Hotel Hesperia's Glazed Dome, Barcelona, Spain

Carles Teixidor, Eng., Bellapart S.A.U, Olot, Spain

Summary

This paper describes the design and construction of the glazed dome of the EVO restaurant, situated on top of the recently inaugurated Hesperia Tower hotel, in Barcelona. The construction of the dome required some special processes and solutions which enabled the dome to be built on the ground and then lifted to its final position on top of the tower. The 42 t dome, which is 22 m in diameter, was lifted with its glazed cladding completely installed including all sealings between glass panels.

Introduction

A new five-star Hesperia hotel has recently been inaugurated in L'Hospitalet de Llobregat (Barcelona). The main building of the hotel is a 112 m high tower which supports the EVO restaurant, a completely independent round volume floating above the terrace of the building.

The restaurant consists of a round base formed by a steel structure covered with fiberglass panels which contains the kitchen and its related services. On top of the base is the dining room, 95 m above the ground, covered with a glazed dome which shelters the customers and offers a magnificent view of the city.

Geometry

The restaurant's dome is a semispherical glazed surface measuring 21,86 m in diameter and 7,00 m in height made up of 219 high-performance triangular glass panels supported by a steel structure.

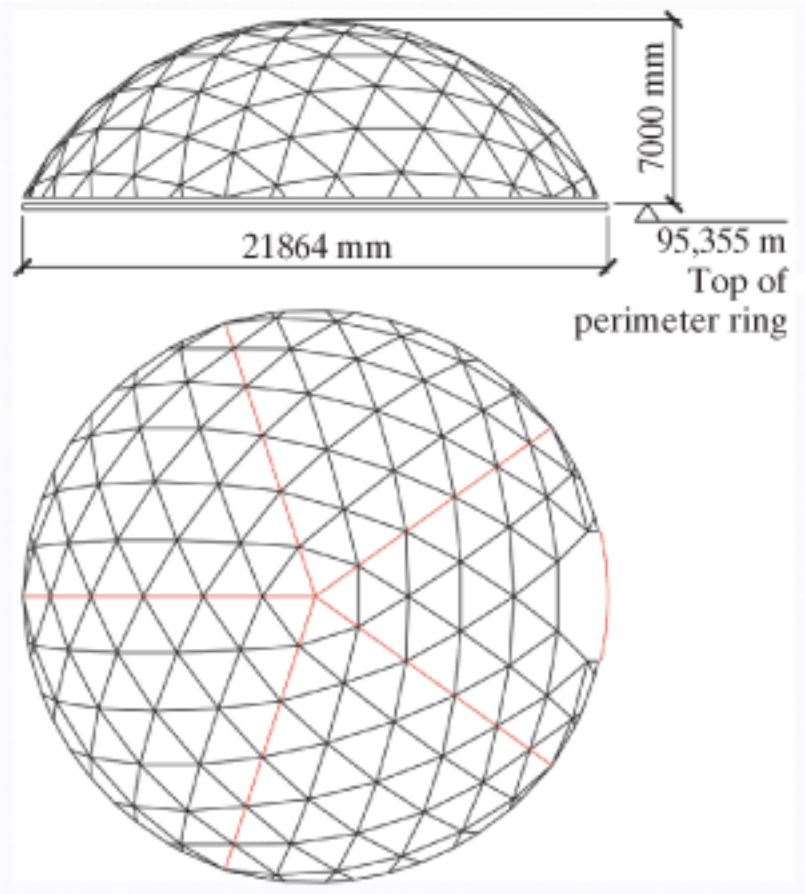

Fig. 1: Geometry of the dome

The faceted surface of the dome was obtained by inserting an icosahedron in a sphere and dividing its edges into six segments and its triangular faces into 36 smaller triangles. These triangles were then projected on the surface of the sphere generating a faceted spherical surface which was scaled and cut to obtain the final geometry of the dome (*Fig. 1*). This design permitted to minimise the steel structure while at the same time using glass panels of reasonable size.

A 5 m wide and 3 m high opening in the dome provides access to the two lifts and the emergency exit staircase through an independent glazed connecting unit.

Steel Structure

Loadings

The dome was designed according to Eurocode 1 snow loads, while wind loads were obtained from a three-dimensional fluid flow analysis of the complete building. Twelve wind directions were analysed, and a specific wind load was obtained for each glass panel and wind direction.

These loadings together with the flexibility of the supporting structure, the construction procedure and the lifting strategy determined the structural solution described below.

Structure

The structure of the dome is composed of steel nodes and members. Each member is formed by a 100 × 60 × 4 mm rectangular tube of steel grade S355 (i.e. having a yield stress of 355 N/mm^2) with two end caps welded on it. The nodes were built from short pieces of 190 diameter × 35 mm thick circular tube of steel grade S355, on which the flat surfaces where the end caps of the members lean were milled to its exact position and orientation. 379 members of 32 different lengths and 151 nodes of 24 different types were necessary to complete the dome.

Two M18 grade 10,9 bolts with an inorganic coating approximately equivalent to a hot dip galvanising were used on each bar-to-node connection. They were inserted into the node through its central opening and then tightened onto the end cap of the member. All bolted connections were prestressed using a dynamometric wrench in order to avoid any fatigue-related problem. All bolts were lubricated to facillitate prestressing. An embellishing steel plate was installed on each node to hide the bolted connections, although they can be easily removed to allow future inspections.

The Elastic Supports

The 51 lowest nodes of the dome are used to fix it to a perimeter ring formed by a 220 mm deep curved I steel section, which is in turn fixed to the steel structure of the restaurant's base.

Both the structure of the base and the perimeter ring had already been designed by the time the authors became involved in the project. So the authors had to deal with a base which was much more flexible than required by the dome. Moreover, the number and position of the connections between the perimeter ring and the base did not coincide with the supporting nodes of the dome.

In order to solve these two problems an elastic support was designed (*Fig. 2*). This was used to connect the 51 supporting nodes of the dome to the perimeter ring while keeping the

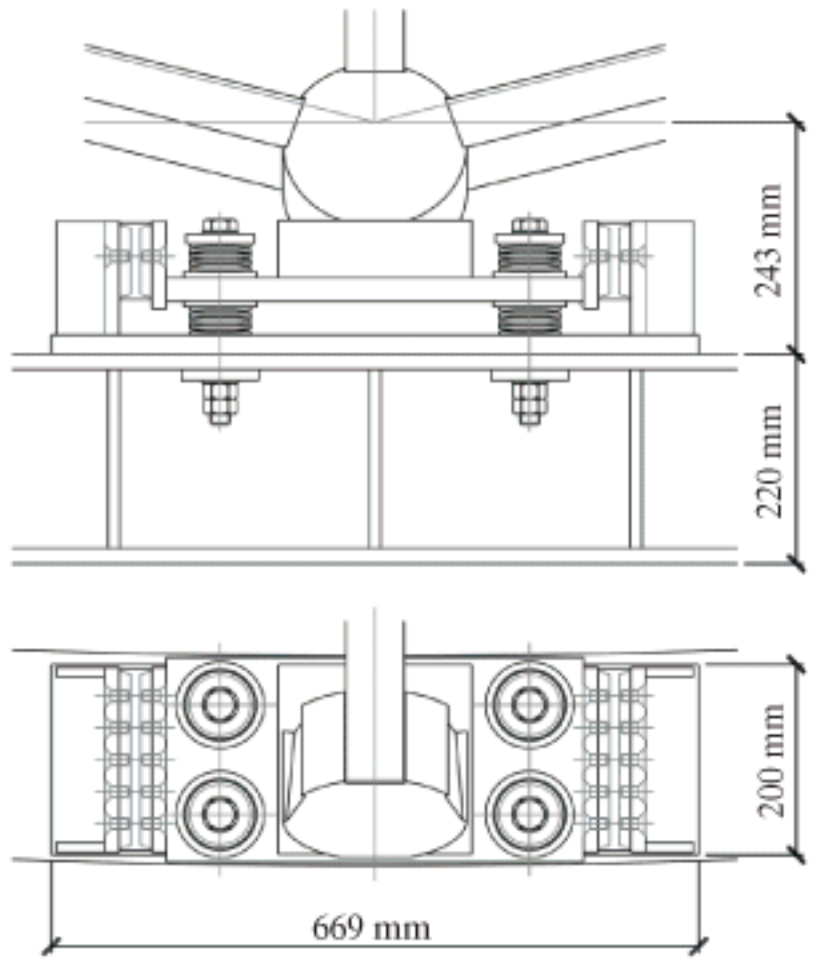

Fig. 2: Standard elastic support

ring rigidly connected to the steel structure of the base in order to increase its stiffness. An elastic connection between the perimeter ring and the base structure was not considered for contractual reasons.

An analysis of the dome taking into account the displacements which were expected in the supports of the perimeter ring indicated that it was necessary to design an elastic support soft enough to accommodate these displacements without generating high stresses in the members, but stiff enough to resist the tendency of the lowest members to bend outwards (traction ring effect).

In order to satisfy these requirements it was necessary to design an elastic support with different translational and rotational stiffnesses in each direction (radial, tangential and vertical). The final design of the support consists of columns of belleville springs combined with elastomer pads vulcanised on steel plates. It was also necessary to design and fabricate 10 twin supports to fix 20 nodes which could not be accommodated by the standard elastic support.

Cladding

The whole surface of the dome is covered with triangular insulating glass panels with an 8 mm toughened glass component with Heat Soak Test outside, and a 44,2 laminated glass component inside. The 19 mm thick air chamber has a continuous aluminium spacer along its perimeter which allows the panel to be fixed to the steel structure by means of intermittent clamps hidden in the sealed joints between panels.

The distance between clamps and the geometry of the aluminium spacer were designed so that the glass panels could be considered simply supported along its perimeter. Therefore, the thickness of the glass components was reduced to a minimum.

This fixing system can accommodate the different angles between glass panels and does not need any external element. The outer glass component is bonded to the spacer by means of the structural silicone sealing of the air chamber. However, as an additional safety measure, external clamps were installed on the three vertices of all panels.

In order to keep the energy consumption of the heating and air-conditioning systems within reasonable limits, it was necessary to use glass with a high-performance magnetronic coating which gives the panel a solar factor of 22,1%, a visible light transmittance of 38,5% and a U-value of 1,485 W/m^{2}K. It was also necessary to relax the comfort conditions for the whole volume while keeping them controlled in the public area.

Construction and Lift

Both to simplify the on-site assembly and for safety reasons, the 42 t dome was built on the ground, including the glass skin and the sealing between glass panels. The dome was then lifted to its final position on top of the tower by means of an 850 t crane (*Figs. 3* and *4*).

The dome was assembled on its perimeter ring, which was fixed to the ground by means of temporary supports situated in the same position as the final supports the ring would have on top of the tower.

During lifting, the dome was supported from 20 special nodes which had a larger diameter and allowed the fixing of the cable net which connected the dome to the hook of the crane.

This cable net was formed by three levels of prestretched cables assembled in the form of inverted V's, as shown in *Fig. 5*. D shackles were used for all connections between cables, so each shackle was free to move along the cable it was fixing, acting like a pulley. This arrangement allowed for the absorption of any inaccuracy in the length of the cables and any small

Fig. 3: The lift

Fig. 4: Final positioning of the dome on top of the tower

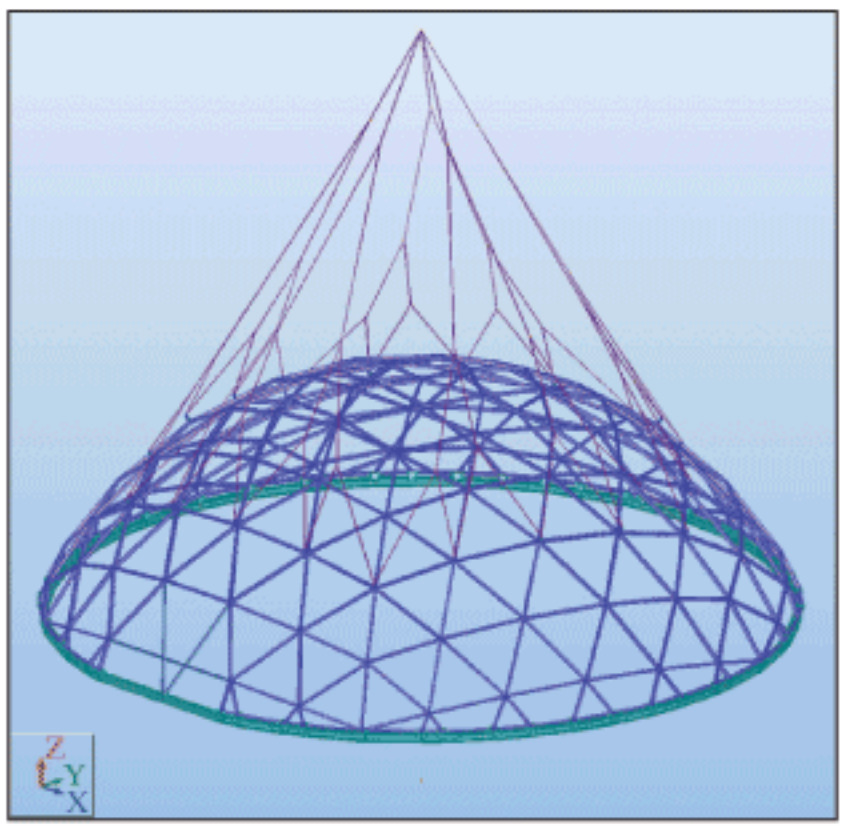

Fig. 5: Lifting model

unbalanced load which might have appeared while lifting.

A careful structural analysis of the dome when hanging from the cable net was necessary to guarantee a successful lift, which in turn necessitated a careful calculation of the three-dimensional funicular shape of the net.

The lift was successfully completed on 3rd May 2005, and it lasted for four hours approximately.

Conclusion

The aim of this paper was to describe the structural solutions adopted in the glazed dome of the EVO restaurant and its construction.

The construction of the dome required a high level of accuracy both during design and fabrication. All supports and connections were accurately designed and fabricated according to the calculation models. The elastic supports are good examples of this aim.

Accuracy was also necessary when fabricating the nodes of the steel structure, in which modern steel milling machinery combined with CAD/CAM/CAE tools proved very useful.

Finally, it was necessary a complete integration of the building process into the design stage, which enabled the successful lift of the completely finished dome, measuring 22 m in diameter and weighing 42 t, from the ground to the top of the tower.

Acknowledgement

Mr Francesc Arbos and Mr Joan Colom are gratefully acknowledged for their constant help during the project.

SEI Data Block

Owner:
Hoteles Hesperia

Architect:
Richard Rogers Partnership
Alonso, Balaguer y Arq. Asociados

Engineering and construction:
Bellapart S.A.U.

Weight (t):	42
Glass (m^2):	450
Estimated cost, without lift (EUR millions):	0,5
Service date:	May 2006