Key Construction Technologies for Large-Span Spatial Truss Structures in Areas Prone to Typhoons

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Abstract. The construction of large-span spatial truss structures faces severe challenges such as strict control of component processing accuracy, complex sectional hoisting conditions, and high requirements for synchronous sliding and unfolding. This paper studies the key technologies for the construction of large-span spatial truss structures in combination with the construction of spatial truss structures with a span of 145 meters. By integrating temporary structure design based on numerical simulation, high-precision positioning and welding deformation control, a technology for high-precision fabrication and segmented precise installation of steel trusses was formed, achieving the control target of component fabrication and installation error not exceeding 4mm. A multi-point sliding unfolding technology for large-span spatial trusses based on modular hydraulic pump sources and computer synchronous control was developed, and the synchronous jacking operation of 12 jacking points was successfully achieved, with synchronous error controlled within 10mm. By adding temporary measures, the spatial truss sliding system successfully withstood a typhoon of level 11 before the structure was formed, which is of great reference significance for similar projects.

Keywords: Large span, Spatial truss structure, Fabrication, Sectional hoisting, Sliding jacking, Resisting typhoons

1 Introduction

Large-span spatial trusses are widely used in large public buildings such as sports venues, exhibition centers and industrial material sheds because of their beautiful form, reasonable force and open interior space. However, there are a series of challenges in building such structures in coastal areas prone to typhoons. It is difficult to control the precision of processing and assembly of large-span steel truss components[1-3]; The sliding construction technology of large-span spatial trusses has a high safety risk of jacking synchronous control[4-5]; In the past, the assembly of large roof trusses was generally

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carried out in inland areas far from the sea, and there were few cases of large roof truss construction in open sea areas[6-7]. During the construction period, when the structural system was not fully formed, its resistance to extreme typhoon loads was far lower than the design state, and anti-typhoon measures became the key to the construction technology[8-10].

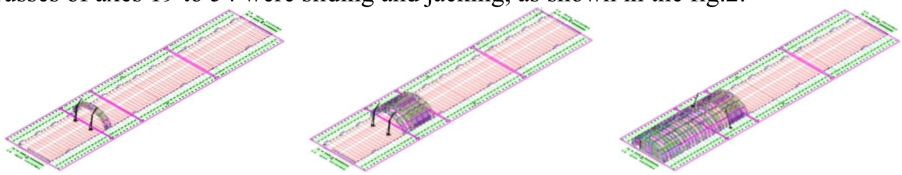
The structure of this project adopts a spatial truss system, with a single truss span of 145 meters, a total structure length of 1035 meters, a height of 49.985 meters, seismic spherical hinge supports, a spatial triangular tubular truss form, and material Q355B[11]. As shown in Fig.1.

Fig. 1. Completion renderings of the project

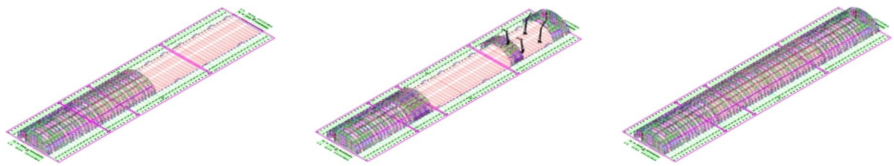
The east side of the project is close to the sea and has a subtropical monsoon climate with frequent typhoons in summer and autumn. From January 2011 to October 2025, there will be 37 days with winds of force 8 or above and 8 days with winds of force 10 or above in the area. Typhoons such as Bebica, Mahogany, Hagupit and Lekima have all had an iMPact in the area.

2 Methodology

The spatial truss structure of this project was constructed using the "in-situ installation + sliding jacking" scheme. There were 72 main trusses, each weighing up to 194 tons, which were hoisted in three sections, with a maximum hoisting weight of 70 tons per section. Among them, trusses of axes 1 to 18 and 55 to 72 were installed in situ, and trusses of axes 19 to 54 were sliding and jacking, as shown in the fig.2.



(a) Phase 1 (b) Phase 2 (c) Phase 3



(d) Phase 4 (e) Phase 5 (f) Phase 6

Fig. 2. Schematic diagram of each construction phase of segmented hoisting

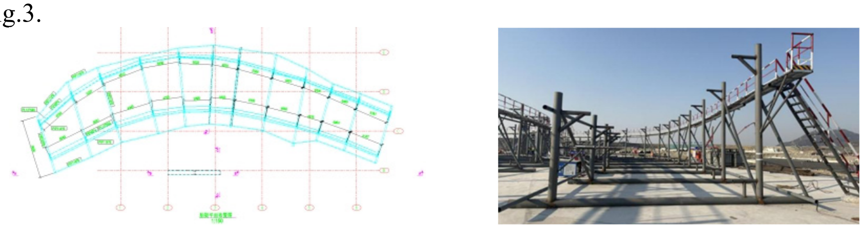
- Phase 1: Install the 37-38th axis truss at the 53-54th axis truss position;
- Phase 2: Slide the 37-38th axis truss 5 meters in the 1st axis direction, install the 39 axis truss and the temporary connecting rods, and repeat the above steps to complete the stacking installation of the 40-54th axis truss;
- Phase 3: Install the 55-72nd axis trusses in place;
- Phase 4: Open the temporary connecting rods of axes 52nd to 53th, slide the trusses of axes 37th to 52nd towards the 1st axis direction by the distance of one truss foundation, install the secondary trusses of axes 52nd to 53th, and repeat the above steps to complete the sliding and unfolding of the trusses of axes 37th to 52nd;
- Phase 5: Install the trusses of axes 1st to 6th in place and stack the trusses of axes 19th to 36th at the position of axes 16th to 20th using the method of Phase 2;
- Phase 6: In-situ installation of the 7-18th axis trusses, using the method of Phase 4 to slide and unfold the 19-36th axis trusses.

3 Key Construction Techniques

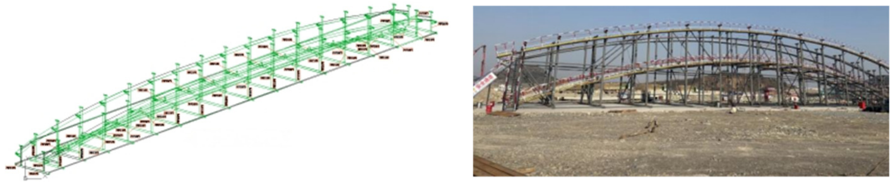
3.1 Steel Truss Arch Section Fabrication

The precision of the steel truss arch fabrication is the basis for ensuring the construction quality and safety of the large-span spatial truss structure system. The design of the processing formwork, the sequence of assembly and welding, and the control of the welding process are very important.

3.1.1 Design of the Processing Formwork.
The single truss structure is constructed by hoisting in three sections. Therefore, the processed formwork is designed in three types: A, B, and C, all of which are made of Q235 steel pipes. The cross-sectional forms are φ219×8 and φ114×6. The formwork of type A and C is 5 meters high, and that of type B is 6.354 meters high.As shown in Fig.3.



(a) Design drawings of Type A and C frame (b) Photos of Type A and Type C frame



(c) Design drawing of Type B frame (d) Photo of Type B frame

Fig. 3. Frame design form

3.1.2 Single Truss Processing Procedures.

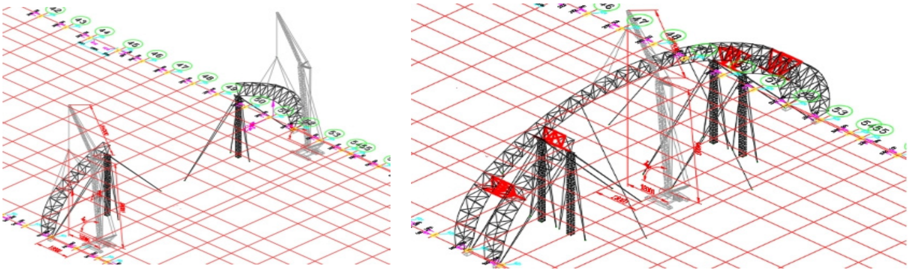
Truss assembly follows the process of "first chord, then web, and welding after positioning qualified". During the chord installation phase, each of the three chord members is hoisted to the designated position of the formwork one by one. The elevation of each positioning point is measured using a level, and the positioning points are projected onto the ground by a plumb Bob to measure the horizontal coordinates. Through the coordinated control of elevation and horizontal coordinates, it is ensured that the three-dimensional dimensions of the truss meet the design requirements. During the installation of the web members, a centerline is projected at each node, and the precise positioning of the web members is achieved through the control of the centerline position. After all the members have been assembled, the assembly accuracy of each member is checked and the welding operation is carried out only after the inspection is qualified.As shown in Fig.4.

(a) String rod installation (b) Ventral rod installation (c) Welding sequence

Fig. 4. Single-piece truss fabrication process

3.2 Hoisting of Large Span Steel Truss Arch Sections

A scheme for hoisting steel truss arches in sections with the assistance of temporary support frames. First complete the overall horizontal assembly of the support frame on the ground, and then use a 350t crawler crane to lift it to the designed installation position. To ensure the continuity of the construction, two sets of support frames were set up in an alternating operation mode. After each set of support work was completed, the top support columns were removed first, then symmetrically lifted out of the truss operation area by two 80t truck cranes, and finally the crawler cranes transported the support frames to the position of the next truss to provide support for the hoisting of the A and C sections of the next truss.As shown in Fig.5.



(a) Installation of sections A and C	(b) Installation of section B

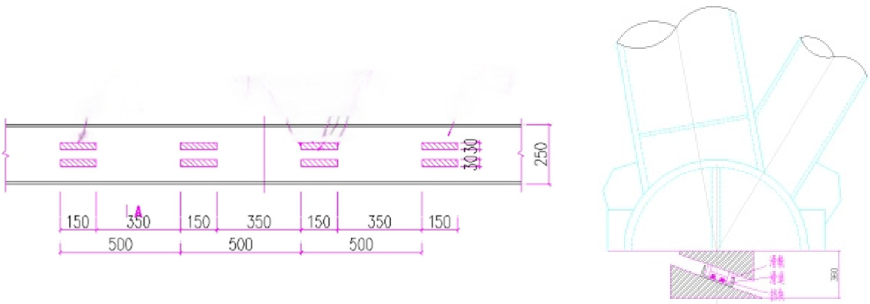
Fig. 5. Structural deformation analysis

3.3 Steel Truss Arch Sliding Construction Method

For the 19-54 axis trusses, a construction technique of first stacking and then sliding and unfolding the trusses in sequence is adopted, which requires high requirements for the design of sliding tracks and the selection of sliding equipment, the simulation analysis of the construction process, and the control of synchronous sliding construction.

3.3.1 Design of Sliding Tracks and Selection of Sliding Equipment.

1. Sliding track design: The sliding track structure plays a role in load-bearing, guiding, and laterally limiting the horizontal displacement of supports during the sliding process of the truss structure. A total of 12 sliding tracks are set up, with one pusher point every two truss supports. The centerlines of the sliding tracks coincide with the centerlines of the supports and are welded to the support embedded parts. A 30×30×150mm sliding block is set up every 500mm and welded to the web of the sliding beam. The installation error of the side blocks on both sides of the same sliding beam is less than 1mm, and the spacing error of the side blocks of adjacent slides is less than 3mm.As shown in Fig.6.



(a) Sliding track plan view	(b) A cross-sectional view of the sliding track

Fig. 6. Schematic diagram of sliding track design

2. Selection of sliding equipment: The hydraulic jack adopts a combined design. The rear part is connected to the slide way through a jacking device, the front part is connected to the The pushed structure through a wrist and connecting plate, and the main hydraulic cylinder is used in the middle to generate the driving thrust. One 100t Hydraulic pusher is arranged at each pusher point. A single jack has a thrust weight of 304t, a coefficient of friction of 0.15, a coefficient of resistance of 1.3, and a maximum thrust required by a single jack is 59.28t. The rated thrust of a single 100t Hydraulic pusher is 100t, and the reduction factor is taken as 0.7. Then, the total thrust at the pusher point is designed as 70t>59.28t, which meets the requirements.As shown in Fig.7.

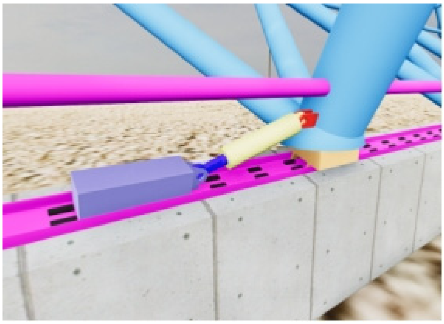


Fig. 7. Schematic diagram of jack installation at the pusher point

3.3.2 Construction Techniques.

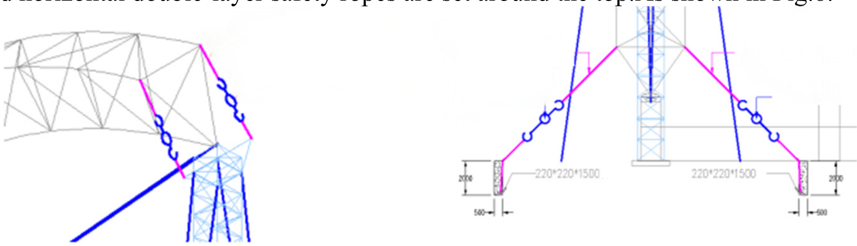
1. The sliding working process: The Hydraulic pusher stop block is installed on the slide way. The hydraulic cylinder ear plate of the main hydraulic cylinder is connected to the The pushed structure through a wrist. The main hydraulic cylinder Stretching, pushing the The pushed structure to slide forward. After one stroke of the main hydraulic cylinder is fully extended, the The pushed structure remains stationary while the main hydraulic cylinder is retracted, causing the jacking device and the slide vane to loosen and move forward along with the main hydraulic cylinder. After the main hydraulic cylinder has completed one stroke of shrinking, drag the jacking device forward by one step distance. Repeat the above steps to complete the sliding of the steel truss.
2. hydraulic pump system: The hydraulic pump system provides hydraulic power for the Hydraulic pusher and completes corresponding actions under the control of various hydraulic valves. To enhance the universality and reliability of the hydraulic jacking equipment, the design adopts a modular structure, allowing for the combination of multiple modules. Each set of modules takes a hydraulic pump system as its core and can independently control a group of Hydraulic pusher. Meanwhile, a Proportional valve box can be used for multi-lifting point expansion to meet the actual needs of various types of sliding projects.
3. Sliding synchronous control: The synchronous control system consists of the power control system, power drive system, sensor detection system and computer control

system. The hydraulic synchronous jacking construction technology adopts the travel displacement sensor monitoring and computer control to achieve fully automatic synchronous action, load balancing, attitude correction, stress control, operation interlock, process display and fault alarm functions.

3.4 Construction Methods for Resisting Typhoons

3.4.1 Design of Temporary Support Frames for Typhoon Resistance.

Tie ropes are set on all four sides of the support frame. Tie ropes are pulled at the top of the support frame. Tie ropes on the foundation side are connected to the embedded parts of the support through ear plates, and tie ropes on the other three sides are connected by horizontal ground anchors. The base of the support frame is made of HW300*300 steel, the top is made of HW300*300 steel, and vertical movable railings and horizontal double-layer safety ropes are set around the top.As shown in Fig.8.



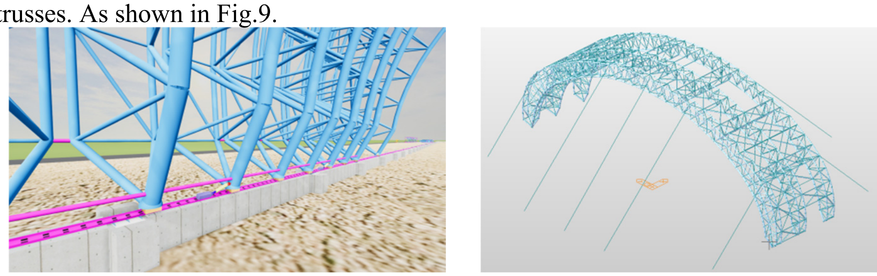
(a)The position of the support points is laterally connected

(b)Lateral connection at the support position

Fig. 8. Schematic diagram of the anti-platform design of the temporary support frame

3.4.2 Arch Bracing Design.

The arch bracing is designed with a combination of guy ropes and temporary tie rods. Due to the construction of superimposed installation and sliding expansion, the secondary trusses of the permanent structure cannot be installed temporarily. To ensure structural safety during the sliding process, temporary tie rods are added, using Q235B, P168*8 steel pipes welded to the front and rear trusses; To enhance structural safety, five pairs of wind ropes are set in the mid-span to increase the wind stiffness of the trusses. As shown in Fig.9.



(a)Temporary tie rod design

(b)Guy rope design

Fig. 9. Schematic diagram of arch frame anti-platform design

4 Results

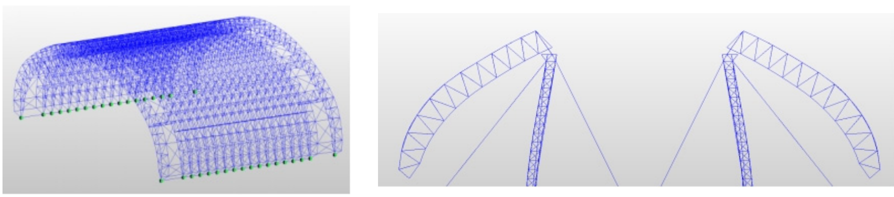
Typhoon Bamboo Grass made landfall in July 2025, with maximum wind speeds of 25m/s and central pressure of 978hPa. The spatial truss deformation, stress and slip process synchronization error were monitored during the typhoon's landfall.

1. During the passage of Typhoon "Bamboo Grass", the deformation of the structure increased as the typhoon approached. The maximum deformation of the structure was 149 mm, located at the top of the 37-axis arch, and no deformation damage occurred to the structure.
2. During the passage of Typhoon "Bamboo Grass", the structural stress increased as the typhoon approached. The maximum tensile stress of the structure was 133 MPa and the maximum compressive stress was 148 MPa. The maximum allowable tensile stress is 470MPa and the maximum allowable compressive stress is 305MPa as stipulated in 《Standard for design of steel structures》(GB50017-2017).
3. Feedback data from the sliding synchronization control system, synchronization error no more than 10mm, synchronous control of 12 pusher points, undamaged sliding system in typhoon environment, high quality and safety reliability.

5 Discussion

5.1 Simulation Analysis of Assembly Construction

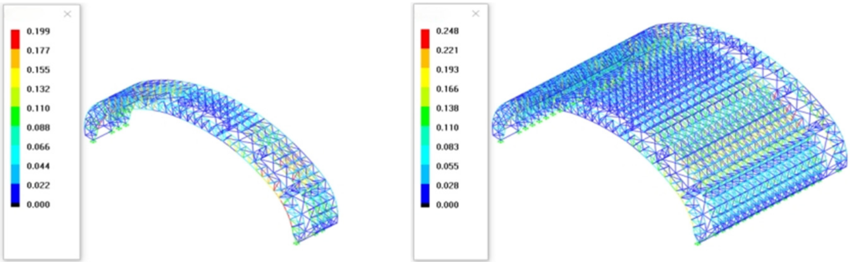
1. Structural deformation analysis: A finite element model of the spatial truss structure was established using Midas Civil for structural deformation analysis. The calculation results indicated that the maximum deformation of the structure occurred during construction phase 1, that is, during the installation of trusses on axes 37 to 38. The maximum lateral displacement occurred when trusses A and C were placed on the temporary support frame, at the apex of the support frame, with axes 37 and 38 being 9.39mm and 10.51mm respectively; The maximum vertical displacement occurred at the arch of the B section of the truss, at the apex of the support frame. The 37 and 38 axes were -14.42mm and -12.01mm respectively. At this time, the vertical displacement at the mid-span of the 37 and 38 axis trusses was -13.37mm and -9.98mm, both meeting the requirements. As shown in Fig.10.



(a) Spatial truss model (b) 37-38th axis deformation

Fig. 10. Structural deformation analysis

2. Internal force analysis of the structure: A finite element model of the spatial truss structure was established using Midas Civil for internal force analysis of the structure. The calculation results indicated that the maximum tensile stress of the structure was 25.5MPa and the maximum compressive stress was -37.9MPa, both of which occurred during the installation of the 54-axis truss and were respectively located in the waist and web members of the 38-axis truss arch and the inner chord members of the 38-axis truss arch foot, meeting the requirements. As shown in Fig.11.



(a) Installation of the 37th to 39th axes (b) 37-54th axis mounting

Fig. 11. Structural deformation analysis

5.2 Slip Simulation Analysis

1. Structural deformation analysis: A finite element model of the spatial truss structure was established using Midas Civil. The calculation results indicated that the maximum vertical displacement of the structure occurred during the first slip expansion, at -27.168mm, at the top of the 19-axis truss arch; The maximum vertical displacement was -25.961mm after full sliding expansion, located at the top of the spatial truss structure system, and the structural deformation during the sliding expansion met the requirements. As shown in Fig.12.

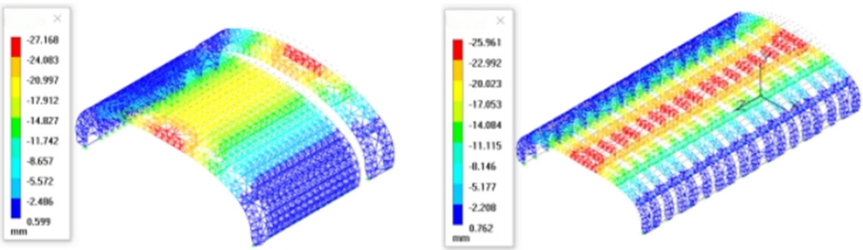


Fig. 12. Structural deformation analysis

2. Internal force analysis of the structure: A finite element model of the spatial truss structure was established using Midas Civil for internal force analysis of the structure. The calculation results indicated that during the sliding unfolding of the spatial truss structure, the maximum stress ratio under each construction condition was 0.259 to 0.270, all of which met the requirements. As shown in Fig.13.

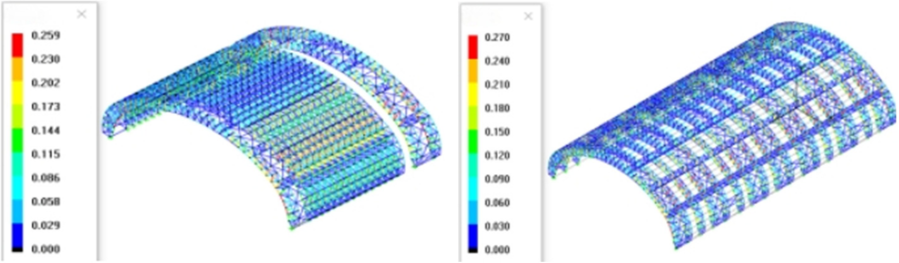
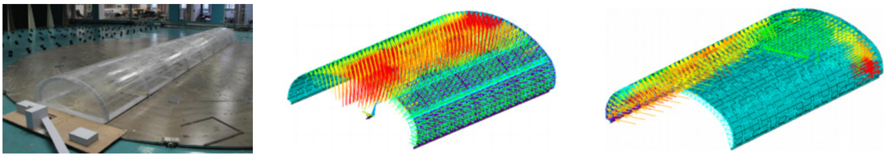


Fig. 13. Internal force analysis of the structure

5.3 Typhoon Resistance Simulation Analysis

1. Wind tunnel test analysis: A 17th-level typhoon wind tunnel pressure test study was conducted on the spatial truss structure by creating a 1/150 scale model. The calculation results indicated that the minimum extreme wind pressure was -9.68kPa and the maximum extreme wind pressure was 4.35kPa. The wind loads in the standard section and the gable section are mainly vertical wind loads, and the main force-bearing wind direction of the structure is the short axis direction of the material shed. The unfavorable wind direction angles in the standard section are mainly 180°, 190°, 340°, 350°, and in the gable section are mainly 200°, 210°, 330°, 340°. The wind vibration coefficients of each block structure at different wind direction angles were also obtained, which can be used for parameter selection in numerical simulation analysis. As shown in Fig.14.

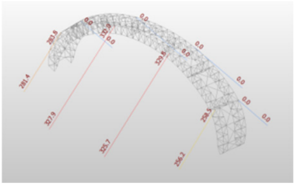


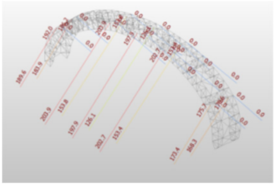
(a)1/150 scale model (b)Standard segment model (c)Gable segment model

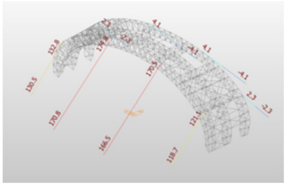
Fig. 14. Arch foot anchoring measures

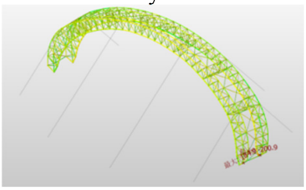
2. Numerical simulation analysis: The basic wind pressure at the location of the structure is relatively high, the overall structure height is relatively high, and the influence of wind load is dominant during the construction process. Therefore, Midas Civil software was used to verify the typhoon resistance under three most unfavorable conditions: assembling two trusses with guy ropes (Condition 1), assembling three trusses without guy ropes (Condition 2), and assembling three trusses with guy ropes (condition 3), and to analyze the displacement of the trusses and the internal force of the guy ropes under a wind load of level 17. The calculation results show that the maximum displacements of trusses under conditions 1, 2, and 3 under typhoon level 17 are 207mm, 190mm, and 204mm respectively, and the maximum tensile stresses are 201.9MPa, 225.3MPa, and 210.4MPa respectively. The maximum compressive stresses are 222.9MPa, 244.8MPa and 215.9MPa respectively, meeting the Standard

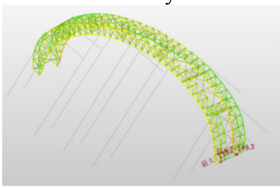
for design of steel The maximum allowable tensile stress is 470MPa and the maximum allowable compressive stress is 305MPa as 《Standard for design of steel structures》(GB50017-2017).As shown in Fig.15.


(a)Condition 1- Displacement analysis


(b)Condition 2- Displacement analysis


(c)Condition 3- Displacement analysis


(d)Condition 1- Internal force analysis


(e)Condition 2- Internal force analysis

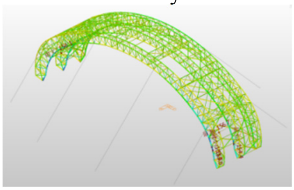
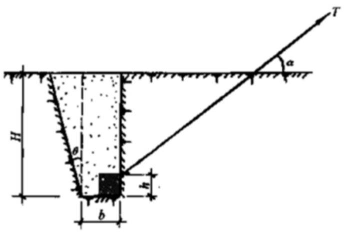

(f)Condition 3- Internal force analysis

Fig. 15. Analysis of typhoon resistance capacity

3. According to the wind load calculation results, the maximum tensile force on the ground anchor occurs at the first working condition, with a tensile force of 203.9kN. Based on the calculation results, the ground anchor was designed with a specification of 48.8cm×48.8cm×2m, with a burial depth greater than 4.035m, and the material was HW500×500 steel. Effective measures were adopted to fix the arch foot and restrict its movement in the longitudinal and transverse directions, with a binding force of no less than 285.5kN, meeting the requirements.As shown in Fig.16.



(a)Design of ground anchors


(b)Arch foot slipper fixation

Fig. 16. Arch anchor measures

6 Conclusion

The key technologies for the construction of large-span spatial truss structures in typhoon-prone environments were analyzed and applied in this project, and the conclusions are as follows:

1. By integrating the research on temporary structure design based on numerical simulation analysis, high-precision positioning and installation methods, and welding deformation control, the "High-precision Processing and Manufacturing Technology for steel truss" and the "Precise segmented Installation Technology for large-span steel truss" have been developed, achieving a maximum axis error of no more than 2mm The Standard for acceptance of 《Standard for acceptance of construction quality of steel structures》(GB50205-2020) meets the requirement of less than 4mm.
2. Based on the modular hydraulic pump source system and synchronous control system, the "Key Technology for Synchronous Control Construction of Multi-point Sliding Expansion of large-span Spatial Trusses" has been developed, with a synchronous error not exceeding 10mm. It is much smaller than the requirement of no more than 50mm in the 《Technical specification for space frame structures》(JGJ7-2010), and the synchronous control of 12 thrust points has been achieve.
3. Wind tunnel test analysis and numerical simulation analysis were conducted on the construction of large-span spatial truss structures under a typhoon of level 17. The "Key Technologies for Typhoon Resistance Construction of large-span Spatial Truss Structure System" were developed. By adding temporary cable facilities and reasonably setting temporary tie rods between trusses, achieve the large-span spatial truss structure resisting relatively large wind loads before the structure was formed.

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