Construction Technology of formwork Support System for Bridge Pier Cover Girder with High and Large Super-Linear Loads

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Abstract. Concrete formwork technology and support system technology are important construction technologies in construction, and have been widely used in long-span projects. With the development of the construction industry, some construction projects are usually applied to tall concrete formwork projects and support systems. The high-rise concrete support system not only plays a supporting role when pouring concrete, but also still has a large safety hazard after the project is put into operation, and the safety and stability of the building is inseparable from the support of the formwork support system. Combined with specific construction cases, this paper studies the construction technology and safety control system of the high ultralinear load formwork support system of the pier cap girder, which can effectively reduce the occurrence of such engineering safety accidents.

Keywords: Tall formwork support; super-linear load; construction technology; safety control

1 Introduction

The importance of formwork support systems in modern construction is increasing, crucial for ensuring quality and preventing safety incidents. Tall formwork support systems, evolved from traditional forms, are essential for high-rise buildings and bridges, providing critical support during concrete pouring and curing to maintain formwork stability. However, challenges such as leadership issues, construction errors, and design deviations often lead to safety accidents. Engineering management plays a vital role in ensuring proper design [1], installation, and safety measures to safeguard construction project success and safety.

Liu et al.[2] analyzed the characteristics and difficulties of dangerous projects, and explore the construction technology of the whole tall formwork support system. Zeng[3] analyzed the problems and consequences of the tall formwork support system in the design, and introduces the system safety control measures in detail. Ding[4] discussed

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the safety of the tall formwork support system on the basis of strict control of its stiffness, strength and stability, which provides a reference for the subsequent construction process. Song[5] put forward the model design based on BIM technology, node labeling method, BIM technology into the tall formwork design, effectively reduce the probability of safety accidents due to the lack of precision in the construction of the support system. Jing[6] put forward to broaden the safety knowledge acquisition channels of the employees of the building construction enterprises, strengthen the practical application of safety knowledge, improve the risk perception ability of the staff, enhance the risk elimination ability of the staff, so that the employees of the enterprise to maintain good personal habits, the use of other people's factors to positively guide the six countermeasures to eliminate the unsafe actions in the tall formwork support system building construction collapse accident, provide management suggestions. Liu and Wang[7] designed the beam bridge structure tall formwork support system, so that the floor-standing scaffolding can meet the construction of ultra-high large-span formwork support. Baskova et al.[8] proposed a dynamic model for efficient optimization planning of formwork in construction projects. The formwork planning is demonstrated by a software application based on the computational algorithm of the proposed dynamic model, and the optimal selection and placement of formwork in the construction of concrete structures are studied.. Shin et al.[9] proposed an AdABOOst-based decision support model to select a formwork system suitable for construction site conditions. In order to verify the proposed model, AdaBoost and ANN selection models were applied to the actual case data of high-rise building construction in South Korea, respectively. The accuracy of AdaBoost model is slightly higher than that of ANN model. The AdaBoost model can help engineers determine the appropriate formwork system at the start of future projects. Golafshani [10] analyzed the potential factors affecting the calculation of the rate of climb. A comprehensive database of 81 sliding mode projects in Iran was then collected. Then, a symbolic regression method based on linear biogeographic programming is introduced, and it is applied to extract the calculation formula of the climb rate of sliding mode system.

At present, many scholars have studied the construction process, mechanical properties, and safety factors affecting the construction of high-formwork support systems, and some scholars have combined high-formwork support systems with BIM technology to carry out construction simulation, but for the dangerous engineering of construction technology and safety control construction, there are relatively few studies on high superlinear load formwork support system. Therefore, this paper takes the Lijiaping Bridge project in Hezheng County as an example to study the construction technology of the high ultra-linear load formwork support system of the abutment cover beam, to avoid the occurrence of such engineering safety accidents.

2 Engineering Overview

The project for Hezheng County Lijiaping Bridge project, selected one of the sub-projects No. 1 abutment, the abutment cover beam for two spans, span of 18.5 meters, cover beam cross-section dimensions: height 2.5m × width 3m × length 40m, the concrete grade for C50, the bottom of the beam from the top of the bearing platform height of 4.5 meters, the bearing platform at the existing ground for the mudstone layer. The line load of the cover beam of this project reaches 267.155 kN/m, and the support belongs to the super-dangerous large sub-parts of the project.

3 Engineering Characteristics Analysis

3.1 Engineering Features

The cover beam of this project is arranged in a rectangular shape. The bottom mold of the cover beam is constructed using a wood glued template with a thickness of 18mm. The secondary keel is comprised of a 100*100 wooden square with a net spacing of 100mm. The main keel is constructed using an I-beam with a grade of 20a#. The bracket is constructed using socketed plate buckled steel pipe scaffolding with a steel pipe specification of 48*3.2 (a wall thickness of 3.0mm is used for safety checking), longitudinal and transversal spacing of 600mm, and the supporting setup of transverse and diagonal rods. The beam side mold is constructed from steel mold plate, with a thickness of 3mm. The secondary flute is comprised of 8# (80*43*5.0) channel steel, while the main flute is 16# I-beam. The tensile bolt is of Φ18 tensile wire rod. The first channel is situated 20 cm below the bottom membrane, the second channel is located 45 cm away from the first channel, the third channel is positioned 60 cm away from the second channel, the fourth channel is situated 60 cm away from the third channel, and the fifth channel is attached to the top of the steel membrane, with a vertical spacing of 60 cm. Tie bolts of diameter 18 mm (HPB300 grade) are used in conjunction with PVC sleeves and plastic plugs of diameter 20 mm.

3.2 Hazard Analysis

(1) Formwork support erection height $H = 4.7$ m < 8 m;

(2) Formwork support erection span $B = 18.5$ m > 18 m;

(3) Concentration of line loads:

$S=1.3\times[(M1+M2)\times b\times h+0.7\times(2\times h+b)]+1.5\times b\times h=1.3\times(25.5\times3\times2.5+0.7\times(2\times2.5+3))+1.5\times2.5\times=267.155\text{kN/m}>20\text{kN/m}$.

To sum up, the support mold of 3000*2500 beam is a dangerous formwork support system with line load exceeding a certain scale, and it belongs to the first grade of safety bracket.

4 Support System and Construction Process

4.1 Racking System

In this project, the template of beam bottom adopts 18mm thickness of laminated wood glued template, and the secondary keel of beam bottom adopts 100X100mm wooden square with spacing @200mm and length of 4m and 2m, and the main keel adopts 20#a I-beam (200*100*7)mm with length of 4m. The vertical rod adopts φ60.3*3.2 socketed plate buckle bracket, with longitudinal and transverse spacing of 600mm, middle step distance of 1000mm, top step distance of 500mm, and the plan is shown in the following Fig.1

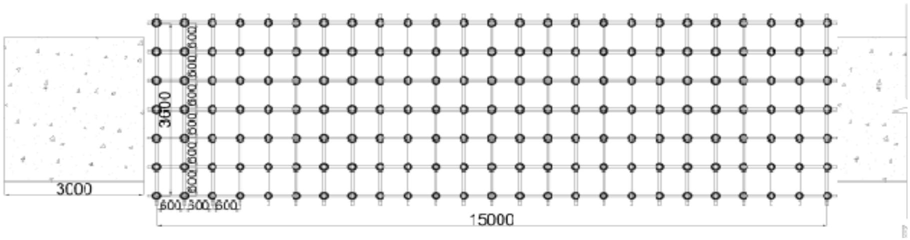

Fig. 1. Riser layout

4.2 Stent Pre-Compression

After the bottom mold is installed, the supports can be pre-compressed. Pre-pressure cover beam 1-0#~1-1# position first, then 1-1#~1-2# position, load pre-pressure span by span. The weight of pre-compression is 120% of the design load (the sum of box girder concrete self-weight, inner and outer formwork frame weight and construction load), and the bracket is pre-compressed with gravel material. The stacking height of the gravel material is taken according to the variation of the beam self-weight distribution curve, so that the distribution of the pre-compression load coincides with the distribution of the beam load. Loading in accordance with the 0%, 50%, 100%, 120% of the design load in three levels of loading, loading the size of the weight and loading rate and the foundation of the strength of the growth of the foundation, to be the foundation in the previous level of load, to achieve a certain degree of consolidation, and then apply the next level of load, especially in the later stages of loading, the loading rate must be strictly controlled, to prevent the foundation due to the overall or local loading is too large, too fast. Shear damage occurs. The maximum settlement of foundation should not be more than 10mm/d; the horizontal displacement should not be more than 4mm/d.

4.3 Beam Side Formwork

The beam side mold is constructed using a steel mold plate with a thickness of 3mm. The secondary flute is comprised of an 8# (80*43*5.0) channel steel, while the main flute is an 16# I-beam. The tie bolt is constructed using a Φ18 tie wire rod. The first channel is situated 20 cm below the bottom membrane, the second channel is located 45 cm away from the first channel, the third channel is positioned 60 cm away from the second channel, the fourth channel is situated 60 cm away from the third channel, and the fifth channel is attached to the top of the steel membrane, with a vertical spacing of

60 cm. The tie bolts are of uniform diameter (ø18, HPB300 grade) and consist of ø20 PVC sleeves and plastic plugs.

5 Support System and Construction Process

5.1 Monitoring of Content

The rods, wall connectors, braces, and scissor braces must be evaluated for compliance with standards. Check wall connectors for looseness. Assess frame settlement, verticality deviation, and bracket and rod deformation.

5.2 Measurement Point Arrangement

Monitoring points are set along one side of the I-beam support, with deformation points placed approximately every three meters and five settlement observation points per span. For a detailed illustration of the measurement points, please refer to Fig.2. Ten detection points are positioned along the spans' longitudinal axis to detect displacement. The monitoring instrument must meet accuracy standards for on-site use, and deformation alarm values should be appropriately set.

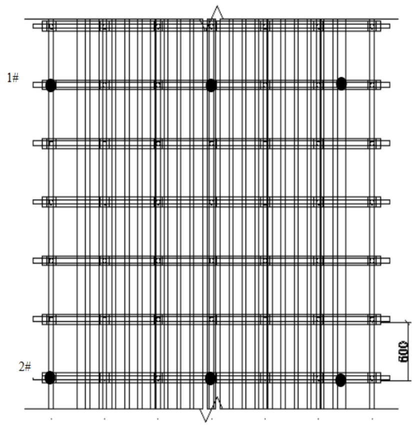

Fig.2 Point of observation for settlement

5.3 Monitoring Frequency

It is recommended that real-time monitoring be carried out during the pouring of concrete. It is further recommended that special personnel be assigned to monitor at any time during the early stage of pouring. The frequency of monitoring during the pouring process should not exceed once every 20-30 minutes. It is also recommended that real-time monitoring be carried out before and after the concrete is solidified and before the concrete is finally solidified up to the age of seven days. Furthermore, it is recommended that the frequency of monitoring after the final solidification be once a day. In the event that sinking, loosening, deformation, and horizontal displacement are identified, it is imperative that they be addressed in a timely manner.

6 Conclusions

By employing a well-designed construction methodology and rigorous safety management, the support system's stability and safety are ensured, thereby guaranteeing project quality and progress. This paper explores the composition, construction technology, and safety monitoring of tall formwork support systems, offering valuable guidance for engineering practices.

Future research should focus on optimizing the support system's design and construction technology, integrating advanced computer-aided design and modeling. This will enhance the accuracy and efficiency of support systems for high loads in modern bridge engineering, fostering development and innovation in the field.

References

1. Zhang, W. Z., Bai, H. X. (2022) Research on management and control system of the high formwork support system throughout the total construction processes and its application. Project Management, 1: 11-15. https://doi.org/10.15968/j.cnki.jsjl.2022. 01.026.
2. Liu, Y. G., Zhang, S. M., Qin T. (2024) Analysis of construction technology of high formwork support system for dangerous projects. Anhui Architecture, 31(4): 50-51. https://doi.org/10.16330/j.cnki.1007-7359.2024.4.018
3. Zeng, X. X. (2023) Exploration of construction technology and safety control of high formwork support system. China Housing Facilities, 12: 172-174.
4. Ding, Y. F. (2023) Safety control analysis of tall formwork support system in building construction. Scientific and Technological Innovation, 6: 169-172. https://doi.org/10.3969/j.issn.1674-3024.2022.17.046.
5. Song, C. (2023) Analysis of engineering curved tall formwork support system based on BIM technology. Informatization of China Construction, 1: 76-78.
6. Jing, R. (2022) Research on the causes and countermeasures of the habitual behavior of the collapse accidents of the tall formwork supporting system. Jilin Jianzhu University .
7. Liu, H. W., Wang, Y. H. (2022) Research and application of high formwork support system for beam bridge structure. Building Construction, 44(7): 1602-1605. https://doi.org/10.14144/j.cnki.jzsg.2022.07.042
8. Baskova, R.., Tazikova, A., Strukova, Z., et al. (2023) A Dynamic Model for Effective and Optimal Planning of Formwork in Construction Projects. Buildings, 13(7): 1794. https://doi.org/10.3390/buildings13071794
9. Shin, Y., Kim, D. W., Yang, S. W., et al. (2008) Decision support model using the AdaBoost algorithm to select formwork systems in high-rise building construction. 25Th International Symposium on Automation and Robotics In Construction - Isarc-2008, 644-649. https://doi.org/10.3846/isarc.20080626.644.
10. Golafshani, E. M., Talatahari, S. (2018) Predicting the climbing rate of slip formwork systems using linear biogeography-based programming. Applied Soft Computing, 70: 263-278. https:// doi.org/10.1016/j.asoc.2018.05.036.