

TW-ICE: A Freestanding Ice Shell Pavilion

Rui LIU*, Mark MISTUR

Kent State University
132 S. Lincoln St. Kent, OH 44242
rliu5@kent.edu

Abstract

TW-ICE, a 10-meter tall freestanding ice shell pavilion formed by two intersecting asymmetrical cones with a scalloped surface, was successfully constructed in January 2019, Harbin, China using removable tension-based soft forms including ropes and fabric as formwork. Its success was based on the knowledge gained from its sister pavilion THRICE, built in December 2017. The paper reviews the major structural-formal challenges identified from the construction of THRICE including: excessive sag on the side of the structure with shallowest slope, excessive deformation caused by high elasticity and creep of polypropylene ropes used for its formwork, and out of plane arches at the intersection of the three cones and at the openings to the exterior.

By investigating the challenges associated with developing a geometry best suited to the reversal of forces from tension (formwork) to compression (the resultant ice pavilion), assisted by digital form-finding and finite element analysis, this paper discusses the design and construction modifications including: (1) increased cone slopes achieved by reducing the diameters of base circles; (2) the use of polyester ropes with higher modulus of elasticity and less creep compared to polypropylene ropes; (3) pretensioned perimeter ropes along their parabolic paths of the openings to reduce the out of plane segmentation caused by scalloping, and (4) improved design of the oculi formed by projecting circles on the tops of the two intersected asymmetrical cones.

This research expands on Heinz Isler's investigations into frozen draping fabric forms. Unlike Isler's frozen fabric forms, in addition to removing the temporary column supports, the debonding between the muslin fabric and the frozen water/cellulose mixture allowed the complete removal of the fabric and interior rope formwork – resulting in a freestanding, fabric-free ice shell structure. The study further confirms the soft tension-based formwork using ropes and fabric is feasible for the form-finding and construction of ice shell structures.



(a) TW-ICE without formwork (ext. view)



(b) TW-ICE without formwork (int. view)



(c) Interior with temporary formwork

References

- [1] R. Liu, and M. Mistur, "THRICE – An Ice Pavilion: Reversing Forces from Construction to Completion," in *Creativity in Structural Design: Proceedings of the IASS Annual Symposium 2018*, MIT, Boston, USA, July 16-20, 2018, C. Mueller and S. Adriaenssens (eds.).