Structure design and analysis of a training track for Bobsleigh-and luge

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Abstract: The construction area of bobsleigh and sled training ground is 10000 square meters. Shear wall structure is below the ground, steel frame structure is above the ground, strip foundation is adopted for the foundation, this paper introduces and analyzes some difficult points of the complex structure in the project, and through the research on the mechanical performance of the structure system and the stress analysis of the key points, the mechanical performance of the structure is studied to ensure the safety and reliability of the construction.

1. Project Overview
This project is located in Beijing, and the venue is the training track for Bobsleigh-and luge. There are three training lanes in the training hall: Bob (snowmobile), Luge1 (sledge 1), Luge2(sledge 2), training track, temporary storage of warm up area and other functional rooms. The storage room of sleigh is the storage room of sleigh, sleigh, steel frame sleigh and the room of ice making division. The track is a concrete slab with built-in ammonia refrigeration tubes, supported by swing columns and portal columns below. The ammonia refrigeration supervisor of the track is arranged in the trench layer below the bottom of the swing column bottom plate. The supervisor connects the refrigeration equipment of the ammonia refrigeration room, and the ammonia liquid is transported by the refrigeration room. The pipe and ditch floor is isolated from the interior of the main building, and separate entrances and vents are set to connect the outdoor, and stairs are set for the access of maintenance personnel. The training track below 0.000 elevation is concrete structure, and above 0.000 elevation is steel structure. The total construction area is about 10,000 square meters, with 3 floors above ground and 3 floors below ground. The height of the house is 15.41 meters. The structural form is shear wall structure + steel frame structure, and the foundation form is strip foundation. The L1 floor is mainly used by the athletes of the national team for pre-competition training. There are two snow lanes, a sled track, a set of 50-meter warm-up track, athletes' warm-up area, dressing room, athletes' training and medical room and ancillary rooms. The outdoor space on the north side is the team garage parking area, which can accommodate 80 team containers. The north side of the field is equipped with a car ramp, from which you can descend to the team garage, which has garages for the national team snowmobile, steel frame snowmobile and sled. The architectural effect is shown in figure 1
Figure 1. Architectural renderings.

The design life of the project is 50 years, the safety level of the building structure is level 1, and the design level of the foundation is level a. According to the "Code for Seismic Design of Buildings" (GB50011-2010) (2016 edition), the aseismic group 2 in the area where the project is located, the site category is category II and the aseismic grade is 8 degrees 0.2g, and the office area is general fortification category (category B).

2. Study on structure selection and difficulties

2.1. Structural system analysis
The project is located in Beijing area, three floors above ground are steel frame structure. The seismic grade of the structure is grade 3. Steel column and steel beam adopt Q345B. The load refers to Load code for the design of building structures. Concrete shear wall structure is adopted in the basement and strip foundation is adopted in the foundation. Concrete strength grade: wall, beam, board, foundation are C30. Compared with general buildings, the main difficulties of this structure are as follows:

(1) the height difference of the basement is large. The east-west length of the building is more than 140 meters. The elevation of the basement floor plate roof is -3 meters in the west and -17 meters in the east. Because the basement retaining wall is high, an buttress is needed as part of the retaining wall.

(2) the floor height difference of each track is large, and the form of the track curve is complex, resulting in the large floor height difference of the foundation, which requires a variety of forms for the foundation slope.

(3) the cantilever in part of plus or minus 0 is too large and the cantilever length is 17 meters, so the prestressed beam shall be installed to solve the deflection problem of beam and plate.

(4) the track structure system is complex, which is a new structure system and adopts a new swing column structure system.

2.2. Analysis of structural difficulties

2.2.1. Basic design analysis
The strip foundation of the track is adopted, and the elevation difference of the track along the east-west direction is large. Because the track varies in slope and the fluctuation of the floor elevation is different, the stepped slope is needed for the foundation design of the ice house strip foundation, a typical section of the Venue is shown in figure 2. In the foundation design, the slope Angle of the bottom plate is 1:2,
and the height of each step of the bottom plate is 500mm. The schematic diagram of the slope is shown in figure 3.

![Figure 2 typical unit diagram](image)

**Figure 2 typical unit diagram**

![Figure 3 Detail of foundation slope](image)

**Figure 3 Detail of foundation slope**

### 2.2.2. Analysis of prestressed concrete structure
At the elevation of plus or minus 0, the frame beam is cantilever 17 meters, so it is necessary to set the prestressed steel bar. The prestressed member beam of this project adopts the post-tensioned bonded partial prestress (mixed reinforcement) technology. The setting conditions of prestressed reinforcement are as follows:

1. Prestressed concrete beam strength grade C40. Prestressed steel strand $\phi_{15.2}$, FPTK = 1860 mpa. Anchor: clamp-type anchor is used for tensioning end, and extruded anchor is used for fixing end.

2. In the process of vibration, the concrete behind the tensioned end plate must be vibrated and compacted to prevent local compression damage during tension, but the vibrator shall not be used for a long time to directly impact the bellows and anchor plate, so as to prevent the failure of the joint and the leakage of slurry.

3. Reliable measures must be taken to protect the bellows from damage during the electric welding operation before pouring concrete.

4. The control stress of prestressed tension is $1860 \times 0.75 = 1395$ Mpa

5. When the concrete strength reaches 100% of the designed strength, it can be tensioned.

6. After the prestressed tension, should be promptly grouting with M40 cement slurry, grouting can be mixed with an appropriate amount of water reducer and expansion agent.

7. The grouting of the prestressed channel should be completed in one time, slowly and evenly, without stopping in the middle. The nozzle must not leave the grouting hole to prevent air from entering the hole and forming bubbles. In order to make the grouting full, the vent is closed after discharging the thick slurry, and the grouting hole is closed after the whole vent is filled.

The prestressed beam section of this project is 600X2600, and 2 sets of $\phi_{15.2}$ prestressed steel bars are used. and the detailed drawing of the joints is shown in figure 4.
2.3. Structural design of swing column structure

Venue in circuit adopts new swing column structure system, swing column structure system in the central structure of each segment has a set of T fixed columns, wall for whole casting, every 4 meters on both sides set symmetric set a pair of swing column, swing and foundation both up and down through the rubber gasket and the track is separated, swing column center has a through vertical steel bar and basic connection with track. Figure 5 is a detailed map of track nodes.
2.4. The setting of structural joints and post-cast belt

Due to the large size of the underground garage (the total length of about 140m), therefore, every 30 meters or so set 800 wide anti-shrinkage post-pouring belt; The above-mentioned post-cast belt shall be reinforced with micro-expansion concrete one grade higher than the concrete strength grade of the corresponding component parts one month after the construction of the structure on both sides. The underground garage is an ultra-long building. In order to reduce the adverse effect of concrete shrinkage and temperature stress on the structure caused by the ultra-long building, the setting of expansion joints is cancelled. In order to solve the adverse effects caused by the excessive length of the structure, it is proposed to adopt the temperature stress analysis for the main structure, and effectively reduce the shrinkage stress by setting the post-pouring zone of temperature, controlling the temperature of concrete entering the mold and adopting appropriate additives to limit the development of structural cracks.

3. Calculation and analysis

According to the code for seismic design of buildings, YJK is adopted as the main tool for structural design and calculation in this project[5]. Three of the seven apartment types are calculated and analyzed.

| Mode of vibration(s) | YJK |
|----------------------|-----|
| T1 0.7523            |     |
| T2 0.5983            |     |
| T3 0.4188            |     |
| T3/T1 0.55           |     |

Table 1. main calculation results

| Maximum displacement of vertex (mm) | X-direction earthquake | Y-direction earthquake |
|-------------------------------------|------------------------|------------------------|
| X-direction earthquake              | 18.91                  | 17.86                  |
| Y-direction earthquake              |                        |                        |

| Maximum inter story displacement angle | X-direction earthquake | Y-direction earthquake |
|----------------------------------------|------------------------|------------------------|
| X-direction earthquake                 | 1/271                  | 1/302                  |
| Y-direction earthquake                 |                        |                        |

| Ratio of maximum displacement to average displacement | X-direction earthquake | Y-direction earthquake |
|--------------------------------------------------------|------------------------|------------------------|
| X-direction earthquake                                | 1.2                    |                        |
| Y-direction earthquake                                |                        | 1.2                    |

Main indicators contrast can be seen by the software, as the main computing software YJK structure analysis, general design index is better, the first, second cycle for translational cycle, the third cycle to reverse the cycle, the structure of the two direction stiffness were similar, and the structure of the first/reverse cycle is less than 0.85, the first translation cycle meet specification requirements, structure in two directions at the bottom of the shear heavier than also meet the requirements of the resistance to gauge is not less than 1.2%. Both directions are less than the standard limit of 1/300. Considering the case of accidental eccentricity, YJK results show that the maximum displacement/average displacement (maximum inter-storey displacement/average inter-storey displacement) of the floor is 1.2, which meets the requirement that the specification should not be greater than 1.4.

4. Conclusion

This paper introduces the structural design of training track venue and introduces the structural system and basic form. The feasibility of the project has been verified. Through the structural design and structural calculation and analysis, the venue has a good seismic performance, which meets the standard research and provides a good guarantee for the practical application of the project.

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