Analysis of Mechanical Performance and Application of Composite Plates with Special Curved Surfaces

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Abstract: Taking the canopy project of Zhengzhou South Railway Station as an example, based on ABAQUS software, the mechanical performance of special-shaped curved laminated plate under three working conditions, such as hoisting condition, transportation condition and stacking condition, is analyzed. In this paper, the design and production process of special-shaped curved laminated plate are studied. The simulation results show that: under the condition of demoulding, the spacing of truss bars does not control the deflection caused by demoulding, and the member does not produce large displacement under different spacing arrangement of truss bars; It is better to reduce the stacking layers of laminated plates by using four point support mode than by changing the support mode. Because of the large curvature, short age and too many stacking layers, the deflection of the laminated plate will be too large. Even if the support method is adopted on both sides, the excessive deflection is still not suitable for engineering use. Through the research on the mechanical performance of special-shaped curved composite plate under three different working conditions, the optimal truss reinforcement spacing and support mode of special-shaped curved composite plate are obtained, which has high engineering application value.

Keywords: Prefabricated Station Canopy; Special Curved Composite Plate; Finite Element Analysis

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1 Introduction

The current assembly building is increasingly concerned with the attention of all parties, which is one of the most widely used and fastest-growing structural systems. [1, 2] Prefabricated now superimposed components are made up of prefabricated lamellar components and rear concrete, [3] which are commonly used in the housing construction project. [4, 5] The steel structure system is used in the domestic station, but the corrosion resistance is not easy to maintain, and the current station is also gradually trying to use the fabricated concrete structure system. [6-8]

The different surface laminated plate is applied to the roof layer of the station, which has the advantages of non-maintenance, decoration and fast construction. However, the different surface superplate components have problems such as complex and vulnerable conditions in the production and transportation stage.

At present, the relevant scholars at home and abroad have conducted some studies on the heterogeneous surface components, and the construction process of the different type of the cylindrical type is summarized, and the main points of the template reinforcement system, the

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concrete pouring and the installation of the components are analyzed, and the problems of the middle class of the construction process are solved. [9, 10] The performance of the laminated plate in the use stage is analyzed, [11] and the construction truss is increased by the bottom of the laminated plate, and the paper puts forward the form, [12] the inspection method and the means of transportation, and the quality of the laminated plate is proposed. [13, 14]

At present, there is no research on the stress performance of the different operating conditions of the different operating conditions of the heterogeneous surface. [15, 16] In this paper, the stress state of the laminated plate in different working conditions is simulated by using the loading plate of the building of an assembly concrete structure, and the stress performance of the laminated plate is analyzed, and some reference for the subsequent similar components are provided. [17]

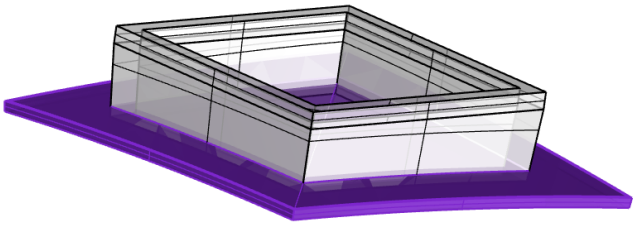


Figure 1 Model of laminated plate with skylight surface

2 Project Profile

Located about 6 kilometers southeast of Zhengzhou Airport, Zhengzhou South Railway Station is an important part of Zheng-Wan and Zheng-fu high-speed railways, as well as one of the important hub stations of the meter-shaped high-speed railway network in Henan Province. The design scale is 16 units with 32 lines. The awning structure project consists of two areas, located on the north and south sides of the station building. The roof section is wavy. The structure adopts reinforced concrete frame columns, grid beams, rail-oriented steel-framed concrete longitudinal beams and prefabricated concrete laminated slabs, which are fair-exposed concrete. The length of the single roof is 97.7m in the direction of the rail and 370m in the direction of the vertical rail. The height of the arch is 3.7m, and the height of the highest point from the track layer is 16.73m. The total construction area of the canopy area is 67,000 square meters.

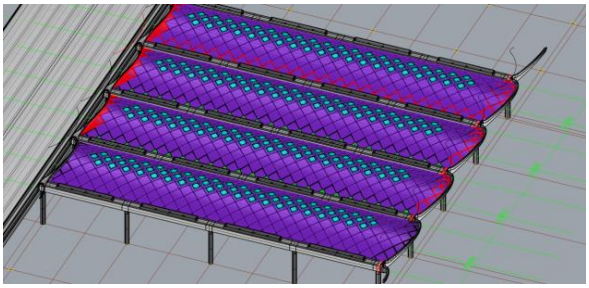


Figure 2 Overall effect

3 Finite Element Model Establishment

There are four types of special-shaped surface laminated plates, namely, triangular plate, pentagon plate, diamond plate and diamond plate with skylight. The curvature of the plate is 13652mm. The dimensions used in this paper are 2479mm×2479mm, and the longest diagonal direction is 3477mm.

According to the actual stress conditions of the special-shaped surface laminated slab, the stress models under lifting conditions, transportation conditions and stacking conditions were established respectively. Based on the CEB-FIP1990 standard model, the creep value of concrete under stacking conditions was calculated by using the UEXPAN subroutine [3] to write the shrinkage method.

The finite element model was established based on ABAQUS, and C3D8R unit was selected as the element type of concrete and steel column. In order to reduce the number of units and better simulate the stress situation of rebar, the type of rebar unit is T3D2 unit.

In the grid division, the concrete and steel column elements are distributed with 0.1 spacing, and the reinforcement elements with 0.01 spacing. All contacts in the paper are selected according to Tie contacts. Figure 3 shows the finite element assembly model.

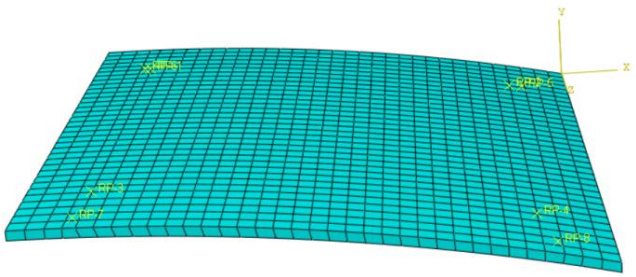


Figure 3 Finite element assembly model

4 Analysis of Simulation Results

Based on the stress state of prefabricated curved composite plate under different working conditions such as lifting, transportation and stacking, 14 models were established respectively. The variation of deflection and crack of composite plate under 14 working conditions is compared and analyzed.

The finite element model information under different working conditions is shown in Table 1.

Table 1 Finite element model information under different working conditions

	Side bracing	Four-point bracing	Age of laminated plates	Number of stacked boards
Transport condition	A2	B2	/	4 pieces
	A3	B3	/	6 pieces
Stacking condition	A4	B4	1day	4 pieces
	A5	B5	7day	
	A6	B6	1day	6 pieces
	A7	B7	7day	

4.1 Mechanical Performance Analysis of Composite Plates Under Lifting Conditions

In the hoisting condition, the spacing of truss bars plays a crucial role in the deformation of composite plates. The finite element model of the truss bar spacing of 600mm (A1) and 400mm (B1) was established to compare and analyze the deformation of the composite plate.

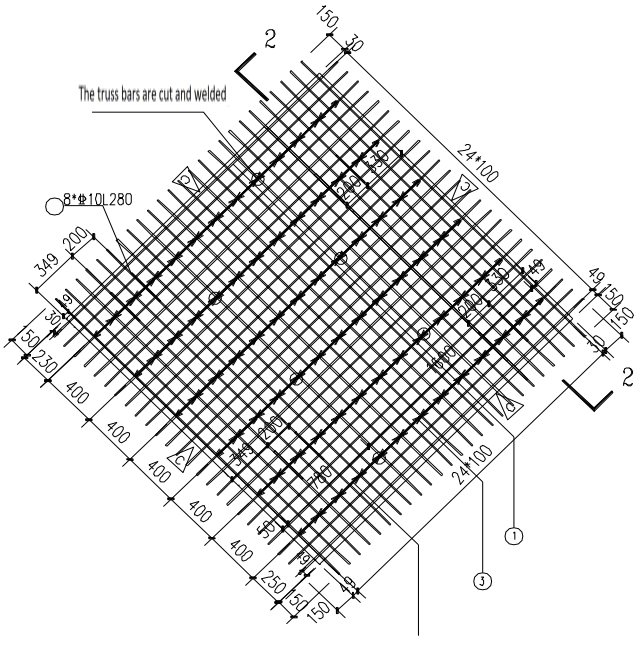
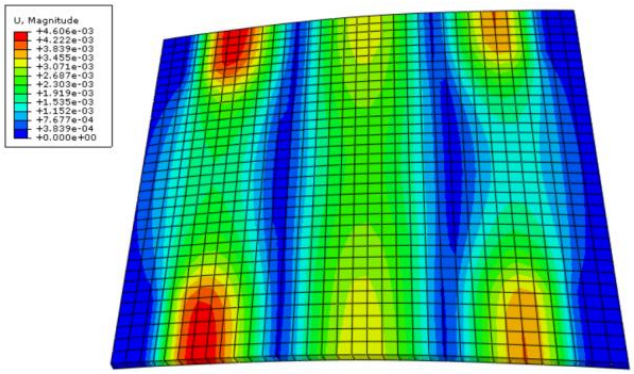
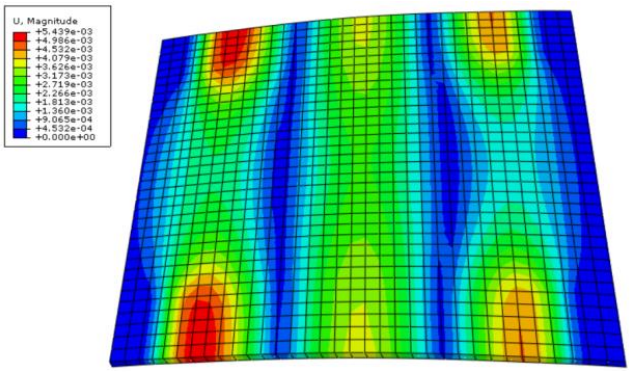


Figure 4 400mm spacing diagram of truss bars

According to the comparison of models A1 and B1, the maximum displacement of A1 member and B1 member is 4.61mm and 5.44mm in the lifting and demudding process, and the maximum displacement appears around the lifting point. The lifting of this project is carried out by the hook hanging on the upper string of the truss, and the bottom is arranged with reinforcing bars. Small deformation occurs in the middle of the composite plate under vertical tension. However, under the arrangement of different truss bar spacing, there is no significant displacement.



(a) Stress cloud map of model A1



(b) Stress cloud map of model B1

Figure 5 Stress cloud image

4.2 Mechanical Performance Analysis of Laminated Plates Under Transportation Conditions

By selecting two typical support modes of composite plates supported by four points and two sides, the influences of different support modes and stacking layers on the mechanical properties and cracks of composite plates under transportation conditions are analyzed.

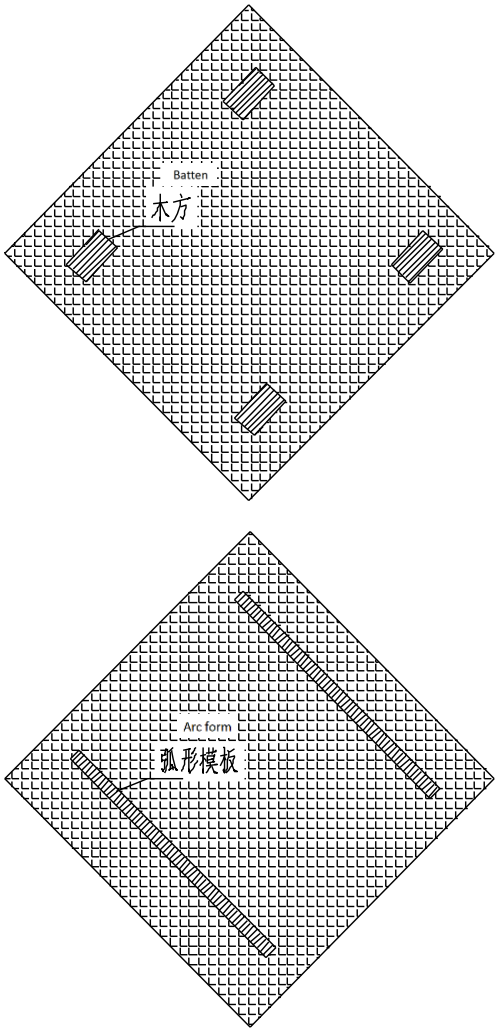


Figure 6 Schematic diagram of composite board support

Comparing the deflection curves of the two models in the figure, it can be seen that the deflection of the superimposed plate decreases layer by layer with the increase of the number of layers, and the deflection of the superimposed plate at the top is the lowest value. Among them, the deflection of the topmost composite plate model A2 and A3 with two-sided support mode is 0.5mm, and the deflection of the topmost composite plate model B2 and B3 with four-point support mode is 1.2mm.

The maximum deflection of B3 composite board is 9.8mm, while the maximum deflection of A3 composite board is 7mm, and the deflection of B3 is 40% less than that of A3 composite board.

The bottom deflection of B2 composite plate is 5.6mm, which is 75% less than that of B3 composite plate. The lowest deflection of the fourth layer of B2 is 1.4mm less than that of A3. It can be seen from the data that even if the four-point support mode is used for transportation, reducing the number of stacked layers of the laminated board is still better than changing the support mode.

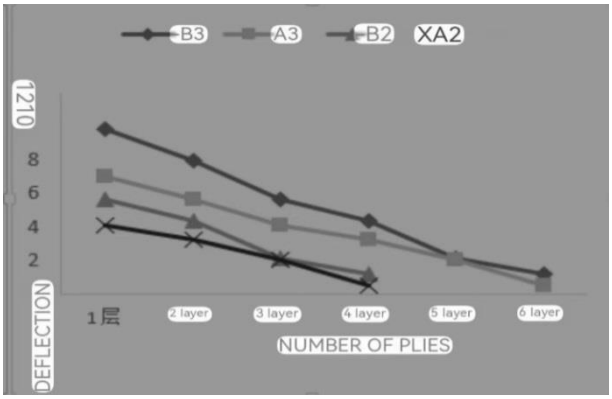


Figure 7 Deflection curve of composite plate under transportation condition

4.3 Analysis of Mechanical Performance of Laminated Plates Under Stacking Conditions

By comparing the composite plates of different ages, the influence of different bottom support modes on the deflection of composite plates under stacking conditions is analyzed.

As can be seen from the figure below, under stacking conditions, the one-day age composite board B6 with four-point support has the largest deflection, with a maximum value of 10mm, followed by the composite board of the B7 model, with a maximum value of 9mm. In general, the deflection value of the bottom two layers of laminated plates is larger after the stacking of more than 4 layers. In engineering practice, the laminated board with cracks also exists in the bottom two layers of the 6-layer laminated board.

Due to the large curvature of the curved composite plate, the short age period and the excessive number of stacking layers, the deflection of the composite plate will

be too large, even if the method of supporting both sides is adopted, the excessive deflection is still no longer suitable for engineering use.

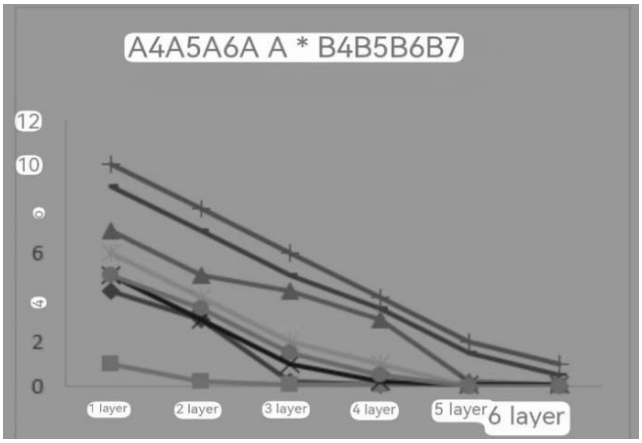


Figure 8 Deflection curve of laminated plate under stacking condition

5 Research on Design and Production Technology of Curved Laminate

5.1 Design and Research of Curved Lamination Board

The awning span of this project has many dimensions, and the laminated panels of different dimensions can not be completely used. According to the architectural structure drawing, Rhino3D software was used for modeling in order to make the size of the composite panel members accurate.

According to the structural design drawing, the further design of the cast-in-place joint is carried out, including the size of the protruding steel bar of the laminated plate, the connection form of the cast-in-place joint steel bar, etc.

Due to the large arc of the member, the superimposed plate truss bars cannot be bent. In order to ensure that the height of the superimposed plate truss bars meets the design requirements, the truss bars are cut at 780mm away from the edge. When the member is poured and before being hoisted, the side bar welding should be carried out in time.

5.2 Research on Production Technology of Curved Laminate

Since the bottom of the canopy is a clean water component, the bottom mold joint and the finished product look and feel are stricter than ordinary components. Through the mode of sample test, a number of mold splicing methods are adopted. At the same time, in order to ensure that the component placement meets the thickness requirements and increase the concrete collapse, the vibration method is independent.

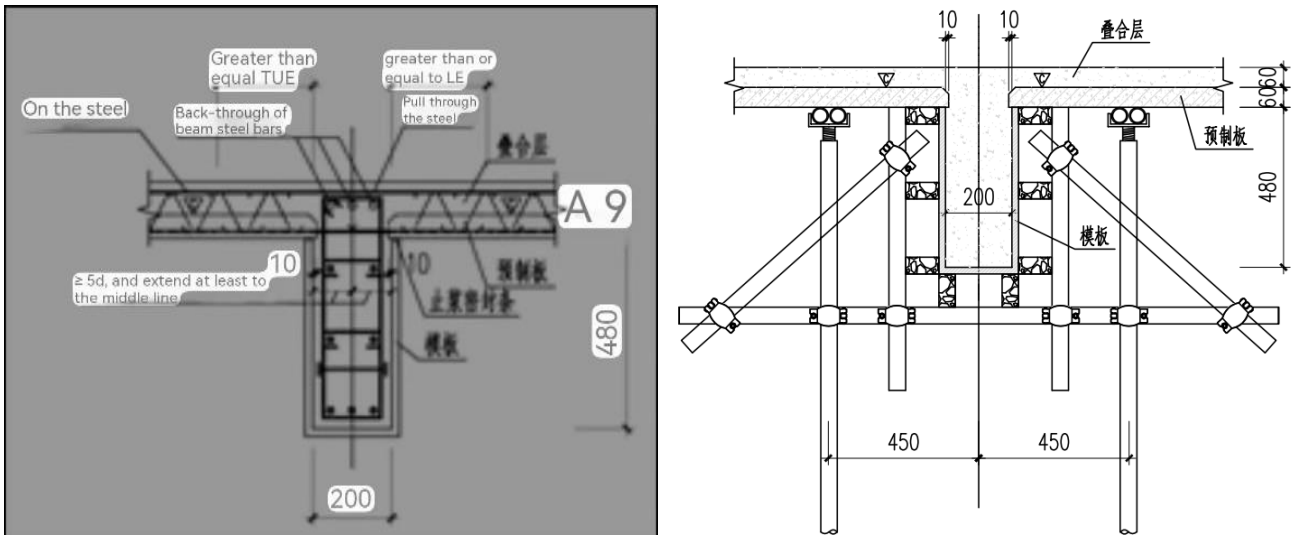


Figure 9 Composite board support diagram

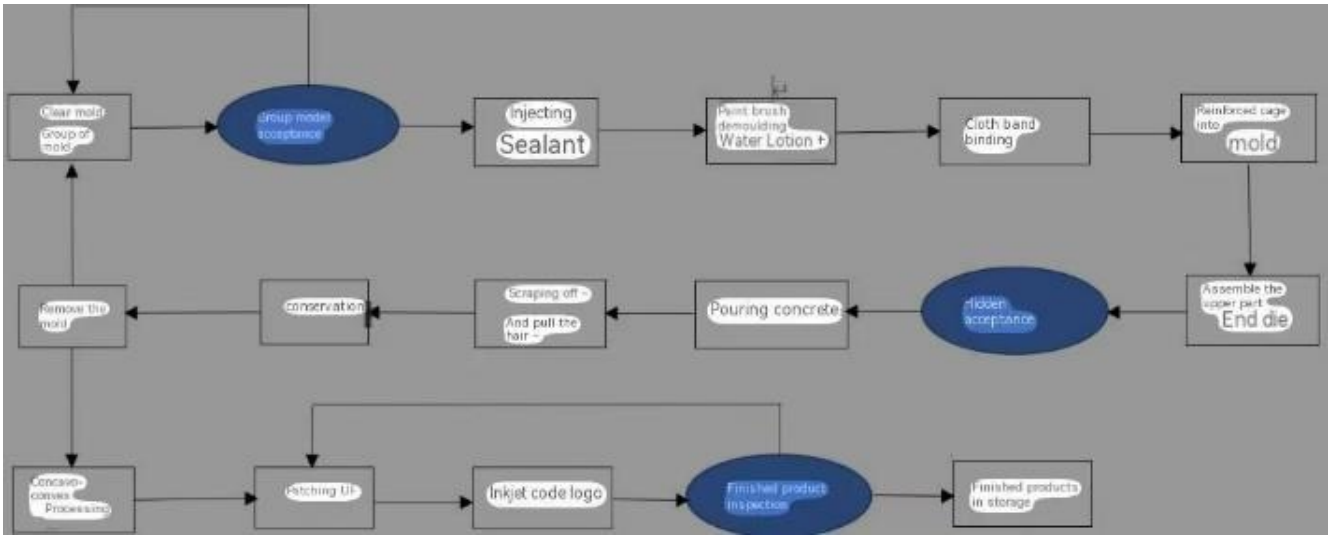


Figure 10 Production process flow char

6 Conclusions

1) In demoulding and lifting conditions, since the member already has a certain strength and the die adsorption force is uniform load, the spacing of truss bars does not control the deflection caused by demoulding, and the member does not produce a large displacement under different layout of truss bar spacing.
2) The maximum deflection of B3 composite board is 9.8mm, the maximum deflection of A3 composite board is 7mm, and the deflection of B3 is 40% less than that of A3 composite board. The bottom deflection of B2 composite plate is 5.6mm, which is 75% less than that of B3 composite plate. The lowest deflection of the fourth layer of B2 is 1.4mm less than that of A3.

Even if the four-point support mode is used for transportation, reducing the number of stacked layers of the laminated board is still better than changing the support mode.

3) In engineering practice, the laminated board with cracks also exists in the bottom two layers of the 6-layer laminated board. Due to the large curvature of the curved composite plate, the short age period and the excessive number of stacking layers, the deflection of the composite plate will be too large, even if the method of supporting both sides is adopted, the excessive deflection is still no longer suitable for engineering use.

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