MASS TIMBER INSTITUTE

UNIVERSITY OF TORONTO
JOHN H. DANIELS FACULTY OF ARCHITECTURE, LANDSCAPE, AND DESIGN

News From MTI

Hello Mass Timber Colleagues!

Feature: Aeolian Soundscape Pavilion - An Interview with Nicholas Hoban and John Nguyen

MTI, Nicholas Hoban, and John Nguyen

If you've had a chance to visit the Lumière festival at Ontario Place, you may have seen the Aeolian Soundscape Pavilion. This month, MTI editor Sanjana Patel spoke with Nicholas Hoban and John Nguyen, who led the pavilion's design and production with Brady Peters. This project has been sponsored by the Mass Timber Institute, the John H. Daniels Faculty of Architecture, Landscape and Design, and Ontario Place. Nicholas Hoban is a lecturer and Digital Fabrication Coordinator at the University of Toronto Daniels Faculty. John Nguyen is a PhD student at the faculty, specializing in architectural acoustics.

The Aeolian Soundscape pavilion is an experimental timber structure made of unique components made possible by digital fabrication. The expertise of such projects lies not only in their proposal, but also in creating makeshift assemblies to solve problems as they arise and the workflows of coordinating large teams.

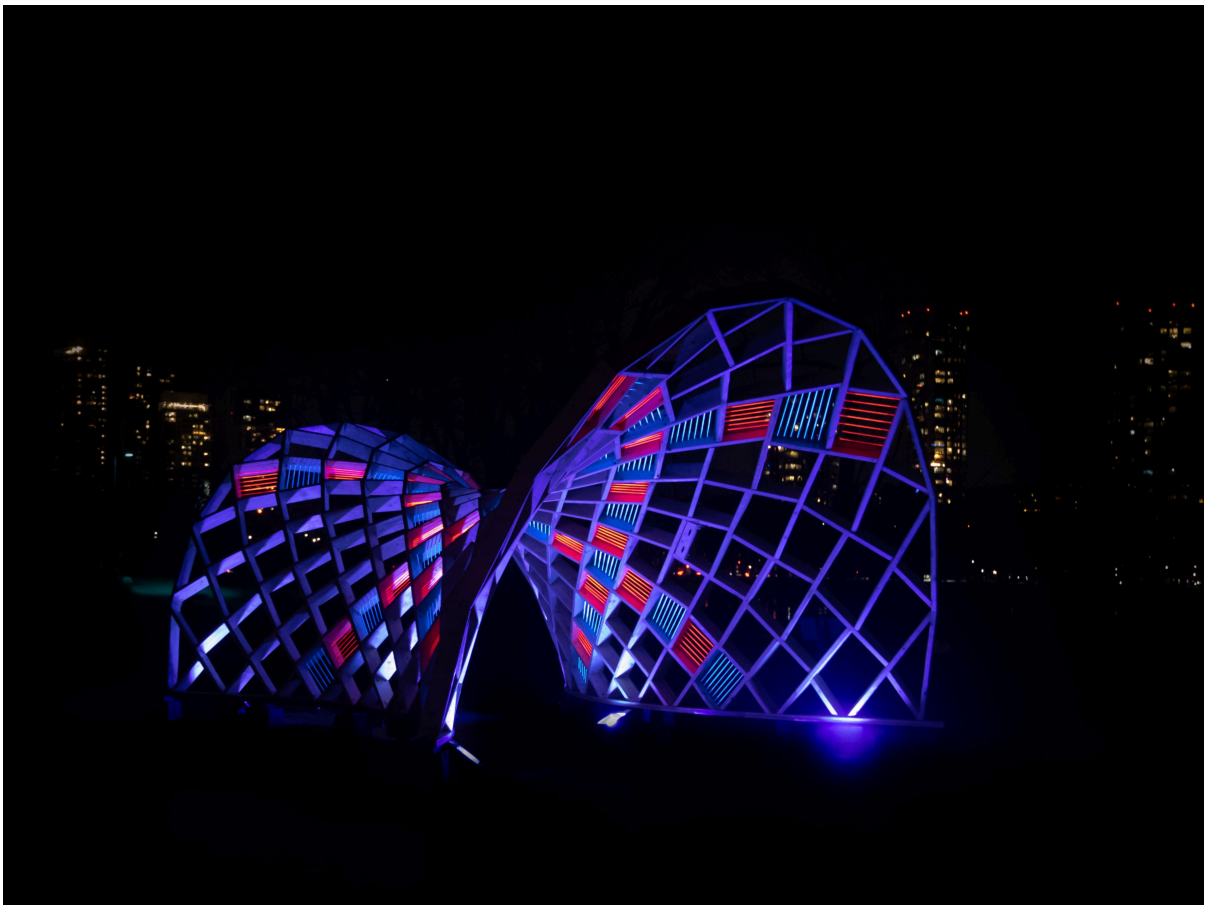


Image: Aeolian Soundscape Pavilion structure at night. Credit: Liam Cassano

SP: What are the research goals of this project?

We wanted to look at complex compression timber assemblies, to highlight the capability of the reciprocal frame structures, which are underutilized. In addition, we wanted to demonstrate the technical capabilities of the Daniels Faculty and to give students an opportunity to participate and develop experience in a project of this nature.

SP: Can you elaborate on how reciprocal frames are underutilized? In construction or in educational contexts?

At present, there are only three lamella structures in Ontario. Originally, they were used as military structures for storage during WW2 when timber was scarce. Lamella structures offered the ability to span large distances with small discrete timber elements.

SP: Were there any unexpected challenges in the design/fabrication/installation?

Our greatest challenge was a short timeframe – from the time we learned that our entry had won, we only had a month to re-write our code, prototype and develop a workflow for production. We barely had time to double check and were production testing as we went along. We could easily have used another month.

SP: It's interesting to learn this required continuous refinement. What elements did you have when you originally submitted your competition entry?

We had a few test prototypes and had also built a jig to allow the robot arm to reach 5 of 6 sides in a wooden element. A partial assembly was tested without going through full production. For reference, the final production took place over 10 days of around 12 hours each. That's why we needed a large team.

SP: How many people were on the team?

The team consisted of 11 people that were assigned to various production tasks and some additional people that came on for site installation.

SP: Was there a consultant needed for working with the site?

No, but the site did require special consideration since we were not permitted to go below grade with foundations. In lieu of this we developed a system where a series of tensile cables runs through every pair of footings on either side of the LVL base. The footings were tied at the lap joints on the LVLs. The cables were buried only an inch below the soil, this configuration prevents splaying in case people try to climb the structure, or any of the compression loads cause the pavilion to push outwards. Although the pavilion stands without it, this was overengineered to create additional safety.

SP: Why were there lap joints in the base instead of a continuous piece?

Given the size limitation on the LVL board, multiple curved pieces were cut out and joined together – we used 3-axis milling for this.

SP: What was the design to fabrication workflow?

The entire project was parametrically modeled within Grasshopper, starting from the base saddle geometry to lamellae member extractions. This type of parametric workflow allowed us to efficiently parse geometry from Grasshopper that would go into a milling software called Powermill from AutoDesk.

SP: Is it a plug-in like KUKA PRC?

This is a stand-alone software which allow the setup of 5-Axis milling paths to be attached to robotic arm. It also simulates milling paths and motions of the robot arm. Powermill simulation matches our physical robotic cell for precise simulation and code generation.

SP: I see The KUKA robot was selected because it is 5-axis, allowing undercuts. Were there any attempts made to simplify the connections to make this project with the faculty's 3 axis CNC mill?

There was no way to do it. We needed to reach five out of six sides of a box, which is not possible with a 3-axis CNC machine. Initially, we tried to do it with 3-axis, but it created edge faced connections (meaning only a single line edge between two pieces). It's hard to make that type of connection structural as you lose most of the face-to-face material to transfer load. Many of the precedents we evaluated only produced a small canopy, rather than the shell to take advantage of the reciprocal frame structure. We decided a full face cut connecting to the beam to face would produce the desired results. We then provided Ontario place with different connection options.

Image: KUKA 5-axis robot milling a piece of wood at the Daniels Robotic Facility at UofT. Credit: Six Films

SP: Is there a panel for design review?

Yes, there's a team of different people that evaluate proposals although we only work directly with one contact person. They also gave us the site just beyond the gateway bridge for the installation so it could function as a lookout point to Lake Ontario as you pass through the pavilion.

SP: Do they let the teams pick a site?

Yes, they give us 16 sites to pick from. This project also required a flat topography, which directed our decision making.

Image: Soundscape Pavilion structure at Ontario Place seen at dawn. Credit: Liam Cassano

SP: How did the acoustics component play into this?

The site is windy, so the Aeolian harp became an inspiration for our project. Due to the proximity of the airport and many sound installations nearby, there are still many unpredictable factors in experiencing it as consistent laminar flow would be required.

SP: Going back to the prototyping, were there any times during the testing where a component didn't fit in place?

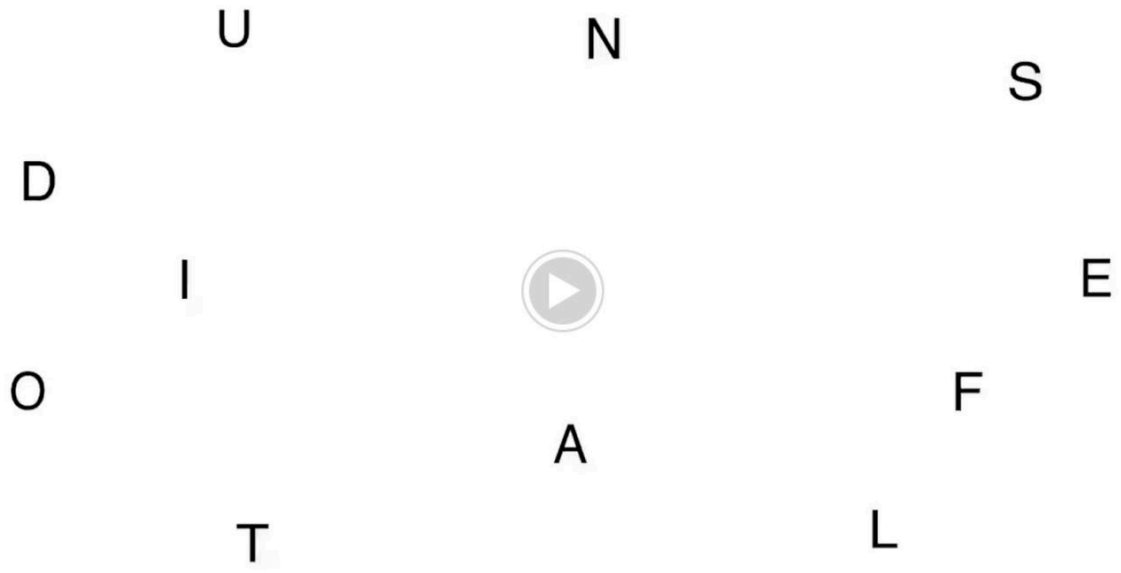
No, the robot is absolute. However, the dimensional lumber can warp. We selected our materials knowing that if we used fully dressed high grade lumber, we could limit the warping. Given that the lead times for Douglas fir were very long, we selected a 2” x 6” dressed spruce for the project. Selecting a locally harvested species was a priority. The wood was sourced from New Canadians Lumber in Toronto.

SP: How did the project budget play into design decisions?

The original plan was to use plywood because it would be faster. However, the cost analysis determined it would be 6 to 7 times more expensive. This is because plywood needs to be heavily sealed against the weather which causes delamination. We would have had to use 1 inch plywood as minimum thickness.

SP: Was there ever a time you considered assembly by robot as well?

No, it would overcomplicate the process – given that the construction is offsite (outside of the Daniels building) and the pavilion is too big for the reach of the robot. In our workflow, the beam is stationary and only the path planning to mill is required. Imagining paths to pick up and assemble components would introduce a lot of tolerances to consider.
In our workflow, we had three different teams of people to undertake production: an assembly team, a site install team, and a transportation/flexible support team. Groups of 4 beams would be assembled into “cells” before being transported to Ontario place. Weight constraints were a factor as there was no access to heavy machinery on site. Each cell could be lifted in place by teams of two people. Altogether, the pavilion is about 2,000 pounds of timber. The benefit of LVL and above grade foundation is that it can take a large amount of weight.



Aeolian Soundscape Video. Credit: Nicholas Hoban, John Nguyen, Six Films

SP: That's a lot of teams to coordinate.

We had an updating digital model to track so that the site team would know which cells were coming with the transportation team as the assembly team built the cells at the robotic lab. A happy accident was that the jig we built to hold the timber elements for the robot to mill became great for holding multiple beams together during preassembly.

SP: Having had this experience, what advice would you give to others pursuing this kind of project?

Pursue it! We have found it productive looking into history and seeing how those techniques can be translated today. Many of these forms date back to the renaissance – Da Vinci proposed a reciprocal frame bridge structure. The most common reciprocal structures are Zollinger lamella structures, typically used for single curvature, with one repeated unit. When you get into double curvature, every timber element is unique.

SP: Will you be submitting this to any conferences? This would be a good fit at conferences like ACADIA which explore computation design.

Yes, we are aiming for ACADIA and have the full paper in progress for that. We are also hoping to publish a journal article after that.

SP: How do you think this work will translate into your future projects/initiatives?

We have always been talking about pushing more complex timber structures. Our hope is to engage actively with MTI and external industry partners to research and explore timber assemblies.

News from the Institute

1. New Website Resources Page

Interested in furthering your mass timber knowledge? Our new Courses and Resources webpage compiles links to institutions which offer courses and online resource libraries.

2. Mass Timber Today Podcast

Our new podcast, Mass Timber Today, has officially launched! The podcast series will explore the opportunities and challenges of sustainable mass timber construction. Out now on Spotify, Google, and Apple Podcasts.

3. Hiring Thesis Research Student

Rasoul Yousefpour is hiring a graduate level researcher for Summer 2023 to undertake a thesis project titled *Panelized, Prefabricated Modular Construction Value Chain Map & Regulatory Scan.* To learn more, see the posting on our website.

Other Updates

- Check out Lihan Jin's thesis Accounting for Time in Life Cycle Assessment: Case Study of a Mass Timber Building