Optimization Study on the Safety of Shoring Scaffold under Beams with Composite Beams

Bo Peng¹ and Dong Wang²
¹Faculty of Civil Engineering and Architecture, Kunming University of Science and Technology of Kunming, China
²Faculty of Civil Engineering and Architecture, Kunming University of Science and Technology of Kunming, China
Email: 406495830@qq.com; edit-me@163.com

Abstract. The actual project in beam concrete pouring of large volume, under beam shoring scaffold span and interval are smaller, while in use process to shoring scaffold the safety stock is bigger, set-up shoring scaffold but there is time consuming, shortcomings and so on greater danger and not economic. Combining with engineering examples, using the finite element software Ansys in birth and death in the composite beam casting was simulated, the use of composite beam under the shoring scaffold of the casting mode beam buckling analysis, and shoring scaffolding system, safe and economical optimization under the beam.

1. Introduction
Transfer beam by beam of high-rise buildings and large span, the section size of beam concrete volume also increases accordingly, the increase of the size and structure of the construction technology of the demand is higher and higher. If the transfer beam by a casting when casting molding whole beam optimization into two casting molding composite beam, the beam span and shoring scaffold under the step distance will decrease, and with the increase of time, after the initial set of concrete frame body stud pressure decreases instead, in the after pouring 12 d, poling stress basic no change [1]. In this paper, starts from the construction method of the laminated beam, uses the characteristics of the composite beam, reaches the beam to lift the girder, reduces the support engineering quantity, thus enhances the beam under the shoring scaffold to set the speed and the security purpose.

2. Introduction to engineering
The proposed building is a renovation project of a shanty town in a city, with a total height of 98.9 meters. The structure of the structure is partly framed with shear wall structure, the structure security level is level 2, the design service life is 50 years, and the building fire resistance level is 1. Project is located in the city on the west mountain area, building structure seismic fortification intensity of 7 degrees.

Under the original beam, the shoring scaffold is designed to be 0.6 m along the longitudinal span of the beam, and the step distance is 0.9 m, and the bottom of the beam is increased by three shoring scaffolds, with a spacing of 0.3 m. The shoring scaffolding pole is a bowl button-type scaffold. The material is made of Q235, ø48 mm×3.5 mm steel pipe, the beam section size is 0.5 m×1.5 m, the beam is 9 m, and the concrete grade is C40.
3. Design optimization under beam shoring scaffold

3.1 Analysis of stability calculation formula of shoring scaffold rod

The bearing capacity of the shoring scaffolding (hereinafter referred to as shoring) design under the beam is large, because in the actual project, the calculation of the stability under the beam is calculated according to the formula given in the literature [2].

\[
\gamma_0 \frac{N}{\varphi A} \leq f
\]  

In the formula, \(\gamma_0\)-structural importance coefficient; \(N\)-the axial force design value of the standing tube (N); \(\varphi\)-the stability factor of the axial compression member; \(\lambda\)-slenderness ratio, \(\lambda = \frac{l_0}{\varphi}\); \(A\)-the gross section area of the standing tube (mm²); \(f\)-the strength design value of the steel (N/mm²); \(l_0\)-standing tube calculates the length (mm);

Through the analysis of equation (1), the cross-sectional area of the standing tube is a fixed value, and the higher the axial force design value is, the more likely it is to be unstable. The calculation method of axial force design value is to carry the load combination of the shoring member and the component's self-weight and the half of the total load of the upper load in one longitudinal span[2]. The stability coefficient of axis compression member values according to stud slenderness ratio, slenderness ratio \(\lambda\), the greater the stability coefficient of axis compression member of \(\varphi\) is smaller, according to the type (1) calculate the buckling stress is larger, the more prone to instability. Through analysis, can be diminished by shoring the upper load and reduce the shoring scaffold of slenderness ratio of standing tube spacing, increase shoring scaffold the stability coefficient of axis compression member and so on ways to improve the overall stability of the shoring scaffold.

3.2 Calculation of different span and step bearing capacity of the whole casting

The span selection is 0.9m, 1.2m and 1.5m, and the step distance is 0.6m, 0.9m and 1.2 m, respectively. The stability of the scaffold is determined by calculation results of the axial force design value and the single-root pole. Whether the stability meets the requirements of the specification is based on the yield strength design value of the standing tube is less than the yield strength of steel, 205 N/mm².

Combined with the above analysis and calculation results, it is known that the factors affecting the stability of the riser include span and pace. The span length plays a decisive role in the load area of a single upright standing tube, so the design value of the axial force of a single upright standing tube increases with the span. For the design value of vertical force, the maximum axis force should not exceed 20 kN when the span is less than 1.2 m, and the maximum axis force should not exceed 15 kN when the span is greater than 1.2 m. Therefore, the original construction scheme selected the span 0.9 m and the step distance 0.6 m.

In order to meet the requirements of stability, the stability calculation results of the support single pole under the beam are analyzed. The results show that the stability of the single pole is greatly influenced by the step distance of 1.2 m. Therefore, the size of the step size affects the calculation of the length of the vertical tube, and the step distance has a decisive influence on the stability of the single pole.

To sum up, the stability of the shoring can be improved by reducing the load on the upper part or reducing the slenderness ratio of the bar by reducing the step distance. Therefore, based on the construction technique of composite beam casting, this paper focuses on the two aspects of the span and step distance of the pole, and the stability of the shoring system is checked and optimized.

3.3 Calculation of different span and step bearing capacity of different laminated beams

It is obtained from table 1 that the cross section of the beam is 500 mm×1500 mm. When the shoring span is 0.9 m and the step distance is 1.2 m, the strength reserve is close to the limit, although it meets the requirement of stability. Therefore, the method of composite beam pouring is adopted to reduce the design value of the axial force of the beam under shoring, so as to achieve the purpose of increasing the step and span. That is, pouring concrete with a certain base at the bottom of the 1500 mm beam height. When the strength of the concrete reaches 80%, the upper concrete will be poured again. The span of beam shoring is 0.9 m, 1.2 m and 1.5 m, and the step spacing is checked according
to 0.6 m, 0.9 m and 1.2 m. The height of the first pouring beam varies from 600 mm to 900 mm.

When the beam span is 0.9 m, and the beam height increases from 600 mm to 900 mm, the stability of bracing decreases by 8.78% to 26.36% compared with the height of beam section 600 mm. The percentages of the remaining span stability decreased from 9.05% to 27.17%, 9.22% to 27.69%, and 9.35% to 28.07%. According to the above checking calculation, when the span is 0.9 m, the 1500 mm high beam is divided into the first pouring of 600 mm, 700 mm, 800 mm and 900 mm, and the two pouring of 900 mm, 800 mm, 700 mm and 600 mm after the construction of 900 mm, 800 mm, 700 mm and 600 mm, the stability calculation of the shoring of the beam under the beam meets the requirements.

In order to calculate the stability of the shoring, there are the following shortcomings: for the convenience of calculation, the beam is separated from the shoring, and the load of the beam is transferred to the shoring. The stiffness and strength of the concrete can reduce the internal force of the shoring, and the deformation coordination between the shoring and the concrete beam is not considered. The connections at the shoring nodes are assumed to be rigid or articulated. The calculation of the shoring of the beam is only a standing tube, and the space system is simplified as a plane system. These assumptions are not consistent with the actual conditions in the construction. This article mainly carries on the numerical simulation analysis to the first pouring beam cross section is 600 mm, the overlapping section is 900 mm, the shoring span and the step distance are 0.9 m and 1.2 m respectively.

4. Numerical simulation analysis

In order to solve the deformation coordination between concrete beams and braces, the effect of concrete setting and hardening on shoring and space effect on the stability of beams under braces. In engineering, some engineering software is often used for simulation analysis. This paper simulates the casting of composite beams by means of element life and death function in ANSYS15.0, and carries out buckling analysis of shoring under the beam.

4.1 Selection of model elements

The shoring bar model is established by beam188 element. The element has 3 nodes, each of which has 6~7 degrees of freedom: the translation along the node x, y, z direction and the rotation of the x, y, z axis around the node, and the seventh degree of freedom as the cross section of the warp [3]. The tube is beam188, the cross section is 48 mm×3.0 mm, the yield strength of steel is fy=205 N/mm², the elastic modulus is E=2.06×10¹¹ N/mm², and the density is 7850 kg/m³.

The combin14 spring element is used to establish the connection point of the bowl connection. According in literature [2] to article 5.1.12 and document [4]~[7], when the shoring structure under the beam is considered as a whole, the bowl buckle node should be considered as a semi-rigid node. When the axis of the rod is parallel to the coordinate axis, the rotational stiffness of the axis rotates around the axis of the rod to 9.68×10⁴ kN∙m/rad, and turns around the axis perpendicular to the axis. The dynamic stiffness is 25 kN∙m/rad~40 kN∙m/rad.

The SOLID65 element is selected for the casting and shaping of the beam model. For the convenience of modeling, the reinforced SOLID65 unit is adopted in this paper. The strength of the material of concrete is selected as the design strength rather than the standard strength. The shear transfer coefficient of the crack is extended to βt=0.5, the shear transfer coefficient of the crack is closed to βc =0.95[8], and the modulus of elasticity is determined according to the original tangent modulus of the stress-strain curve, and the Poisson ratio ν=0.2. The stress and strain curves of concrete are modeled by the ascending section of Hongnestad model [8][9], and the multilinear isotropic strengthening model MISO is used to simulate the stress-strain relationship. The stress and strain relationship of two bars is adopted in the reinforcement, and the stress-strain relationship is simulated by the bilinear follow-up hardening model BKIN.

4.2 Establish composite beam and scaffold model under the beam

According to the selection of the above-mentioned model elements, the model of the overall beam and the scaffold model under the beam are established according to the actual situation of the beam.
construction. The scaffolding model is first established, then the whole beam model is established, and then the casting process of the composite beam is simulated by means of element birth and death function. The shoring model is set up first and then the line segment is set up, the whole model is established by the method of copying line segment. Finally, the spring unit is set up at the reclosing node, and the coupling node is coupled. The model shown in Figure 1 is a beam shoring model with span 0.9 m and 1.2 m. The model of cast-in-place beam can be established when the beam shoring model is established.

Convenience to analysis, this paper adopts the method of integrated modeling, this method is gives solid65 element to the corresponding real constant as reinforced concrete, without the need to use other elements as reinforced modeling, real constant values for volume reinforcement ratio. Beam model is set up according to the design of the beam size, the overall dimension beam model is divided into casting parts and composite cross section for the first time, based on the grid size 50 mm grid, using death unit killed composite section and load solution casting parts for the first time, activate composite section again after the completion of load solution. In order to make the force close to the actual situation and avoid the phenomenon of stress concentration when the load is applied, the concentrated load is converted into uniform load. Figure 2 shows the model of the first pouring part of the laminated beam and the construction of the shoring under the beam. The section size of the beam is b×h=500 mm×600 mm, the shoring span of the beam is 0.9 m, and the step distance is 1.2 m.

### 4.3 Analysis of simulation results

According to the result of the model calculation, the maximum displacement of the whole model is 0.38 mm, and the maximum stress of the scaffolding standing tube is 19.80 N/mm², which is 21.91% less than that of the same case: 90.39 N/mm². The axial compressive stress of the shoring bar under the beam can be found to be maximum at the bottom of the beam, and the stress of the lateral shoring bar is the least. The load obtained by buckling analysis is 923.42 kN, far greater than that on the shoring.

When the strength of concrete reaches 80%, the scaffolding underneath the beam is removed and the result of concrete placement is achieved. When the concrete strength reaches 80%, the scaffolding under the beam is dismantled, the deflection of the concrete beam is increased to 5.375 mm, and the mid span deflection is 6.288 mm after pouring the overlapped concrete. As the first pouring concrete has the bearing capacity, it is increased by 0.913 mm compared with the scaffolding of the dismantling scaffolding. Although the increase of deflection is larger than that without unbracing, it is still less than the specification limit. After dismantling scaffolding, the maximum stress of concrete is 3.868 N/mm², and the maximum stress of concrete is 4.151 N/mm² after pouring the overlapped concrete. At this time, the concrete bottom has a small crack.

The simulation results of the beam cross section height of 700 mm to 900 mm and different span and step are as follows: the deflection of the scaffold is 4.46 mm to 2.05 mm, the maximum stress of concrete is 1.39 N/mm² to 1.75 N/mm², and the deflection of the concrete is 5.43 mm to 3.17 mm, and the maximum stress of the concrete is 3.32 N/mm² to 3.30 N/mm². The deflection obtained by the simulation meets the requirements of the specification.

In summary, the deflection of concrete beams and the stress of concrete decrease with the increase of the section size of the first casting. The reason is that the section modulus of beam increases, the neutral axis moves upward, and the bearing capacity of beams increases greatly due to the increase of
beam section height.

When the beam is 600 mm high, the beam can be scaffolding under the beam of 1.5 m and step distance 1.2 m. When the beam is divided into cast-in-place 700 mm or above, the shoring of the beam under the span and the step distance is 1.2 m. In this project, the shoring of the beam under the beam is the span of 1.5 m, the step distance is 1.2 m, and the height of the cross section is 600 mm high. When the strength of the concrete is 80%, the shoring of the beam is dismantled, and the height of the remaining section is 900 mm.

5. Conclusions
(1) For the concrete beams with large cross section, the construction method of composite beams can be used. When the strength of concrete reaches 80% of the load, the scaffolding beneath the beam should be removed, and then the concrete with overlapping sections will be poured. In this paper, the 1500mm high beam is divided into 600 mm to 900 mm, and then pouring 900 mm to 600 mm, so that the method of trabecular lifting beam is realized. And the deflection of the beam is smaller, and the deflection can meet the requirements of the standard, and can also increase the span and step distance of the scaffold under the beam, so as to reduce the cost of the scaffolding and improve the use performance. After simulation, the four kinds of successive casting methods can meet the specifications, but it is advisable to first pour 600 mm and then pour 900 mm into subsections.

(2) The casting method of composite beams with high section concrete beams is beneficial to the recycling of the formwork. In the way of pouring the laminated beam, because of the early dismantling of the scaffold under the beam, the transfer times of the scaffold under the beam can be greatly increased, and the lease time of the scaffold components and accessories can be reduced. At the same time, because of the construction method of the superposed beam, the reduction of the amount of scaffolding ensures the safety and rapidity of the workers during construction.

6. References
[1] Li Ming. Analysis and study on the stress analysis of template shoring scaffold system for large cross-section beams [J]. Construction, 2015, 37 (6): 753-753.
[2] JGJ-166 construction bowl 2016 type steel pipe scaffold safety technical specifications [M]. China building industry press, 2016.
[3] Xin-min wang, yi-qiang li, hong-wei xu. ANSYS structural analysis unit and application [M]. People's traffic press, 2011.
[4] Liang Chaoan, liu fang, still, etc. _ Liang Chaoan steel concrete composite beam formwork construction technology [J]. Journal of construction technology, 2015, 10 (2): 126-126.
[5] Zou, quan-wang li, He Minghua, etc. Based on the three line of semi-rigid node model bowl scaffold mechanical finite element analysis [J]. Journal of building structures, 2016, 37 (4): 151-151.
[6] Gao Qiuli. Bowl buckles type steel pipe scaffold and shoring scaffold frame mechanical performance test and analysis [D]. Tianjin University, 2011.
[7] Bin Wang Bowl type high modulus construction technology research and application [D]. Anhui University of science and technology, 2015.
[8] Jian-jing, Jiang Xin-zheng Lu. Finite element analysis of concrete structure [M]. Tsinghua university press, 2013.
[9] Li-feng,li,lian-hua,Wang. ANSYS civil engineering example explanation [M]. People's posts and telecommunications publishing house, 2015.