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Shenzhen University City Sports Center Structure Analysis

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Abstract: Shenzhen University City Sports Center was composed of three parts: stadium, gymnasium, and natatorium. It took advantage of new technology and modern structure, such as reticulated shell and cable-stayed grid structure. It created light and characteristic architecture profile, and showed beauty of structure. Today, it was one of the most popular and beautiful places for visitors in Shenzhen. And it became international symbol of the city.

Introduction

Shenzhen University City Sports Center was located at the foot of Tang Lang Mountain and Big Sha River. With a total land area of 171917.9 square meters, and a total construction area of 38493 square meters. It was composed of three parts: stadium, gymnasium, and natatorium. Now, it was not only used as a facilities for exercises and entertainments for citizens, but also as a venue for domestic and international games.

The Stadium Structure System

The Stadium Structure Overview

The stadium was located in the middle of Sports Center. It covered a land area of 29400 square meters, and a construction area of 15300 square meters. It could seated over 15942 peoples. The stadium canopy used steel structure, which covered with light steel purlins, and aluminum alloy roof panel system. The canopy structure of pyramid reticulated shell was welded into crescent shape by steel hollow spheres. It covered projective plan area of 5122 square meters, which was 207.2m long , and 35m wide. The canopy structure hanged prestressed cables from 10 steel lattice columns. The bleachers frame structure was made by the lower concrete steel tubular column and reinforced concrete structure. The upper steel tubular columns connected with the shell through shafts, and transferred horizontal load from reticulated shell. Stadium canopy was a cable-stayed grid structure comprised of prestressed cable, the upper latticed columns and shell components.

The Stadium Structure Composition

The Stadium Reticulated Shell Structure

Main part of stadium roof was made up of double pyramid reticulated shells which was welded by hollow spheres. It used 13 types of hollow steel tubes. The maximum tube section was φ426*24, and the minimum tube section was φ76*3.5. There were 7 kinds of welded hollow spheres. The maximum size of welded hollow spheres was WSR6025, and the minimum size of welded hollow spheres was WS2006. The upper and the lower layers of the shell connected with steel tube columns and shafts. Cables hanged reticulated shell through welded hollow sphere anchor and cast steel joint. And steel tubular column and cable comminute shell structure, could improve deformation and stress of the reticulated shell structure.

The Stadium Steel Latticed Column

Steel tubular lattice column was the core of the stadium structure. Each steel lattice column was made up of 4 φ426*24 steel tube and φ245*14 hanging shaft. The steel tubular columns were filled with C25 concrete below level of 14.045m, to get larger bearing capacity. And at level of 6.930m, it

connected with the lower anti extubation through column foot joint. Lattice column was connected with cable by ear plate at cast steel point. And it was connected with the latticed shell through shafts, forming bleachers frame system by reinforced concrete beam and column.

The Stadium Stayed Cable

Using ϕ5*199 Cable, each lattice column was provided with 4 cables, 2 for the first cable, and 2 for the back cable. At one end of cables, there hanged the shell, and the other end connected with lattice columns. One end of the back cables connected with lattice columns, the other end was connected with reaction tubes through cast steel joints. One end of head cables and one of the back cables hanged the shell, and the other end was connected with lattice columns.One end of the rest back cables was connected with the lattice columns, and the other end was connected with reaction tubes by a steel casting joints.

Characteristics and Advantages of The Stadium Stayed Cable Grid Structure

The whole stadium roof was made of stayed cable grid structure, that hybrid space structure collaboratively worked. It was also a kind of large span structure, which had a wide interior space, a novel design and a lot of scenic spots. The stadium cable-stayed grid structure had following characteristics and advantages:

Canopy structure was a hybrid spatial structure, composed of steel latticed column, cable and double pyramid reticulated shell of welded hollow sphere.

It took advantages of high strength and prestress of steel cables, with large stiffness of spatial reticulated shell structure, good integrity and stability. It had good seismic performance and better architectural effect.

Steel lattice tubular column was distributed in the shell structure, which connected with the shell through shafts, cooperated with cable to hang the shell structure, divided the span of the reticulated shell, reduced the structure deflection under gravity, improved shell internal force, and lowered internal force peak.

Steel lattice column consisted of 4 steel tubes. At top of column, there arranged 4 cables. And each tube provided with only 1 cable, forming the simple column top joint structure.

The Gymnasium Structure System

The gymnasium was located on the northwest side of the Sports Center. As a multi-function gymnasium, its construction area was 14183 square meters. The main body was reinforced concrete structure, with steel tube truss roof structure. The maximum span was 66.30M, which could meet needs of gymnastics, handball, basketball, conference and other functions. The building could supplied 1690 fixed seats, 4006 movable seats, which could accommodate 5696 people.

The roof of gymnasium was steel structure, covered with light steel purlins, and aluminum alloy roof panel. Two pieces of gymnasium steel roof structure scattered at different composition level , and made use of roof height difference form vertical skylight. The upper roof comprised the main shell truss and the surrounding edge. The secondary trusses connected the main trusses together, forming roof secondary stress system. The main truss ends were connected to the shell edge, forming the main roof force system. In addition to a shell contact effect on the main and secondary trusses, being external ring beam, and transferred force from main truss to the lower shell and the concrete column below. The roof skylight latticed columns played role of connecting the upper and lower roof, and transferring force from the upper roof shell edge to the lower roof and bottom concrete cylinder. The lower roof was comprised of trusses and shell edge. Trusses was the main force system of the lower roof. Shell connected trusses with ring beam, bore the upper load from skylight lattice roof column, and transferred the force from trusses to the lower part concrete column.

The Upper Roof Structure of Gymnasium

The upper roof structure was composed of 13 primary trusses, 3 secondary trusses and reticulated shell of double layer welded hollow spheres with surrounding sealed edge. The main and secondary trusses were inverted triangle tube truss structures. The main truss was the main roof support system. The maximum span was about 64.4m. The distance between the main trusses was 8.1m. Secondary trusses connected every two main trusses, to improve lateral stiffness of the main truss, and to avoid the lateral instability of main trusses. The main and secondary truss formed shell structure and was supported at the sealed edge. The load was transferred to the shell structure through the main and secondary trusses, and then transfered to the lower concrete support system by reticulated shell bearings.

The maximum shaft section of the upper roof main truss was Φ426*24. The maximum shaft section of roof truss structure was Φ273*16. There were 8 kinds of welded hollow spheres. The maximum welding hollow specifications was WSR6025, and the minimum specifications was WS2006.

The Lower Roof Structure of Gymnasium

The roof structure was composed of 13 primary trusses, 1 arch truss and reticulated shell edge. The main truss was the main supporting component of roof system. The maximum span was about 21.6m, the distance between main trusses was 8.1m. There was no secondary truss between main trusses. One end of main truss connected with arch truss, and connected together with the upper roof through skylight frame lattice column, the other end support on shell edge.

The Gymnasium Support Structure of Gymnasium

There were 3 kinds of stadium support form, ball bearing, steel tube joint support, stabilizer support. Among them, the stabilizer support was welded by the half hollow ribbed ball, and was welded with embed parts at level of 4.500m.

Ball joint bearing and tubular joint bearings were made of rubber bearings, which was made of natural rubber, The middle rubber sheet was 8mm thick, the upper and lower surface rubber sheet was 3mm thick. 6 pieces of middle steel plate was 3mm thick. The total thickness of rubber pad was 64mm. The main purpose of laminated rubber bearing was to reduce or eliminate the influence of temperature stress, to reduce horizontal thrust from roof structure to the lower concrete column, to reduce vibration, and have vibration isolation effect on structure.

The Natatorium Structure System

The natatorium was located on the southwest side of Sports Center, with construction area of 9894 square meters. The main body of bleachers was reinforced concrete structure, with aluminum roof panel system. Facade maintenance structure was curtain wall, at the first floor, where below windowsill used stone curtain wall, at height range of truss structure, where facade maintenance used metal curtain wall, and the rest part used semi hidden frame glass curtain wall.

The bearing structure of natatorium roof was steel structure, covered with cold-formed thin steel purlins, and aluminum alloy roof panel system. The roof steel structure was curved reticulated shell with a crescent-shape plan, 120m long, 65m wide, projective area of 6500 square meters. The thickness of interior shell was 3M, and that of outdoor part was 1.5m. It connected by welding hollow ball joints. The reticulated shell structure was supported by reinforced concrete frame and steel lattice columns, which structure spanned 48m.

The Reticulated Shell Structure of Natatorium

The main part of natatorium roof was double welded hollow sphere pyramid reticulated shell. Except for surrounding shell, part of ventral and the lower shafts were subducted interphasly from the pyramid, to expand the lower grid. A series of continuous cones were considered as a generalized beam, whose mechanical properties were similar to that of bidirectional orthogonal trusses. Although internal force and stiffness of reticulated shell decreased, it still could meet

engineering requirements. To subducted pyramid reticulated structure, there was less shafts, more economic value, at the same time, it could make use of space as a skylight.

The shell shafts used 10 types of hollow steel tubes, the maximum shaft section was φ245*2, and the minimum section was φ60*3.2. There were 7 kinds of welded hollow spheres, the maximum specification for welded hollow sphere was WSR5022, and the minimum specification for welded hollow sphere was WS2006. Part of roof load was transferred to the lower part of concrete support system by reticulated shell pedestal, the other part of roof load was transferred to connected steel lattice column by reticulated shell.

The Natatorium Steel Lattice Column

7 steel lattice columns supported crescent-shape reticulated shell at concave edge, forming one of natatorium main load-bearing structure. Each column connected by 3 steel tube struts through lacing steel shafts. According to different support positions and stress states of columns, strut section was different, and the largest strut section size was φ245*14. Each column podium was connected with embedded foundation by pivot, formed hinge joint, and released deformation and additional internal force from the upper structure.

The Support Structure of Natatorium

The Steel Lattice Tubular Column Supports of Natatorium

Steel lattice tubular column supports connected with embed foundation by φ130 shafts, forming hinged steel tubular column bearings.

The Flat Pressure Supports of Natatorium

Flat pressure supports were simple joint constructions which could be conveniently processed, but could not rotate or translate.

The Plate Rubber Supports of Natatorium

In support system, ball bearings made use of rubber joints. The main purpose of plate rubber supports was to reduce or eliminate influence of temperature stress, and decrease roof structure horizontal thrust on the lower concrete columns.

Conclusions

Shenzhen University City Sports Center included stadium, gymnasium, and natatorium. It adopted new technology and modern structure, including reticulated shell and stayed cable grid structure, to create light and characteristic architecture profile, and to show beauty of structure. Today. It was the most popular place for visitors. And it remained international symbol of the city.

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References

[1] X. H. Zhu, Z. B. Jiang, "Construction Monitoring Method of Gui Dan Intercity Bridge in Guang Zhou", Applied Mechanics and Materials, Vols. 578-579, pp. 1157-1160, 2014.

[2] X. H. Zhu, Z. B. Jiang, "Construction of Fo Zhao Gui Dan Intercity Bridge Project in Guang Zhou", Advanced Materials Research, Vols. 915-916, pp. 133-136, 2014.

[3] X. H. Zhu, Z. B. Jiang, "Restoration of Eco-River in Hefeng Village", Applied Mechanics and Materials, Vols. 522-524, pp. 963-966, 2014.

[4] X. H. Zhu, C. Zhong, Z. B. Jiang, "Solar Biogas Digester and Wetland-Pond System for Rural Wastewater Treatment", Advanced Materials Research, Vol. 800, pp. 610-613, 2013.

[5] X. H. Zhu, “On the Ecological Idea in Highway Landscape Design”,JOURNAL OF LUOYANG INSTITUTE OF SCIENCE AND TECHNOLOGY,2010, 20(4).