Application of large-span steel roof construction technology for low-rise public buildings

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Abstract. Along with the continuous development of China's construction industry, the scale of public buildings is also expanding, especially the rapid development of high-speed railroads, making more and more complex shapes, large spans and large volumes of station buildings rigid structural roofs are widely used. Based on this, this paper takes a steel roof truss project of a school gymnasium as an example and uses theoretical analysis and empirical research to explain the application of its construction technology, so as to provide some reference for the efficient development of the construction of large-span steel roof of low-rise public buildings.

Keywords: public building; large span; steel structure; roofing.

1. Introduction

In recent years, with the rapid development of social economy and the continuous improvement of construction industry technology, the development of large-span steel structure is very rapid and has been widely used in large public buildings such as sports and cultural halls, airport terminals, exhibition centers and so on.In a school gymnasium building steel structure construction project, due to the tight schedule and site construction environment restrictions, can only be combined with the actual characteristics of the project, for different working conditions, take different steel roof construction technology.

2. Overview of the main truss structure of the steel roof of the school gymnasium

The school gymnasium building has a total area of 4243m2, with one underground floor and two above-ground floors, the second floor is a swimming pool, the second floor is a basketball court, and a partial equipment mezzanine. The structure below the roof is steel-hybrid structure, and the roof structure is large-span curved steel structure and metal roofing. The total height of the building is 22.4m, and the maximum span of the steel structure is 46m.As shown in Figure 1.

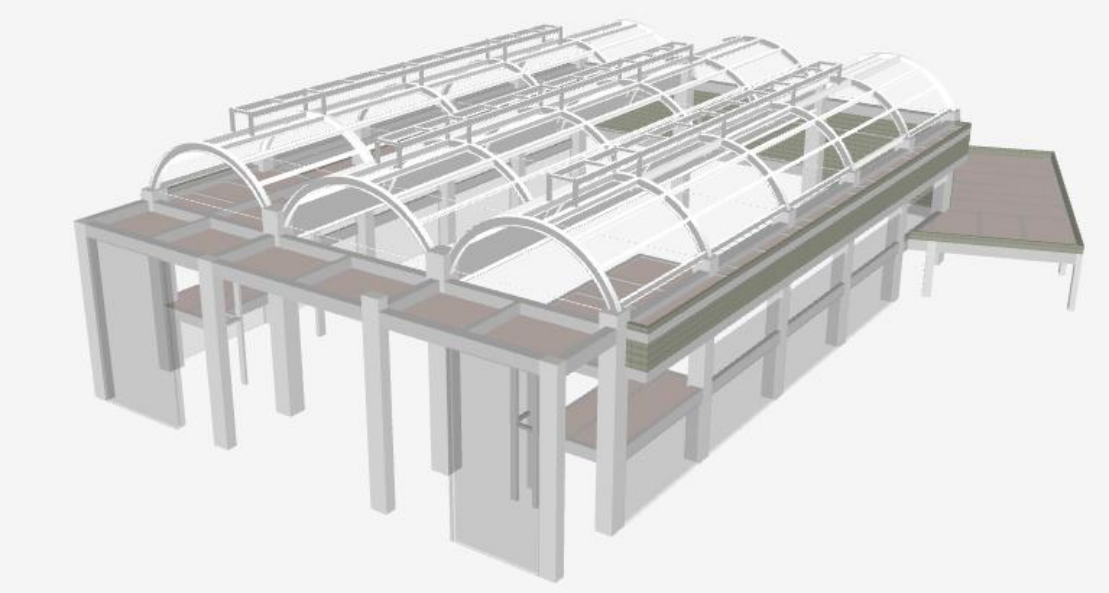

Figure 1 Engineering effect

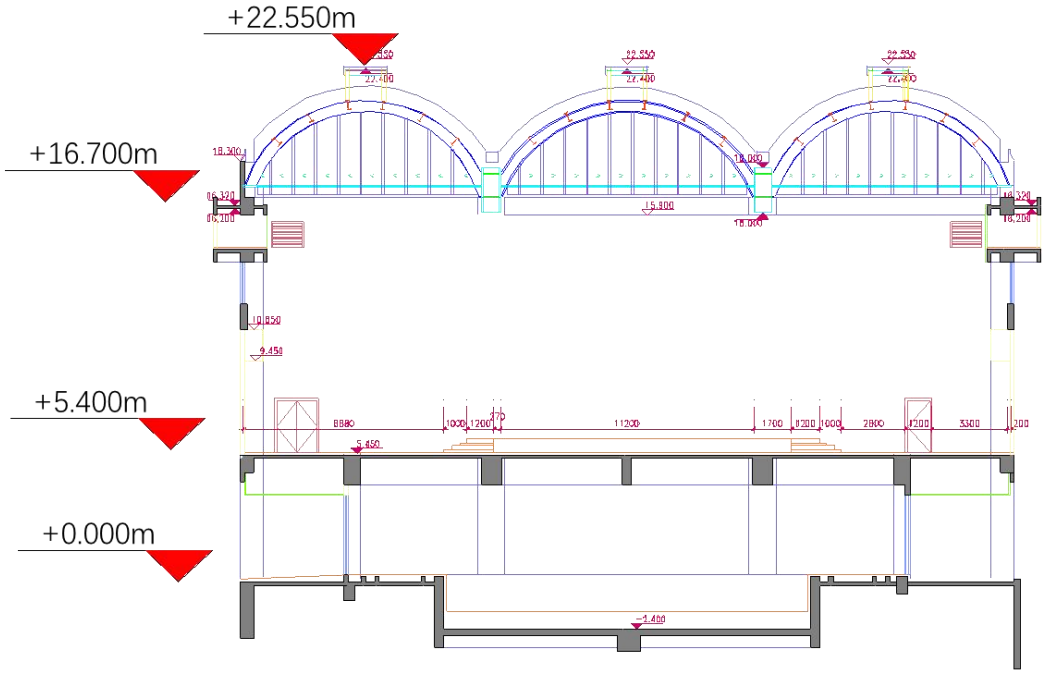

Fig.2 Section of main truss structure

The steel structure is mainly the superstructure of the rail-bearing level (-2.900m), the steel column starts from the steel pipe column of the rail-bearing level -1.2m, mainly composed of steel pipe column, box-type plane truss, steel beam and roof pipe truss, the total steel consumption is about 37,000 tons, as shown in Figure 2.

3. Station steel structure roof installation plan design

3.1 Selection of installation method

Combining with the structural characteristics, the initial selection is the overhead bulk method, the split strip or block installation method and the overall lifting method. All three methods are more suitable for the installation of flat steel joist. The three methods are evaluated in terms of

construction period, construction site, machinery and equipment, and installation accuracy, etc., as detailed in Table 1.

Table 1 Analysis table of installation method selection

Method	Duration	Site	Machinery	Precision	Difficulty
Overhead bulk method	Longer	Less demanding, mainly erecting temporary support	small lifting equipment	Welding work is mainly done at height and accuracy cannot be guaranteed	Aerial welding and assembly work progress control
Slit or block installation method	medium	Low requirements, need to build part of the temporary support tire frame, leave the crane machinery running route	small and medium-sized lifting equipment	The precision control is relatively good	Reasonable division of lifting unit and selection of unloading scheme
Integral lifting method	Shorter	High requirements, need to set up the running route of lifting machinery	large lifting equipment	Less overhead work, ground finish welding and installation work, high precision	Collaboration of multiple cranes in aerial lifts

Combining with Table 1, considering the installation of steel roofs of axes 1~7 and 22~28 separately, both methods are feasible, i.e. strip or block installation method and overall lifting method, but considering that if overall lifting method is adopted, small, medium and large cranes will be needed on site, the installation of steel roofs of axes 1~7 and 22~28 is finally adopted from the perspective of engineering economy and construction management.

3.2 Steel joist segmentation

Combined with the segmentation principle of steel joist, the segmentation method of main joist of roof cover: 1 axis to 7 axis and 22 axis to 28 axis main joist is lifted as a whole; 8 axis to 21 axis main joist is lifted in 4 sections; secondary joist is installed in sections with the spacing between two main joists.

Considering that HJ-13 is the heaviest truss among the main trusses from axis 1 to 7 and from axis 22 to 28, and HJ-6 is the heaviest truss among the main trusses from axis 8 to 21, HJ-13 is the heaviest truss among the main trusses from axis 8 to 21. Then, HJ-6 and HJ-13 are selected to analyze the lifting stage of steel joist. The specific segmental size and weight are detailed in Table 2.

Table 2 Main joist segmentation table

Number	Build Name	Segment Length（m）	Weight（t）	Remarks
1	HJ-6	25.1	17.50	8Axis - 21Axis
		27.0	15.35	
		27.0	11.79	
		14.1	8.06	
2	HJ-13	45.2	24.86	1Axis - 7Axis、22Axis - 28Axis

3.3 Lifting scheme of steel joist

The layout of the lifting points of the joist lifting unit of the project is mainly determined by the minimum bending moment criterion combined with the principles and methods of lifting point layout. The first section (length 25.1m, weight 17.50t) and the second section (length 27.0m, weight 15.35t) of HJ-6 were selected, and their lifting point layouts were detailed in Fig. 3(a) and Fig. 3(b) respectively.

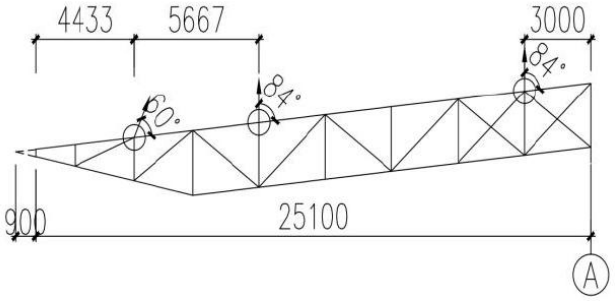

Figure 3(a) HJ-6 first section lifting point layout

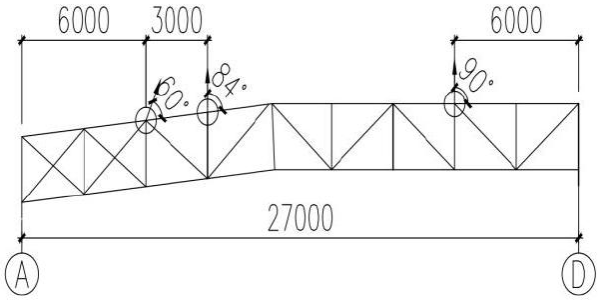

Figure 3(b) HJ-6 second section lifting point layout

3.4 Feasibility analysis of steel joist hoisting scheme

The theoretical analysis of the feasibility of steel joist lifting scheme can be realized through the simulation of finite element software. Considering the large number of hoisting units, the two representative hoisting units are selected for analysis.

(1)Calculation assumptions: ① the nodes of the joist are smooth and frictionless ideal hinges; ② the rods are all homogeneous equal-section straight rods and pass through the center of the hinges; ③ the load and support reaction force act on the nodes; ④ when the wind is too strong, the lifting operation will be stopped on site, so only gravity acts during the lifting process. Besides, the lifting process of steel joist is uniform rising process, one of the equilibrium states is taken for analysis in the calculation; the lifting rope is simulated by applying a hinge support in the same direction as the lifting rope at the lifting point position.

(2)When the lifting load is calculated and analyzed, the specific load combination should be considered

$$G_1 = K_1 K_2 \gamma_G G_{K1} \quad (1)$$

Where K_1 ---dynamic load coefficient, take the value of 1.20.

K_2 --unbalanced load coefficient, generally take the value of 1.10 ~ 1.25

γ_G --Gravity load sub-factor, take the value of 1.30.

G_{K1} --load standard value (kN).

In addition, the weight of the spreader needs to be considered when lifting, the weight of the partial safety consideration is, then

$$G = 1.2K_1K_2\gamma_G G_{K1} \quad (2)$$

Where G -the load design value after considering the weight of the spreader (kN).

At the same time, the deflection calculation is considered according to the standard value of the load, i.e. the load is taken as

$$G_K = 1.2K_1K_2G_{K1} \quad (3)$$

where G_K -the load standard value after considering the weight of the spreader (kN).

(3) Calculation results

The internal force and deformation of the specific lifting unit can be analyzed by the static analysis of the structure to obtain the stress and displacement of the lifting unit and the maximum stress ratio of the bar. The first section and the second section of HJ-6 can be named as working condition one and two in turn, and the calculation result data are detailed in Table 3.

Table 3 Simulation calculation results of lifting members under two working conditions

	$\sigma_{\max}(MPa)$	$\sigma_{\min}(MPa)$	$\sigma_{\max}/f_y$	$\sigma_{\min}/f_y$	$\delta_{\max}(mm)$
1	25.5	-28.8	0.084	0.094	6.75
2	64.1	-48.6	0.21	0.16	13.13

From Table 3, it can be seen that under the three working conditions, the stress value of each rod is small, and the maximum stress ratio is much less than 1. Moreover, each rod works within the elastic range, and the maximum displacement value is also within the limit, which all meet the requirements of the specification, and the lifted unit has sufficient safety reserve.

4. Key points of steel roof truss installation in school gymnasium

Make good splicing of joist on the ground, and forecast and correct the model, length, bolt hole, friction surface and winding of joist when assembling. After assembling, the steel members should be checked and qualified before lifting.

The hoisting should be balanced and the hook should be raised slowly to lift the joist above the top of the column, then the rope should be rotated to align with the top of the column to make the hook fall into position, the hook should be dropped slowly and the brake should be applied to align with the bolt hole of the column when the joist just touches the top of the column, and the bolt should be threaded into the hole for temporary fixing and verticality correction and final fixing at the same time. After correction, all kinds of purlins and supports can be installed and the bolts are finally screwed for final fixing.

The position of lifting point and hoisting should be checked 500mm above the ground when the joist is hoisted and then continue to hoist. When installing the joist, make preliminary correction before releasing the hook, align the positioning axis of the top of the column, adjust the verticality of the joist and check the bending of the beam side, and fix it with four cable ropes in two directions.

When hoisting the joist, the column must also be reviewed and checked by using hoist pulling wire rope cable, and the cable can be loosened only after the installation of the beam is completed. The ridge line of joist must also be controlled so that the joist and the center line of both ends of the column have equal deviation so that each span of joist is on the same center line.

5. Conclusion

In summary, this paper explores the construction technology of the steel roof of a school gymnasium, and proposes the lifting plan and installation points, unloading plan, etc., so as to provide some reference for the efficient development of the construction work of the steel roof of the school gymnasium.

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