

## The World's first Sprayed Net Hyperboloid Ice Structure

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### Abstract

Ice is a sustainable and reusable material suitable for construction in cold climates. Ice blocks are most commonly stacked to produce carved structures, but it can also be sprayed into unique forms. In the winter of 2018, a team of architects and engineers from the University of Cambridge realized the world's first hyperboloid sprayed net ice structure during the annual Harbin Institute of Technology "International Ice and Snow Construction Festival", as shown in Figure 1. This paper describes the design, modelling and construction of the hyperboloid. Ice has been researched as a structural material since the 1940s [1]. Ice is stronger in compression than in tension so is suited to certain structural geometries such as domes, in a similar way to concrete. However, ice construction is difficult because the formwork required is large and technically challenging as it must hold the water before it freezes. The authors propose a novel and efficient solution by using a rope net which acts both as formwork during casting and as a pretensioning system in service that can keep the cast structure in compression.

It was thus desirable to obtain a form which enabled a net held in tension to be sprayed to create a compression only structure. A tree-like design was developed, taking inspiration from the work of Vladimir Shukhov [2]. The final design used two timber hexagons with a rope net pretensioned between them. Cellulose was mixed with water to increase the strength of the ice [1]. The final piece was 5m tall with a top hexagon diameter of 5m and a bottom hexagon diameter of 2.5m. The tapered inclined columns were designed to vary in diameter from 150mm at the base to 75mm at the top. Scale modelling as well as finite element analysis was employed during the design process. A major consideration was the structural stability during construction. This paper will explore ice construction before discussing the design of the hyperboloid. Special focus will be given to construction phases and the cross-section optimization performed. This project explored areas of ice construction which have been little researched; spraying of rope nets, difficulties in the construction of ice nodes, and buckling of ice struts all be discussed before avenues of future research are identified.



Figure 1: The world's first sprayed net ice hyperboloid structure

### References

- [1] Anro Pronk et al, "Design and Construct of the 30.5 meter Flamenco Ice Tower" in *Creativity in Structural Design: Proceedings of the IASS Annual Symposium 2018*, MIT, Boston, USA, July 16-20, 2018.
- [2] Matthias Beckh, *Hyperbolic Structures: Shukhov's lattice towers: forerunners of modern lightweight construction*, John Wiley & Sons Ltd, 2015.