Irregular Concrete Structure Construction Technology of Cement Spraying for Bowl-shaped Steel Framework with External Suspended Mesh Attached

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Abstract. For the complex construction of a bowl-shaped concrete structure, this paper proposes a construction technology of cement spraying for steel formwork with external suspended mesh attached, which successfully solves the technical problem of construction of the hyperbolic non-load-bearing structure with a radius of 5250 mm at the entrance of sales office of Wanda Plaza in Jining of Ulanqab. The proposed method reduces the use of formwork, cuts construction period and cost, realizes green construction and has good economic and social benefits.

1. Introduction
With the rapid development of society and economy, various kinds of landmark buildings with complex shapes emerge constantly, including bowl-shaped and other irregularly-shaped concrete buildings, which places high requirements on construction technology[1-3]. The traditional cast-in-place concrete construction technology is difficult to achieve the accurate control of spatial positioning. Also, a large number of formworks are needed, with huge amount of concrete pouring work, resulting in poor overall construction effect[4-5]. With the bowl-shaped concrete structure of the Wanda Plaza in Jining of Ulanqab as the study case, this paper proposes a construction technology of cement spraying for steel framework with external suspended mesh attached, that is, using BIM to design steel framework, attaching suspended mesh to the main body, and adopting layered cement spray technology, which can better solve the technical problems of spatial positioning, curvature accuracy control and complex technological process[6-7].

2. Project overview
Located in Jining District, Ulanqab City, Inner Mongolia Autonomous Region, with a total construction area of 379276 m², the Wanda Plaza in Jining of Ulanqab is a commercial and residential complex including residences, garages, shopping centers and businesses along the street. The entrance to the sales office is designed as a double curved non-load-bearing structure of a 5250 mm radius with cast-in-place fair-faced concrete structure. The design is shown in Figure 1.
3. BIM deep processing

3.1 BIM modeling

The BIM 3D modeling is used to determine the steel framework model and give the hyperbolic parameter. After structural calculation, it is determined that the project adopts two kinds of galvanized steel pipes of 100×100×6.0 mm and 80×80×4.0 mm for the main framework and the galvanized steel pipes of 50×50×3.0 mm for the auxiliary framework, with the steel material of Q235-B. The 3D solid printing of 1:25 scale model is carried out, as shown in Figure 2.

![BIM 3D modeling and solid model](image)

(a) BIM 3D modeling                 (b) 3D printing of the finished product

Figure 2 BIM 3D modeling and solid model

3.2 Component processing

The BIM technology is used to divide, deepen and program the overall shape, and each component is uniformly numbered and marked with name, number and label; the "big bowl" structure is divided into six curvature ranges vertically and horizontally from inside and outside, and the specific division is shown in Figure 3. When processing steel components, the names, numbers and labels are marked on the components, and a 1:1 model of a 9cm plate is carved according to the 3D model, for a total of 24 kinds of 9cm plate models. The steel is shaped according to the camber of the model until 100% coincidence to pre-assemble. After the assembly, the camber of the inside and outside is adjusted with 9cm plate model. A total of 36 pieces of units with different curvature are assembled. If the trial assembly results reach the modeling accuracy, the steel framework is divided into 9 pieces and transported to the site.
4. **Key points for on-site construction**

4.1 **Installation of steel framework**
The steel framework is connected by welding. Before welding, trial assembly shall be carried out in the open field. After the trial assembly is qualified, different steel framework blocks will be assembled by welding. After assembly, the 25-ton truck crane is used for lifting operation. After the steel framework is assembled, the internal and external camber will be compared with the 1:1 arc scale to fine-tune the deformation caused by welding. During the lifting process, the space position of the steel framework will be checked simultaneously with the laser instrument.

4.2 **Construction of steel framework with different height**
The steel framework structure is different at different elevation. Figure 4 shows the boundary between rock wool and perlite cement mortar for the steel framework.

1) For the steel framework with elevation below 1.8 m, the main steel framework is filled with perlite cement mortar. During the construction, the steel framework will be welded on both sides with the φ6.5 mm single-layer two-way steel mesh in a spacing of 100×100 mm, and the steel mesh will be bound with the φ0.6 mm steel mesh of double-layer mesh with a size of 10×10 mm. When the φ 6.5 mm steel mesh is welded, each steel framework is taken as the positioning point. The steel bar is close to the steel framework, and the camber changes gradually with the steel framework. Before binding the steel mesh, the curvature of the steel is checked with a 1:1 arc scale. Perlite cement mortar pouring construction is carried out in the upper area without welding and binding. Before pouring perlite cement mortar, slurry splashing operation is carried out for inner and outer steel mesh. The perlite cement mortar is poured in layers with a thickness of each layer of 300 mm.

2) For the steel framework with elevation above 1.8m, the main steel framework is filled with rock wool. During the construction, the outer steel framework will be welded with the φ6.5 mm single-layer two-way steel mesh in a spacing of 100×100 mm, and the steel mesh will be bound with the φ0.6mm steel mesh of double-layer mesh with a size of 10×10 mm. On the inner side of the steel framework, the steel bar welding and steel mesh binding in the 1 m ring-shaped area are carried out first.

![Figure 4 Boundary between rock wool and perlite cement mortar](image)
4.3 Cement mortar spraying
The technological process is as follows: base course spraying → putty leveling → surface cleanup and local protection → production of base color and effect → soft polishing → adjustment and correction → site cleaning after construction. Among them, 1) when spraying the base course, spray the sulphoaluminate cement bonding mortar with the thickness of 20-40mm for 2-4 times. After the spraying, polish the surface. At last, the 1:1 arc scale is used to check the flatness and camber. The spray maintenance time is 3 days. 2) When producing the effect, the texture adjustment cloth is used to create the texture of fair-faced concrete by hand. 3) When spraying the coating material, the wall shall be fully coated for two times, and the spraying should be uniform, with the dosage of 0.15-0.2 kg/m².

4.4 Analysis of application effect
The traditional cast-in-place concrete construction of irregular structure needs custom steel formwork, which has long custom period, high cost and difficult repair of arc deviation. By using the construction technology of cement spraying for steel formwork with external suspended mesh attached, the period of customizing framework can be shortened, and the deviation of camber can be adjusted at any time by the cement spraying, which is simple in construction. The outer surface is not easy to crack, thus avoiding the later repair cost. The construction period of the project using the above technology is 30 days in total, with a time saving of 20 days and a total cost saving of 172059.72 yuan.

![Reducing the use of formwork](image1.jpg) ![The effect after site construction](image2.jpg)

(a) Reducing the use of formwork    (b) The effect after site construction

Figure 5 Remarkable effect of the project

5. Conclusion
For the complex construction of a bowl-shaped concrete structure, this paper proposes a construction technology of cement spraying for steel formwork with external suspended mesh attached, which successfully solves the technical problem of construction of the hyperbolic non-load-bearing structure with a radius of 5250 mm at the entrance of sales office of Wanda Plaza in Jining of Ulanqab. The proposed method reduces the use of formwork, cuts construction period and cost, realizes green construction and has good economic and social benefits.

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