TIMBER GRIDSHELLS: DESIGN METHODS AND THEIR APPLICATION TO A TEMPORARY PAVILION

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ABSTRACT: This paper describes timber gridshell design methods and building techniques. The authors’ experience with such projects is used to highlight the advantages of timber gridshells. Relevant built examples are presented and their form-finding and analysis methods are discussed. The relevance of the timber gridshell technique is illustrated by a recently built project in Cluj, Romania that builds upon previous knowledge and takes advantage of modern computational tools that are available for both architects and engineers.

KEYWORDS: Timber structure, Gridshell, Form finding, Structural analysis

1 INTRODUCTION

Timber gridshells are a solution to the growing interests of free-form architecture in the context of an ever increasing awareness of the natural limitations of our environment. The characteristics of timber gridshells - long-span, lightweight, affordable and sustainable - argue that it should be a perfect fit to the architectural programmes of our time. However, their use has so far been limited to experimental pavilions and a few very worthy, large-scale, permanent buildings. In this paper, we present existing gridshells that have answered the needs of architecture and discuss various methods used to design them, including physical and computational methods. We conclude by presenting a recent example that was informed directly by the construction process.

2 BACKGROUND

Gridshells, also referred to as lattice shells or reticulated shells, are defined as structures “with the shape and strength of a double-curvature shell, but made of a grid instead of a solid surface” [1]. The materials out of which such structures can and have been constructed include aluminium, steel, timber, cardboard or glass-fibre composites.

2.1 TIMBER GRIDSHELLS

The timber gridshell technique was first developed by Professor Frei Otto and involves deforming a flat grid of straight timber laths into a doubly curved shape. This is made possible by the low torsional stiffness of timber and by ensuring that nodal rotations are allowed [2]. Using a double-layered system, with 4 sets of laths arranged in two directions, allows such structures to achieve higher curvatures and hence, more exciting architectural expressions.

Due to the two-directional arrangement of members, timber gridshells can support forces along the two directions and out-of-plane bending. In order to provide in-plane shear strength and stiffness, the structures need to have diagonal bracing in the form of cross ties, rigid bracing or an active covering system.

This technique was first used on a large scale for the Mannheim Multihalle in 1975. The building, shown in Figure 1, featured a 60m x 60m span dome achieved by 50mm x 50mm hemlock sections [3].

Figure 1: Mannheim Multihalle: exterior with two domes and connecting pathways; interior of one of the domes (images – SMD Arquitectes)
2.2 MODERN EXAMPLES

The Weald and Downland gridshell was built in 2002, more than two decades after the Mannheim project. It features an uninterrupted floor space which is 48 m long and between 11 and 16 m wide, enclosed by a corrugated barrel vault shape.

The Savill Garden gridshell was built in 2006 and is also a corrugated barrel vault that spans over a 90 m long and, at its widest, a 25 m wide space. The gridshell roof is supported all along its perimeter on a tubular steel beam raised above ground on slanted columns.

3 DESIGN AND ANALYSIS

Form-finding timber gridshells has evolved, together with computational technologies. At first, hanging chain models were used to produce funicular shapes, including the one of the Mannheim project.

The Weald and Downland gridshell was developed from the architectural concept using physical models. In the initial stage, these informed a computational process that led to a non-funicular, corrugated form. Since the self-weight of the building was relatively small, this form was better suited to resist lateral wind loads [4].

The Savill Garden project departed entirely from the use of physical modelling. The computational process involved translating the architectural shape into a geometric definition using a damped sine wave for the centre line and varying size parabolas for the cross-sections. A regular grid was then imposed on the surface generated [5].

Figure 2: Form-finding: flat grid to final shape

More recently, a double-layered timber gridshell was designed during a student workshop in Cluj, Romania with the widely used digital physics modelling package Kangaroo Live Physics.

Unlike the aforementioned gridshells, the form-finding, seen in Figure 2, was based on the proposed construction process by starting with a flat grid and pushing the support nodes towards a desired support configuration, while also pushing the grid upwards. Areas of high curvature around the entrances used 2 thin laths in place of a single one, ensuring the desired shape could be achieved. The gridshell subsequently functioned as a temporary cultural venue, spanning 18 m x 13 m and it is shown in Figure 3.

The structural analysis of timber gridshells requires a non-linear study to evaluate buckling behaviour. For the projects described here custom computer programs were used, as well as commercial software packages.

Figure 3: Gridshell in Cluj (image – Dragos Naicu)

4 CONCLUSIONS

Timber gridshells offer the attractive possibility of creating complex surfaces and spaces using a set of straight elements that are bent into shape. This makes them affordable and relatively easy to build. Their design and analysis methods are diversified and have evolved over time, while the convergence of sustainability concerns and computational abilities makes the technique relevant now.

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REFERENCES


