

Design of Discretized Acrylic Shells with Heat-Induced Form-Finding

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Abstract

Two Blue Shells is a pavilion proposal for the exhibition of innovative lightweight structures at the 2019 IASS Conference in Barcelona. This paper presents the research and design process of the proposed design; the pavilion consists of two discretized acrylic shell structures that utilize the response of materials exposed to heat as a generator of form. Adding to the ongoing discourse surrounding the challenge of plastic in the waste stream, *Two Blue Shells* proposes a novel way to reuse acrylic plastic in the built environment.

Physical form-finding using fabric, hanging chains, and pneumatic models are common methods for finding optimal shapes of shell structures. Form-finding based on plastic materials deforming when heated is another method that has been used to create small-scale design and analysis models [1]. *Two Blue Shells* utilizes this technique in a novel way to directly form a full-scale structure (2m x 4m in plan). In this application, acrylic offers a significant advantage over other available plastics because it does not lose its transparency when heated. To make the structure easily transportable and feasible with readily available material dimensions, we have investigated and developed methods for discretizing the structure by connecting small flat acrylic tiles to create a large sheet. This sheet is then heated and allowed to deform into a doubly curved shell form. A small-scale prototype (0.4m x 0.4m) was developed to validate this procedure. Laser cut acrylic pieces were mechanically connected at their corners in a manner that allowed them to be quickly disassembled and reassembled.

The physical testing is complemented by digital modeling that simulates the results of various experiments and allows the team to better understand the performance and experiential qualities of the design. Technical considerations include differential stress concentrations at fastener locations, overall load paths, strength and stability, and the influence of discretization on global and local curvature. Experiential and spatial explorations include the resultant reflection and refraction of light, the transparent qualities of acrylic, the effect on sound and air, and the layering of colored shadows.

The design of the frame used to hang the acrylic in the oven is an integral aspect of the research and development. While the frame must respond to limitations based on available oven sizes, it also provides opportunities to influence the final form through manipulation of the boundary conditions. Future potential avenues for this research could involve scaling the process beyond current limitations, exploring strategies for influencing the final form, and developing new applications for the method.

The design of *Two Blue Shells* integrates a contemporary material with an acknowledgement of past forms like tiled roofs and shell structures found in and around Barcelona. The methodology looks to the past as well as the future to seek design solutions to current environmental challenges.

References

- [1] P. Belles, N. Ortega, M. Rosales, and O. Andres, "Shell form-finding: Physical and Numerical Design Tools", *Engineering Structures*, vol. 31, p. 2656-2666, July 2009. [online]. Available: Elsevier, <https://www.journals.elsevier.com/engineering-structures>. [Accessed Dec. 3, 2018]