Sustainable and Transparent Glass Roofs - Concept and Geometry

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Summary

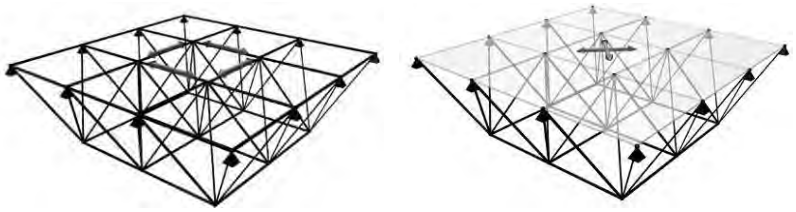
Space grid structures are appropriate to cover large areas. They allow the realization of plain roofs. To improve the transparency of such structures a new type of sustainable und transparent double layer grids is developed. The strict replacement of all bars in the compression layer by glass panes significantly increases the transparency and saves material. The contribution describes the geometry finding for such structures. Basis for the research is the structure geometry of steel space grid structure that is extended to transparent space grids. As result of the research a full-scale mock-up of the most appropriate structure was built to demonstrate the feasibility.

Keywords: Glass, Roof, Space Structure, Transparent, Grid, Structure Geometry

1. Introduction and concept of transparent space grid structures

The objective of the conducted research is the design of a transparent roof that works as bending system and achieves the high transparency of curved translational grid shells (figure 1. Basis for wide spanning column free roofs are space grid structures. Usually the industrially prefabricated space grid structures were made of steel, very seldom of timber or even reinforced concrete. The first space grid system widely available and commercially successful is the MeRo system, developed by Max Mengeringhausen in 1943.

Figure 1: Hippo house in Berlin Zoo as curved roof



Figures 2a and 2b: Concept of transparent double layer grid

Glass is able to transfer significant compression forces of up to 1000 MPa. To use the in-plane strength of glass, the idea of the concept is the consequent replacement of compression bar members in the upper layer by glass panes in a double layer grid. The glazing fulfils a double function: it serves for the load transfer and for the roof covering (figure 2).

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2. Structural geometry of homogeneous transparent double layer grids

The geometric order defines every modular built space structure. At a double layer grid the upper and lower chord layers are the relevant parts of the structure. The material glass requires certain geometric characteristics to be used economically. The surface of polyhedrons can be described as a grid, too. With the main focus on the grid suitability especially homogenous grids are most appropriate for space grid structures, as at them a high repetition of single elements exists.

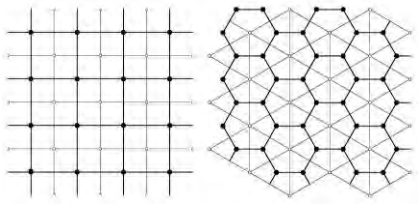

Figure 2: Plain homogeneous grids, their basis are the platonic bodies

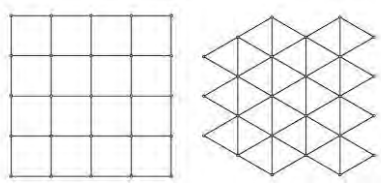

Figure 3: Appropriate homogeneous grids for the compression layer

3. Structural geometry of double layer grids with a glass pane layer

Only a few geometries are appropriate for a compression layer made of glass panes from the various grid geometries. The grid geometry of the compression layer must fulfill the requirement for an economic use of glass. This is defined by the pane size and by the homogeneity of the central knot. The most economic cut of glass panes are squares or rectangles. Consequently the homogeneous compression layer grid consists of square panes, equilateral triangles or even rectangular panes in special cases. At the shown double layer grid example the upper and the lower grid have the geometry of square grids. On this basis different structures are modeled. Mengeringhausen's morphology is used to classify the structures.

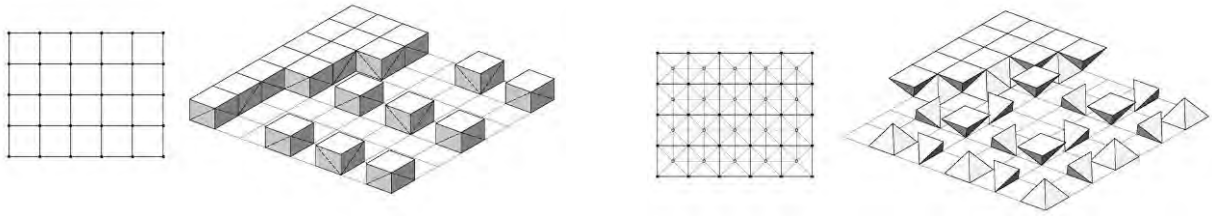

Figure 4: Structure cube and structure half-octahedron plus tetrahedron

4. Mock-up realization

To demonstrate the feasibility a full-scale mock-up of 15 m span was built. The structure is assembled of equal modules. Each module is a stable, statically determined structure in the shape of a half-octahedron. The prototype demonstrated that transparent space grid structures could well be built using steel-glass-modules, which serves as basis for extended load-bearing tests, either on the global system or on single modules.

5. Conclusion and acknowledgments

Transparent space grid structures assembled of steel-glass-modules are bending systems with an increased transparency and lightness. They base on the structural principle of traditional space grid structures, at which the bar members in the compression layer are replaced by glass panes. Starting with the structure geometry of traditional space grids this new concept has further constraints due to the pane elements to build a suitable and economic grid. A full-scale mock-up was built, that shows the potential of this new construction of transparent space grid structures. This work is funded by the Federal Ministry of Economics in Germany and the companies: Glaswerkstätten Frank Ahne, MBM Metallbau Dresden, Pauli + Sohn, Saint-Gobain Flachglaswerk Radeburg, Thiele Glas.