. The 3D Laser Scanning Results of Long-span Bridge Deformation are Compared with the Finite Element Simulation[J]. Highway Engineering, 2019,44(2):103-108.