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Research on the Structural Design of Academic Report Complex Building in a University

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Abstract. This project is the construction project of the academic report comprehensive building of the Central Youth League School. The main function of the project is the academic report room, including an 800-person lecture hall, a 300-person multi-function lecture hall, a 500-person multi-function lecture hall, an exhibition hall, etc., and three underground floors. There are three floors above the ground, and one floor is partially high. There are 12.8, 13.8, 15.7, 18.2, 18.6, 20.8, 27.8 meters in the sub-regions of the roof structure elevation. This article introduces the structural system, the judgment of structural out-of-limit situations, prestress design, steel truss design, suspension steel structure design, cantilevered large-span concrete beams, etc., through a variety of structural calculation and analysis methods, and find out structural weaknesses, and adopt Corresponding seismic strengthening measures, the calculation results show that the structure has good seismic performance and can meet the requirements of the code.

1 Project Overview

This project is the construction project of the academic report comprehensive building of the Central Youth League School. The total construction area is about 31,500 square meters, the above ground construction area is about 10,500 square meters, and the underground construction area is about 21,000 square meters. The main function of the project is the academic report room, including 800 people. The lecture hall, the multi-functional lecture hall for 300 people, the multi-functional lecture hall for 500 people, the exhibition hall, etc., have three floors underground, three floors above ground, and part of the first floor is full-height. Basic wind pressure: w0=0.45kN/m2 (recurrence period of 50 years); Fortification intensity: The seismic fortification intensity of this project is 8 degrees, the design basic earthquake acceleration value is 0.20g, and the design earthquake is grouped into the second group. The soil category of the construction site is Class II, and the characteristic period value is 0.40s. Building seismic fortification category: key fortification category (category B); design service life: 50 years, safety level of building structure: second class. The effect diagram and structure model are shown in Figure 1, Figure 2.

Fig. 1. Building renderings

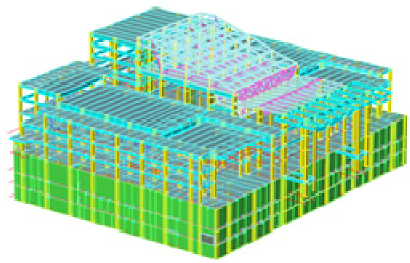

Fig. 2. Structural model

2 Structural system

2.1 Structure selection

In the structural design, the architectural function and plan layout should follow the simple, regular and symmetrical structural layout principles as far as possible in the structural plan and vertical layout. The main structure adopts the form of reinforced concrete frame structure with few walls. The 800-person lecture hall adopts steel truss structure. The truss is connected to the main structure with hinged supports, and the large-span space adopts a prestressed concrete beam structure. The construction length of this project is super long. In order to ensure the use function and the effect of the building facade, expansion joints are not set on the ground and underground, and measures are taken to ensure that the structural cracks under temperature stress meet the specification requirements.

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2.2 Seismic level of components

The seismic fortification intensity of this project is 8 degrees, the building seismic fortification category is the key fortification category, and the structure type is frame structure. The seismic fortification level is increased by one degree. The results are as follows[1]:

Table 1. Earthquake resistance rating.

Structural part	Seismic rating
-3-story frame	Level 3
-3-story frame	Level 2
-3-story frame	Level 1
Above-ground frame	Level 1

2.3 Calculation problems of single-story through-height columns

The software can automatically determine the one-way spanning column, and calculate the reinforcement according to the appropriate calculated length coefficient and column length. But for the overhanging beam on the column, the software judges it to be the constraint of the frame column and judges it as the floor. This is unreasonable. You should manually modify the calculated length coefficient to ensure the accuracy of the calculation.

The design analysis of the story-through high-column is based on three considerations, and the envelope is used for reinforcement. (1) For calculations under frequent earthquakes in the overall model, the seismic resistance level of the seismic structural measures should be increased by one level, according to the second level; (2) Take the single model, input the load effect, optimize the calculation length coefficient, and use the PK software to check; (3) In the overall model, use moderate earthquake elasticity to check column reinforcement.

2.4 Judgment of structure

According to the 2015 edition of the judging standards for the technical points of the special review of seismic fortification of over-limit high-rise buildings, the height of this project is not over-limit, but there are the following irregularities[2]:

(1) Reverse irregularities. Considering accidental eccentricity, the torsional displacement ratio is 1.37, which is greater than 1.2;

(2) Eccentric layout. The eccentricity is greater than 0.15;

(3) The floor is not continuous. The opening area is greater than 30%, and the staggered level is greater than the beam height.

(4) Intermittent components. There are many conversion columns, but the conversion column is converted on the embedded layer of the main structure (first floor ground), so this irregularity can not be counted.

The above two irregularities (1) and (2) belong to the same category and will not be counted repeatedly. Based on the above judgment, this project belongs to two irregular structures and is not an over-limit project.

2.5 The overall calculation results of the structure

The overall calculation results are shown in Table 2:

Table 2. Main calculation results

		YJK	Remarks
Vibration shape (s)	First cycle	0.8225 (Y)	< 0.85
	Second cycle	0.7687 (X)	
	Third cycle	0.6697 (T)	
	Cycle ratio	0.814	
Layer displacement angle	One-way earthquake in X direction	1/626 (n=5)	< 1/550
	One-way earthquake in Y direction	1/595 (n=5)	
Ratio of maximum displacement to average displacement (considering 5% accidental eccentricity)	X direction earthquake	1.21	Prescribed horizontal force
	Y direction earthquake	1.31	
Base shear force (kN) (shear weight ratio)	One-way earthquake in X direction	37204.74(5.602%)	X≥3.20% Y≥3.20%
	One-way earthquake in Y direction	38333.65(5.772%)	
Stiffness to weight ratio	X direction earthquake	52.879	>10
	Y direction earthquake	46.394	>10

3 Important and difficult points of structural design

3.1 Slow bonding technology and its application in large-span prestressed beams

The slow-bonding prestressed tendons are composed of prestressed tendons, slow gel adhesive, and outer protective surface layer. In the early stage, the slow-adhesive adhesive is equivalent to the anti-corrosion grease of the unbonded prestress, which has certain fluidity and good adhesion to the prestressed tendons. With the passage of time, after the cementitious material gradually solidifies, it is closely occluded with the concrete, and the prestressed tendons cannot slide freely in the concrete. The slow bonding prestress produces the bonding effect of the bonded prestress, good ductility and seismic performance, and at the same time has the advantages of convenient construction of the unbonded prestress, and overcomes the disadvantages of the complicated construction process of the bonded prestress.

Due to the needs of building functions, there are a large number of large-span beams (greater than 15 meters) in this project, and the effect of using prestress is obvious. After setting the prestress, the deflection and cracks meet the requirements of the specification. The typical span of the prestressed beam is: 19.5 m, 16.8m, etc., the section size of the 19.5m large-span prestressed beam is 450mmx1150mm, the deflection control limit is L/300, and the crack limit is controlled according to 0.2mm. The main layout positions are as shown in Figure 3:

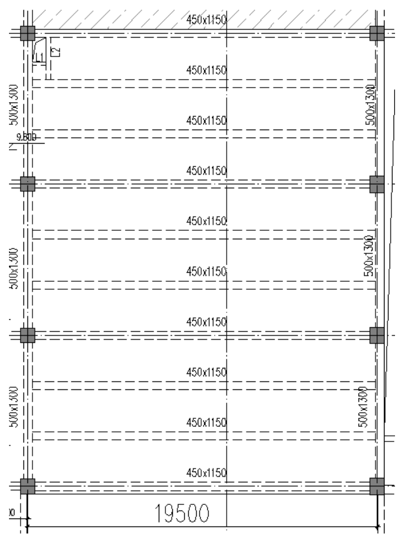

Fig. 3. Layout of large-span prestressed beams

3.2 Steel truss and hanging steel structure

The main structure is a concrete frame structure. The roof of the 800-seat lecture hall adopts a steel truss structure with a span of about 30m. It adopts a deck-type flat steel truss, and the support is a fixed hinged steel support. The truss is equipped with horizontal supports, tie rods and vertical supports. The roof slab is a steel truss floor deck, and the lower chord layer has tie rods, horse road hangers, etc. The splicing of steel components adopts the method of rigid connection[3]. The main truss is considered based on 1/500 of the arch, and the layout of the steel frame is shown in Figure 4 above.

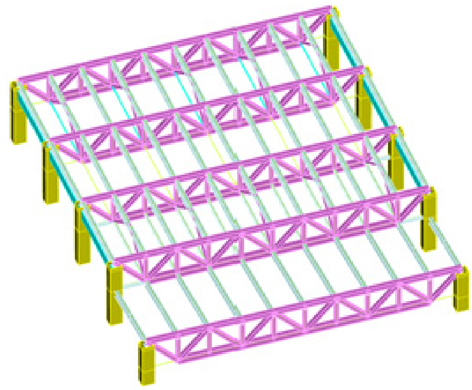

Fig. 4. Layout of steel truss roof structure

The truss members are all made of hot-rolled H-section steel, and the stress ratio of the members is controlled below 0.9. The calculation results of the steel truss are shown in Figure 5. The steel truss roof has a hanging steel structure on the lower chord of the C and D axis steel truss. The steel structure shall consider the construction sequence and the lifting sequence during calculation and analysis.

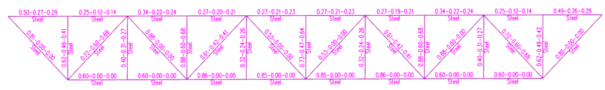

Fig. 5. Calculation results of steel truss

3.3 Stand cantilever beam

The entrance hall requires column-free space, which leads to the oblique cantilever beam of the grandstand above the auditorium. The length of the horizontal cantilever is 8.4m, and the beam section is 600x1300/800, which extends inward for one span. It adopts slow bonding prestress and strict control. The deflection and cracks are calculated to meet the requirements of the specification, and the cantilever beam layout is shown in Figure 6.

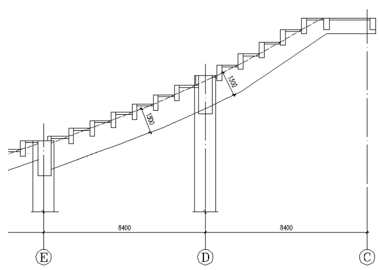

Fig. 6. The cantilever beam of the grandstand

3.4 The frame beams of the auditorium are haunched

The size of the frame column surrounding the large space is 900x1100, and the frame beam width is 400. Due to the wall layout requirements of the building, the frame beam is attached to the outer skin of the column, and the eccentricity of the beam column does not meet the requirements of Article 6.1.7 of the "Technical Regulations for High-rise Building Concrete Structures", see Figure 7. Shown. The frame beam needs to be haunched. After calculation, the horizontal haunched layout is shown in Figure 8.

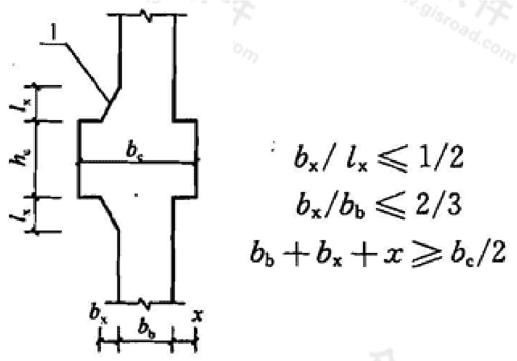

Fig. 7. beam level haunching requirements

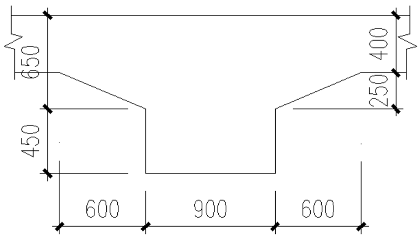

Fig. 8. Beam horizontal haunching situation

4 Conclusion

This project is a public building with complex functions and spatial relationships. In the conceptual design stage, the overall structural system and layout are carefully considered and appropriately optimized to make it have good structural performance. Through the overall calculation, the weak parts of the structure are found, and corresponding seismic strengthening measures are taken. The analysis shows that the structure has good seismic performance, and many indicators perform relatively well, which can meet the requirements of the specification. In engineering, slow bonding technology is used for large-span beams and cantilever beams to effectively control deflection and cracks. The steel truss members are carefully analyzed to obtain the optimal member cross section. The hanging structure should be set in the calculation Good construction sequence, and implement it during actual construction.

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