Optimization of Distribution Network Construction Based on GIS System

Qin Tian *, Zixin Wan, Yunpeng Zou and Chenghao Hang
School of Civil Engineering and Architecture, Nanchang University, Nanchang China

*Corresponding author e-mail: tianqin224@163.com

Abstract. With the rapid development of China's economy and science and technology, people's daily life and scientific research work demand more and more electricity. The traditional distribution network structure and load can hardly meet the actual demand. Therefore, it is very necessary to construct a more stable distribution network system in accordance with the actual demand for electricity. This paper mainly introduces the application of GIS system in power distribution network planning and design, and realizes the optimization and upgrading of power distribution network in coordination with the geographic information of the construction site, so as to meet the increasing demand for electricity.

Key words: GIS system, distribution network, electricity.

1. Introduction
With the rapid development of China's economy and the continuous progress of bridge construction technology, more and more bridges are being built. As a key part of the bridge, cast-in-situ box girder is obviously important. During the construction of cast-in-situ box girder, the foundation is often reinforced and then full steel pipe supports are erected. However, due to the tight construction period and the difficulty of foundation treatment, it is often inappropriate to build full-scale steel pipe supports. Therefore, it is particularly important to find a safe, reliable, economical and effective cast-in-place box girder support system.

At present, Bailey beam support system occupies a certain proportion in road and bridge construction in China. Especially under unfavorable conditions such as heavy tonnage and large span, Bailey beam support system is considered to be a safe and economical construction method [1, 2, 3]. In actual construction, the bearing capacity of Bailey beams can be effectively increased by changing the number of Bailey beams and steel pipe columns according to the changes of span and load. Taking Lianshui Bridge as the engineering background, this paper uses ABAQUS to analyze Bailey beam support system, providing reliable experience for similar cross-line bridge construction in the future.

2. Engineering Situation
The Lianshui Bridge is a split deck, spanning S235 provincial highway, with a structure of 32+48+32 m of the prestressed concrete continuous box girder with variable cross-section. The bridge has a total length of 113.1m and a deck width of 12.0m. In order to ensure the normal passage of the provincial highway under the bridge, it is not suitable to use full steel pipe support construction method, and Bailey...
beam support system construction method is proposed. Due to the large span of the middle beam, it is the most unfavorable section for construction. As shown in Figure 1, only the stress and deformation of the middle beam support system need to be analyzed.

The two-span structure of Bailey beam support system is two groups of single-layer "321" reinforced Bailey trusses, the beam height is 1.4m, and the length of each span is 20.89m. As shown in Figure 2, the side formwork and flange plate are constructed with bowl-buckled scaffolding with a spacing of 60×90 cm. The webs and bottom boards are supported by 12×12 cm square timber with spacing of 30 cm and 40 cm, respectively. The scaffold base and square timber are placed on the spreader beam with a distance of 60cm in the transverse direction, and the whole scaffold is placed on the Bailey beam along the bridge direction. The distance between the Bailey beams under the web plate is 45cm, and the distance between the Bailey beams under the flange plate and the bottom plate is 90cm. The lower structure of Bailey beam support system adopts driven steel pipe column foundation, and the C20 concrete foundation cushion with thickness of 30 cm is set at the side of the bearing platform.

3. Finite Element Analysis Model

3.1. Load Analysis.

According to the construction characteristics of this project, in order to simplify calculation and ensure safety, the beam concrete is completed by one-time pouring. The load consists of reinforced concrete dead weight, formwork dead weight, construction load and wind load. The dead weight of reinforced concrete is 26KN/m$^3$, the dead weight of formwork is 1.5KN/m$^2$, the construction load is 4.5KN/m$^2$, and the static wind load is calculated by basic wind pressure 0.35KN/m$^2$ once in 50 years. Permanent load's partial coefficient is 1.2 and variable load's partial coefficient is 1.4. As shown in Figure 3, according to the arrangement of scaffolding and distribution beams, the whole box girder is divided into 73 units according to certain rules, and each unit is further subdivided into 13 units, wherein the cross-sectional area of the flange plate of the box girder unit is represented by A1-A5, the area of the web plate of the box girder unit is represented by A6, and the area of the top and bottom plates of the box girder unit is represented by A7. From this calculation, the distributed loads on the spreader beams are obtained.

![Figure 1. Elevation view of Bailey beam support system.](image)
3.2. Load Calculation.
Weight of reinforced concrete (KN): \( P_A = V_i \times 26 \), where \( V_i \) denotes the volume of reinforced concrete required for each subdivision. The volumes of \( V_1-V_7 \) are 0.114 m\(^3\), 0.120 m\(^3\), 0.162 m\(^3\), 0.204 m\(^3\), 0.150 m\(^3\), 1.332 m\(^3\) and 1.578 m\(^3\), respectively.

Template weight (KN): \( P_B = A_m \times 1.5 \), where \( A_m \) represents the size of the template required for each subdivision. The areas of \( A_m1-A_m7 \) are 0.594 m\(^2\), 0.360 m\(^2\), 0.360 m\(^2\), 0.360 m\(^2\), 0.216 m\(^2\), 3.72 m\(^2\) and 6.43 m\(^2\), respectively.

Construction weight (KN): \( P_C = A_S \times 4.5 \), where \( A_S \) represents the required construction area for each subdivision. The areas of \( A_S1-A_S7 \) are 0.462 m\(^2\), 0.360 m\(^2\), 0.360 m\(^2\), 0.360 m\(^2\), 0.216 m\(^2\), 0.833 m\(^2\) and 2.142 m\(^2\), respectively.
Total Weight (KN): \( P = 1.2 \times (P_A + P_B) + 1.4 \times P_C \), where \( P_1 - P_7 \) are 7.5KN, 6.7KN, 8.0KN, 9.3KN, 6.4KN, 53.5KN and 74.3KN, respectively.

Ignoring the force of the two scaffolds on the left and right outermost, the total weight of web and floor can be equivalent to the uniform load due to the dense square timber at the bottom. Uniform load (KN/m): \( q = P / L \), where \( L \) is the length of web or floor acting on square timber, which is 1.01m and 3.57m, respectively. Therefore, \( P_6 \) is 53.0KN/m and \( P_7 \) is 20.8KN/m.

3.3. Overview of Modeling Process.
The Bailey beam support system is established by using the general finite element software ABAQUS. It consists of 12φ600X16mm steel pipe columns, 3 2I40a main crossbeams, 18 rows of single-layer "321" reinforced Bailey frame and 73 I20 spreader beams. The Bailey support frame is composed of L63X4 angle steel. The materials of the rest components are Q235-A steel except Q345 steel for Bailey chord, Bailey web member and reinforced chord. According to the principle of structural mechanics, the maximum stress of the Bailey beam model appears at the joint with the middle steel pier, and there is a large local pressure, so the Bailey truss is simulated by the shell element. Other Bailey trusses are simulated by fiber element, and the beam element and slab bridge element are connected by MPC [4]. A structural consistent multi-scale model considering both calculation efficiency and calculation accuracy is established [5]. The finite element model of Bailey beam support system is shown in Figure 4.

4. Force Analysis of Bracket
In most cases, the size of the bracket depends on the principal stress it bears, so it is necessary to analyze the stress of the structure. Based on the fourth strength theory, the strength analysis of each component structure of Bailey beam support system is carried out.

4.1. Strength Analysis of Steel Columns.
As shown in Figure 5, the maximum combined stress of steel column is \( 91 \text{Mpa} < [\sigma] = 235 \text{ Mpa} \), which meets the requirements of the code. The steel columns are mainly under pressure, and the overall combined stress is symmetrical distribution. The steel columns on both sides are stressed evenly, and the joint between the middle steel column and the main beam is stressed greatly.

At the same time, the pressure stability is analyzed. The steel column is equipped with a steel hoop every 3m high. The NO.14 double channel steel is used as the cross-longitudinal and oblique connection, welded to the steel hoop and 3m is taken as the calculation free length. Steel column Radius of Gyration \( i = 0.414 \), slenderness ratio \( \lambda = 14.5 \), stability coefficient lookup table \( h = 0.947 \), steel pipe maximum pressure \( N = 575 \text{KN} \). Assuming a maximum eccentricity of 10cm, eccentric compression bending moment \( M = 57.5 \text{ KN-m} \), steel column cross-sectional area \( A = 29.35 \times 103 \text{mm}^2 \), and steel column
bending interface coefficient $W=4.17 \times 10^6 \text{mm}^3$, then $e = \frac{N}{hA} + \frac{M}{W} = 34.5 \text{ MPa} < [\sigma] = 190 \text{ MPa}$, so the steel pipe stability meets the requirements.

4.2. **Strength Analysis of Main Beam.**
As shown in Figure 5, the maximum combined stress of the main beam is $137 \text{ MPa} < [\sigma] = 235 \text{ MPa}$, meeting the specification requirements. Under the arrangement of equidistant steel pipes, the combined stress of the whole beam body is distributed symmetrically, and the stress at the fulcrum of the cantilever part is the largest.

4.3. **Strength Analysis of Bailey Beam.**
As shown in Figure 6, the maximum combined stress of Bailey beam is $192 \text{ MPa} < [\sigma] = 345 \text{ MPa}$, which all meet the specification requirements.

![Figure 5. Stress nephogram of steel tube column.](image)

![Figure 6. Stress nephogram of Bailey beam.](image)
5. Key Points of Construction

In order to ensure the coordination and unification of theory and practice, Bailey beam support system can be accurately applied to actual projects. The following points should be paid attention to during construction:

1. The joints between steel pipe columns must be fully welded, the embedded parts of anchor bolts and flange plates of steel pipe columns must be closely embedded, and the embedded depth must reach the national standard.

2. If the Bailey beam and the distribution beam are rigidly fixed with riding bolts, the riding bolts shall be tightened and properly arranged so as not to affect the erection of the distribution beam.

3. Materials used in the construction must have factory certification. During the erection process, the impact should be avoided as much as possible to reduce vibration and prevent distortion.

4. Bailey beam support shall be subjected to preloading test. The preloading load is 1.1 times of the dead weight of the beam body. Sand bags shall be pushed according to the different weights of the web plate and the bottom plate. The sandbags shall be observed every 6 hours. If the average settlement for 24 hours in a row is less than 1mm or the average settlement for 72 hours in a row is less than 3mm, preloading shall be completed.

6. Conclusion

Taking Lianshui County Bridge as the engineering background, this paper uses ABAQUS, a general finite element software, to carry out a systematic stress analysis on Bailey beam support system. All the analysis results meet the specification requirements, providing reliable experience for similar cross-line bridge construction in the future. The main conclusions are as follows:

1. Bailey beam support system can be used for cast-in-situ box girder construction of cross-line bridges, and is safe, reliable, economical and environment-friendly, and has strong applicability.

2. The maximum stress of Bailey beam support system usually occurs at the fulcrum of each member. When the fulcrum stress approaches or exceeds the limit value, safety can be ensured by strengthening the connection at the fulcrum.

3. The stress on the steel tube column is relatively uniform. The stress on the main beam, Bailey beam and distribution beam are distributed symmetrically, with small stress at both ends and large stress in the middle.

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References

[1] C.H. Cui and J.J. Wei: Application of Steel Pipe Bailey Beam-column Bracket in High Pier and Long Span Cast-in-situ Box Girder Construction, J. Highway, 2005, 10: 10-16.

[2] Y.Q. Bi: Application of Steel Pipe Pier and Bailey Beam Support in Cast-in-situ Beam Construction, J. Construction Technology, 2011, 7: 84-86.

[3] Q. Fu and Y.Q. Li: Research on Application of ANSYS in Bailey Beam Construction Support Inspection and Deformation Prediction, J. Railway Architecture, 2012, 8(6): 30-33.

[4] X.C. Lin, X.Z. Lu and L.P. Ye: Multi-scale finite element modeling and its application in the analysis of a steel concrete hybrid frame, J. Chinese Journal of Computational Mechanics, 2010, 27(3): 469.

[5] Z.H. Sun, Z.X. Li and H.T. Chen: Structural Multiscale Simulation Method Considering Local Detail Characteristics, J. Special Structures, 2007, 24(1): 71-75.