Tortuca

An Ultra-Thin Funicular Hollow Glass Bridge

Yao Lu, Alireza Seyedahmadian, Philipp Amir Chhadeh, Matthew Cregan, Mohammad Bolhassani, Jens Schneider, Joseph Robert Yost, Gareth Brennan, Masoud Akbarzadeh

Designed with Polyhedral Graphic Statics (PGS), a geometry-based structural form-finding method, Tortuca presents an efficient and innovative structural system constructed by the dry assembly of thirteen hollow glass units (HGU). It also proposes a new language for glass that is carefully treated, structurally informed, fabrication-aware, and environmentally responsible. Each HGU of *Tortuca* is made of 1 cm (3/8 inch) glass deck plates and 2 cm (0.7 inch) acrylic side plates precisely cut with 5-axis abrasive waterjet cutting and CNC milling to match the structural geometry. The structure spans 3.2 m (10.5 ft) with a mass of only 250 kg (550 lbs), where the float glass is the primary load-bearing material. Thanks to the efficiency and light weight of the construction system, a single person can assemble and disassemble the structure without needing a crane or additional labor. Moreover, this research explores the potential of using an extremely delicate material such as float glass for the primary structural system to encourage minimizing the material and energy demands in buildings and infrastructural projects. Additionally, it shows how utilizing the material in its purest format could simplify the recycling process after the life cycle of the structure has ended. Also, this research project is achieved by collaboration across different institutions, from design to engineering, from theoretical to practical, and from academia to industry. We appreciate the value of breaking disciplinary boundaries and joining forces from multiple fields.

STRUCTURAL FORM-FINDING

The generation of the base geometry (Figure 3) is achieved through PolyFrame (Nejur and Akbarzadeh 2021), a Rhino plug-in that implements PGS. The generated form diagram with thirteen polyhedral cells is then optimized regarding global dimensions, individual edge lengths, and face angles, to better satisfy the fabrication constraints and increase the ease of the subsequent fabrication process. As a result, the bridge dimension is set to 3.2 m(L) × 1.3 m(W) ×0.55 m(H), the thicknesses of the polyhedral cells are set to around 100 mm, and each cell is constrained to a size that one person can handle during the construction process.

MATERIALIZATION

After obtaining the base geometry of the bridge, each polyhedral cell is materialized as one HGU. The HGU details and

PRODUCTION NOTES

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Status:	Completed
Site Area:	50 sq. ft.
Date:	2022

1 Side view of the assembled hollow glass bridge structure

2 The assembled hollow glass bridge structure

the steel abutments that hold all HGUs are devised based on the material selection and fabrication constraints. Each of the two top and bottom faces of every polyhedral cell is materialized as a glass deck plate using 9.5 mm annealed glass. For the smaller side faces, they are materialized as either 9.5 mm thick glass side plates or 21 mm thick acrylic side plates, depending on whether they need to accommodate the connection mechanisms with the neighbor HGUs (Figure 4). Improved from a precedent (Lu et al. 2021), the connection mechanism between neighboring HGUs contains two pocket channels on the pair of facing side plates and a locking strip that has a butterfly shape section profile. Between the neighboring HGU deck plates and between the HGUs and steel abutments, Surlyn sheets cut with a 3-axis CNC router are placed and used as the interface material preventing direct glass-to-glass, and glass-to-steel contact.

NUMERICAL SIMULATION

Before HGU fabrication and bridge assembly, a static numerical finite element analysis is conducted using ANSYS, which follows the previously established analysis sequence as explained by Yost et al. (2022). The result shows that the bridge successfully sustains its self-weight.

FABRICATION AND ASSEMBLY

The glass parts are cut using 5-axis abrasive waterjet cutter (Figure 5), and the acrylic parts are milled using 5-axis CNC router (Figure 6). The assembly process consists first of the construction of the individual HGUs (Figure 7) followed by the assembly of the entire bridge (Figure 9). The heaviest HGU of the bridge weighs about 23.3 kg, meaning that the assembly process can be handled by one person without any heavy construction machinery. Moreover, most material can be easily dismantled and recycled at the end of its life cycle as a consequence of the dry assembly process.

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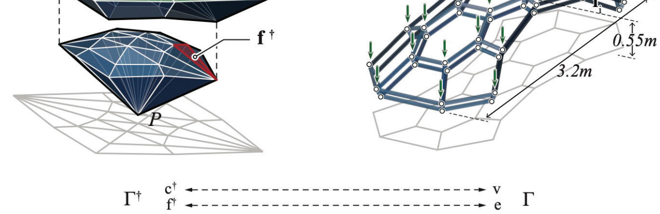
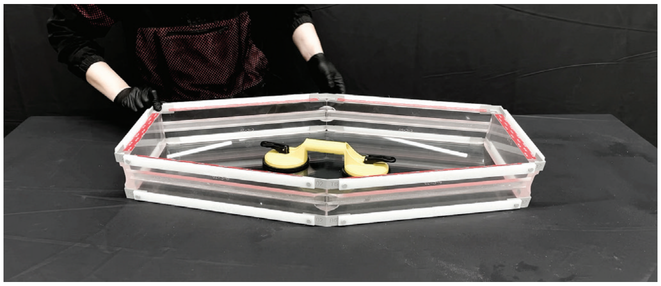


3 Form-finding using Polyhedral Graphic Statics (PGS)

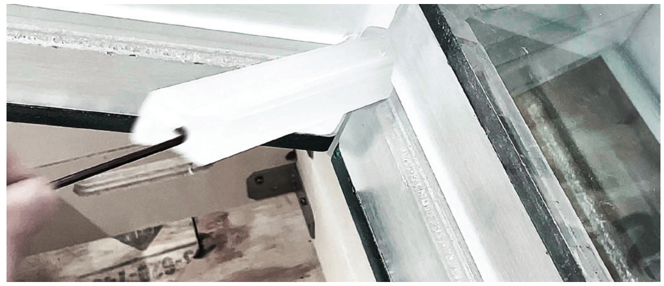
4 Close-up of the butterfly connection mechanism

5 5-axis abrasive waterjet cutting for glass fabrication

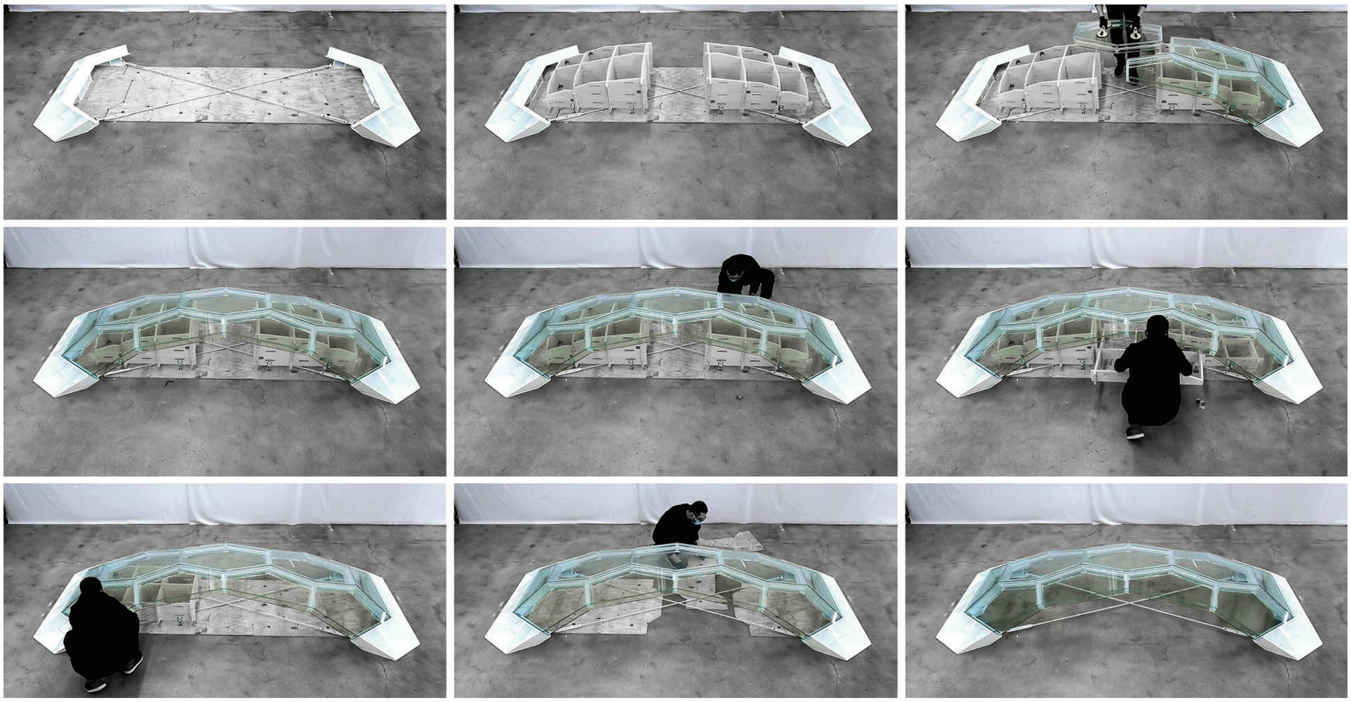
6 5-axis CNC milling for acrylic fabrication



7 Construction of a typical hollow glass unit



8 The locking strips can be easily inserted and removed during assembly



9 The modular assembly process of the structure can be handled by one person thanks to the lightweight of the hollow glass units

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IMAGE CREDITS

All other drawings and images by the authors.

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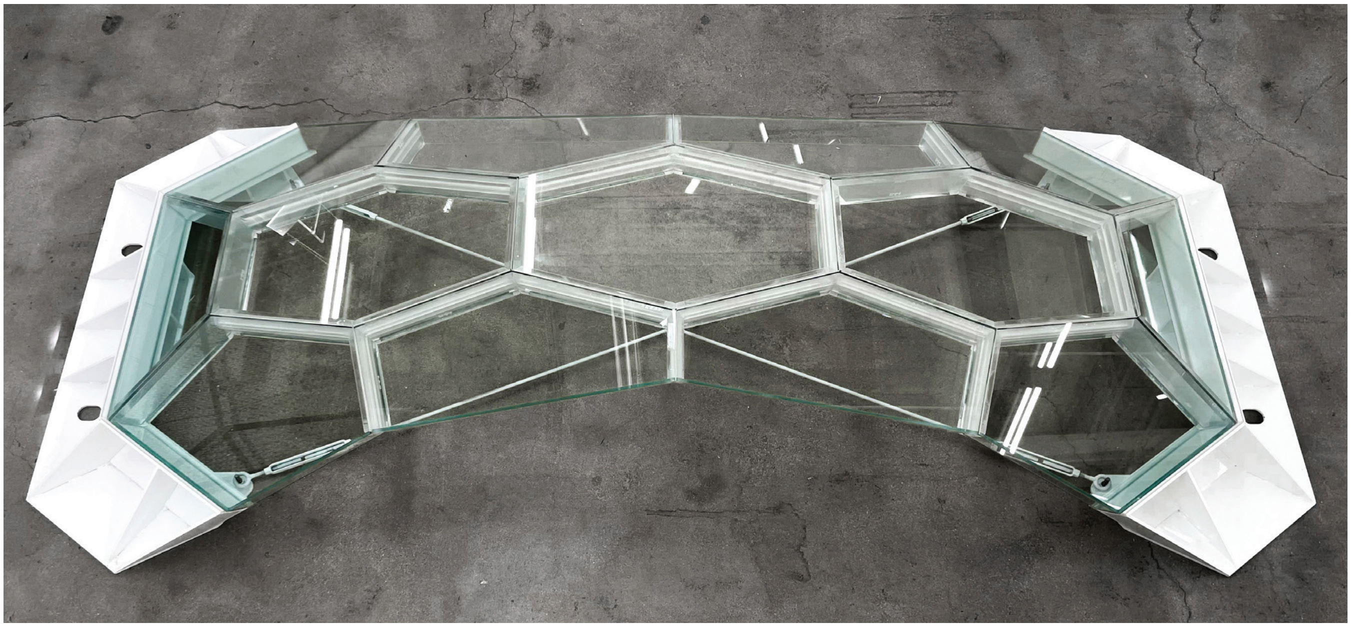

10 Aerial view showing both the compression and tension members

11 View looking up at the steel abutment

12 View from under the glass bridge structure

Matthew Cregan received a Master of Science in Civil Engineering with a structural concentration from Villanova University in 2022. He is currently employed as a bridge engineer with Hardetsy & Hanover in New York City.

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