A doubly curved steel and glass dome for the historic Maritime Museum Amsterdam

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Summary

An international design competition was launched in 2004 to design a glass roof for the courtyard of the Dutch maritime museum in Amsterdam.

The building was designed by Daniel Stalpaert in 1656 as a warehouse in the water. The building needed drastic renovations in order to continue its mission, since it had been turned into a museum in the 1970’s. The renovation/restoration of the building was designed by Dok Architecten.

The lines on a historic navigation map serve as a basis for the design of the structure of the roof. In order to maximize the graphic effect of thin lines, the final shape of the roof was determined using form finding and form optimization thus creating a doubly curved shape. Through an integrated 3D calculation model it was designed to be entirely supported by the original masonry walls of the museum.

This paper discusses in detail how the glass roof was designed such that all polygonal glass panels are planar, that the structure is only 40mm thick, and that the entire roof only transfers vertical loads to the historic masonry walls.

Keywords: Doubly Curved Grid Shell, Geometry Optimization, Computational Methods, Conceptual Design and Realization, Morphology and Formfinding, Museum Reconversion, Historic Building.

1. The museum

The building is a historic monument. This has as the direct consequence that the construction of a glass roof has to be a reversible operation, that the courtyard has to remain an outdoor space, and the roof cannot affect the aesthetics of the courtyard facades.

2. Design Concept

The point of departure is to design a glass dome that rests lightly on a precious building. Also, the new roof should not be higher than the adjacent roofs. This is, again, a matter of respect towards the 17th century building.

The combination of both design intentions result in a dome with a maximal height of approximately 5m for a span of 47,94m (in diagonal). This proportion of L/10 is relatively flat. It is clear that a higher dome would render the structure more efficient, but is unwanted in this context.

Compasses on maritime maps are often divided in 32 parts. As a figure, they form the basis for loxodrome maps, and were used to sail towards a destination in 'straight line'. The radial repetition of the compass on a Mercator map results in the line pattern as shown above.

The new roof rests on the historical brick walls. In order to arrive at a solution that requires no reinforcing of these walls, the roof rests lightly on the wall, transferring mainly vertical forces. All

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horizontal reaction forces are brought in equilibrium in the new roof structure itself. This is achieved by a form finding, using the method of dynamic relaxation.

A priori this method renders a solution that has an optimal shape, where optimal is defined in terms of light weight. However the fact that many of the faces have more than 3 edges, this method does not take planarity of these faces as a criterion for optimization. A second method, using origami principles, was therefore applied.

In 2006 Chris Williams, from Bath University UK, created a folding mechanism based on 23 independent folding mechanisms in order to obtain the loxodrome lines on a doubly curved dome consisting of planar shapes having 3 to 6 edges.

3. Structural design

The entire roof has been modeled in SAMCEF-FIELD. Thus, the exact geometry (after the folding mechanism conversion) and precise dimensions of each element are taken into account for the steel code check. Also the glass panels are modeled as elastic plates to arrive at a precise load distribution.

Using the exact sections, taking into account the varying stiffness, implies that the steel code check is an iterative process. The steel code check itself is performed based on Eurocode steel code checks.

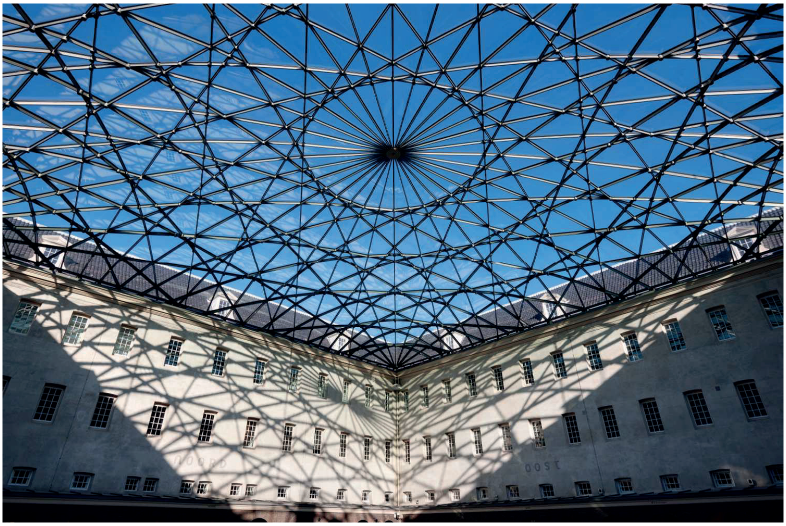

Figure 1: finished glass dome (image: Ney & Partners)

The glass roof was finished in May 2012 and consists of 1016 unique flat glass panels (ranging from triangles to six sided polygons), 2.2km of steel ribs and over 1000 RGB leds.

4. Conclusion

Covering an inner courtyard is a challenge looked at for many old buildings. In the case of *Het Scheepvaartmuseum* it allows to drastically alter the way the building is used. By changing the inney courtyard into the central point of the building and its experience, many questions are raised. How to relate a modern, lightweight, transparent structure with the laden history and appearance of an architectural monument?

The *Scheepvaartmuseum*'s steel and glass dome was conceived as a conceptual extension of the museum's maritime archive. At the same time, these structural lines, derived from maritime maps, provide with a structurally sound concept. Although visually subordinate, the soundness of the structural concept is the foundation for the feasibility of a structure in a historic context.