INFRAME: Art in elastic timber frame

by Judyta Cichocka

Structural Art

> “For all ... structures, efficiency and economy are absolutes, something all engineers must strive for, but elegance is the bulls-eye, if you hit elegance, and efficiency, and economy then you have reached a level called Structural Art.”
>
> -M. Garlock

Idea

INFRAME means “art in frame”. The structure was imagined as a lightweight, reusable timber gridshell, which, as a picture frame, creates in its inside a space for artistic expression.

INFRAME transforms the function of the public staircase between buildings E15 and E25 on the MIT campus into a performance area. A single layer gridshell becomes a real temporary outdoor stage for the electronic music performances, a canvas for the video-mapping show and has multiple imaginary roles invented by potential next owners.

The ultimate goal of the project was to design an elastic timber gridshell, which can be constructed in real-life scenario, providing a functional space for experimental artistic performances and which endeavors to embody the principles of structural art: economy, efficiency and elegance. The challenge lied in development of the design strategy, which allows rapid construction by a small group of inexperienced builders at minimum cost while complying to the building code in Massachusetts (which was required by MIT).

The principles of structural art driving the INFRAME were interpreted as follows:

> Elegance: simplicity – minimum material use, optimal distribution of laths (material)
>
> Economy: selection of material and fabrication methods, minimal use of materials, recyclability of the structure, symmetry of the structure for faster manual fabrication, fitting all elements to minimum number of plywood boards
>
> Efficiency: maximum buckling factor, minimum deflection, meeting the ASCE maximum stress requirements for timber structures, constructability

Methodology

The early conceptual design was exploratory and involved consultations of the location with the owners of the ground – LIST and the MIT EHS Department. The overall size and evaluation criteria for conceptual designs were established with the artists and included among others: the visibility of the performer, the potential rain coverage, speakers' location and space for the audience inside the pavilion. After selection of location, overall form and size, a parametric model was prepared.

A computational model of the pavilion enabled the multi-objective optimization of the lath configuration. The optimization procedure was minimizing the maximum displacement and cost while maximizing the buckling factor. Cost was evaluated using a custom cost function based on the total length of members, numbers of supports, number of joints. The best performing design was selected and verified towards the building codes for timber structures.

Outcomes

It was difficult to meet the building regulations in Massachusetts with a single layer structure of the overall dimensions for a mid-size outdoor stage. Therefore, the structure was designed with a few double-layer members. Due to very constrained approved time for the construction on the MIT campus, the second layer members were not mounted as planned in the approved project.

Nevertheless, the single layer constructed structure successfully served for the planned artistic performances. Before the planned disassembly phase, the structure was relocated overnight in an act of the student's prank. It seems the gridshell was relocated in one piece from Media Lab courtyard to the East Campus (150m). INFRAME was found on Friday, September 20, 2019 in perfect condition on the beach volleyball playground in front Goodale building. Students probably tried to save INFRAME a night before the planned disassembly. After its unexpected relocation, INFRAME was successfully disassembled and will be repurposed for future installations and activities.

Remarks

The mix of low-cost materials and state-of-art design tools can result in the design of a structure buildable without sophisticated construction tools within a few-day time frame. The ease of construction creates an opportunity for structural systems that not only are cost-effective but can also be built by communities. The feeling of shared creation produces a special connection between builders and the structure and makes structures naturally sustainable.

Some data:

Materials & cost: total: $3,335

Plywood for laths: $1,780

Red Oak plywood for base: $833

Hardware: $722

Cross section: 100x9 mm

Total length of members: 234.1 m

Weight: 96 kg (without the base)

Fabrication and erection: CNC fabrication of the base, manual fabrication of the gridshell members, sequentially erected

Fabrication time: CNC fabrication of 7 8x4 ft board for the base: 7 h (1 CNC Router)

Manual fabrication of the laths: 12 h (4 people)

Assembly time: 20 h (4 people)

Disassembly time: 7 h (2 people)

Contributors:

Construction: Camp Daniel Seats, Michael Ramirez, Daniela Hensel, Judyta Cichocka, Loai Namaani, Media Lab City Science, CEE MEng 2020 group, random passengers

Consultation: Paul Richardson, Jonathan Roynon (BuroHappold Engineering), Riccardo La Magna (Struct.ure), Emil Adelis (Chalmers University of Technology)

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Sponsors: MIT CEE Department, Council for the Arts at MIT