Catenary Timber: The 2022 Barry Onouye Studio

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ABSTRACT: The annual Barry Onouye Studio in the Department of Architecture at the University of Washington investigates the intersection of architecture and structural design through hands-on exploration. In Spring 2022, the studio focused on the rising importance of structural timber as part of a larger transition to lower embodied-carbon buildings. This studio utilized a pre-determined donation of sustainably-sourced timber from local foresters as the sole material of construction. Students were challenged to collectively design and build a free-standing timber pavilion that demonstrated the structural design potential of dimension lumber, and expand the existing formal and assembled logics of timber.

The studio was offered to first-year graduate Master of Architecture students, as an 'exploration' studio. Initial assignments fostered an appreciation for timber as a grown, natural, organic material. By researching the specific forester locations, wood species, forest climate, and distances of forest-to-mill-to-UW, students began to understand wood as both a standardized building product and natural artifact of our surrounding environment. Students then focused on the specific 2x3, 2x4, and 2x6 geometry of the donated stock (60, 8'-pieces of each), and identify guiding values of their design process. These values included the need to make the most of the material we had (minimize waste both during construction and at the end of life), while creating something exciting and interesting for our UW community. They identified three priorities: 1) Make Structurally Efficient Use of Material, 2) Create a Unique Spatial Experience, and 3) Design for Disassembly.

Through a series of case study assignments and charettes, the studio arrived at a design rooted in process more than form. In the north lawn of Gould Hall at the UW, two elevated bridges span over a sunken courtyard. This courtyard would be the site of our installation, and the bridges would become the generator of our form. Students fabricated a set of 'timber chains' – standard sized segments of wood doweled together at each end to form a flexible chain. These chains were then hung from the elevated bridges to 'find' an efficient structural shape. This shape was then marked, and 'vouissoir' blocks of wood were cut to fit between the links. Once brought to the ground, the efficient, hanging form could be re-configured as compression arch. These arches were pinned to a platform base and stabilized by a diagonal lattice in between.

At the end of life, the dowel-connected arches could be easily disassembled. The standardized pieces were then re-purposed into furniture and other small-scale artifacts, and the pavilion was distributed and dispersed throughout the community.

In the end, this studio was successful in its attempt to both challenge the existing logics of timber construction, and deeply consider the material consequences of architectural design – from acquisition through dispersal.

KEYWORDS: timber, wood, structure, structural design, studio, catenary, interdisciplinary.

INTRODUCTION

Since its beginning in 2012, the Barry Onouye Studio at the University of Washington has encouraged architecture students to consider the creative potential of structural design, and the important relationship between architects and structural engineers in the realization of buildings. With this as a premise, this studio aims to:

1. Encourage design thinking that equally considers both architectural and structural opportunities
2. Explore possibilities that challenge the conventional separation of disciplines, and suggest new areas of innovation
3. Foster mutual understanding and appreciation between architects and engineers

Past studios have welcomed visiting professors to the University of Washington (like John Ochsendorf, 2017, Mark West, 2018, Sigrid Adriaenssens, 2019) and explored a variety of topics, like wood shells, fabric-formed concrete, and hanging nets. Returning to in-person instruction meant the Spring 2022 studio could resume the hands-on exploration of pre-pandemic studios, and connect to a pressing issue in the built environment: the rise of timber as a primary structural material. The studio was offered to graduate students in the Master of Architecture program, as an Exploration studio (for first-year students in the 2-year program, and second-year students in the 3-year program). These students had all taken structures courses, as well as Foundation and Integration studios.

1. STUDIO PARTNERS

The Onouye Studio has always relied on a large network of collaborators and partners. These individuals or organizations provide design expertise, material donation, and important contextual/ cultural insight in to the design work. While the studio prioritizes structure, it still embraces the full complexity of architecture as a situated, culturally-produced artifact.

1.1 Structural Engineering Collaborators

With an interest in wood design, the studio partnered early with the structural engineering firm Fast+Epp. Originally based out of Vancouver, BC, Fast+Epp has become a global leader in the design of timber structures. Notable structures include the Grandview Heights Aquatic Center (Surry, BC, 2016) with a timber tension-roof, hung in a catenary shape, and the Richmond Olympic Oval (Richmond, BC, 2010) with hybrid timber trusses. The Seattle-office of Fast+Epp were involved in the early stages of the studio and served as important critics along the way.

1.2 Foresters

The emphasis on timber in the studio was, in part, based on the large role that forestry and timber practices play in the Pacific Northwest. The large expanses of timber wilderness in Washington State fueled early, resource extraction economies in the 19th and early 20th centuries. In more recent times, second- and third-growth timber (of smaller diameter) continues to make the region one of the top producers of wood products in the country. The current arrangement of foresters, timber harvesters, and lumber mills are key parts of the state's future – both in the management of forest lands and in the economy of the state.
Through a previous relationship with the Sustainable Forestry Initiative, the studio instructor contacted the Washington Implementation Committee about a material donation. With an intention to showcase the structural potential of timber, several companies agree to donate and deliver a stock of dimension lumber from their mill. Rather than secure the donation after the design was compete, the studio chose a different approach. Without knowing what design would take place, the instructor and the lumber mills decided on a donation consisting of the quantities and sizes of different lumber species (Table 1).

Table 1: Donated Lumber for Design.

Quantity	Dimensional Size	Species	Lumber Provider
60	2x3	Douglas Fir	Hampton Family Forests
60	2x4	Mix (Doug Fir, White Fir)	Yakama Forest Product
60	2x6	Douglas Fir	Sierra Pacific Industries

Each of these foresters provided lumber that was a product of their forest lands, forest management practices, mill size and capacity, as well as their overall approach, or philosophy, to harvesting timber. Their approach was evident in the material that each provided, and served as the starting point for the studio exploration.

Figure 1: Donated lumber. Source: (Tyler Sprague 2022)

2. SITE

2.1 Gould Hall Lawn

Our studio installation would take place on the north lawn of Gould Hall. This lawn space is adjacent to the primary building for the College of Built Environment. As Gould Hall navigates a significant slope, the rectangular lawn is also a level (story) below a nearby sidewalk and below two bridges that connect to the second level of Gould Hall. (Figure 2). This site is highly visible to both the occupants of Gould Hall on the first floor, and to the people entering the building via the two bridges.

Figure 2: Gould Hall, north lawn. Source: (Tyler Sprague 2022)

3. STUDIO PROCESS

The instructor divided the 10-week studio in to a series of assignments intended to first introduce students to the studio topic and prepare students to embark on collective design work. These assignments presented the underlying premise of the studio – that locally grown timber is a carbon-friendly, renewable resource that can be used to generate new formal geometries.

3.1 Material thinking

The first assignment asked the students to work individually, and do a thoughtful study of the donated material. It began:

> This lumber represents a connection to the forest lands of Washington State, the people who work and manage the forest lands, the processes of their production and a latent architectural potential.
> Each board was once a tree growing in a forest. Each board is a specific species of wood. Each board experienced a carbon-sequestering life time before being harvested, processed and arriving at our university. This exercise is intended to help gain an intimacy with wood, prior to the design & construction process – through both qualitative and quantitative means.

Students read responses gathered from the local foresters on the specific location the trees were grown, species harvested, age of tree, and general forest management tactics. Students then selected two specific boards to examine specific dimensions, grain pattern, knot location, stamped markings, tool markings, etc. As a deliverable, students produced a graphic collage of their exploration and a one-page reflection.

Student responses highlighted the natural quality of the wood, even as it came in standardized, dimensioned shapes.

Figure 3: Material Thinking, Stephanie Cote. Source: (Stephanie Cote 2022)

3.2 Precedent review

For the next assignment, students researched other timber pavilion structures. The assignment asked students to focus on the material, structural form and assembly process of each timber structure. Working in pairs, the student groups looked at work by Kengo Kuma, Shigaru Ban, Rural Studio, Toyo Ito, and others, examining how the structures utilized the unique qualities of wood. The logics of assembly connected to labor, fabrication, and ultimately the forest that grew the wood. The idea that the site (or location of a project) could physically generate a structure was a powerful idea that remained with the studio throughout. While some precedents were permanent structures, others were temporary pavilions – begging the question, what happens at the end? Disassembly? Land-fill? These precedents rooted the idea of re-use as a core studio value, inspiring the students to design for a second life.

The studio also undertook the simple assembly of a DaVinci bridge – a simple, reciprocal structure with compression-only connections. Through a sequence of assembling longitudinal and lateral beams, a spanning structure can be easily constructed. This exercise introduced students to the hands-on work of assembling a load-resisting structure and the impact that a vaulted form can have on space.

3.3 Conceptual design work

With these assignments complete, the studio began the design process – progressing quickly through conceptual design (many individual ideas quickly presented) to several options (developed by small groups).

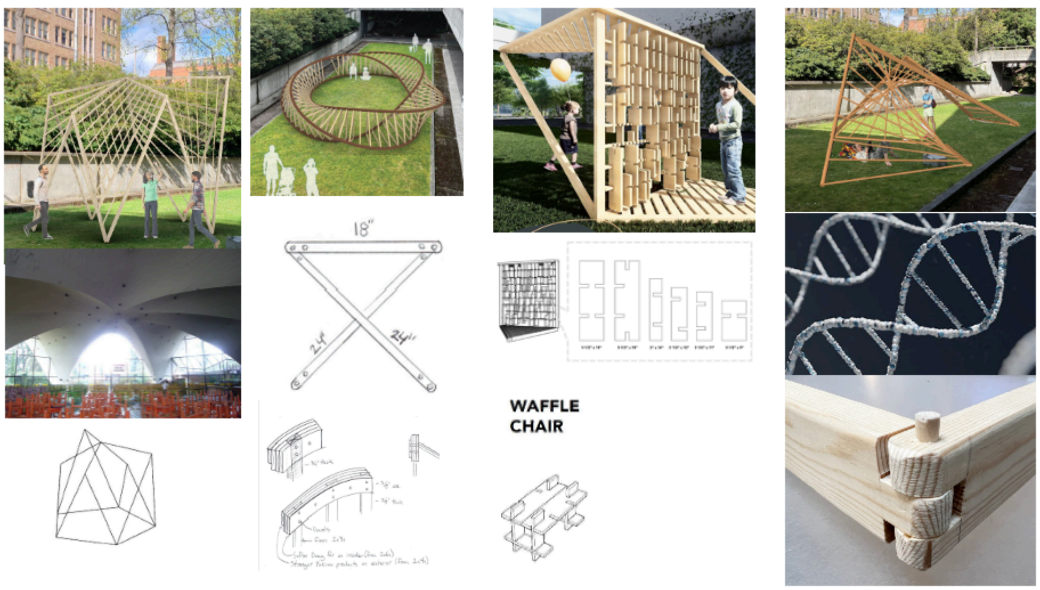

Figure 4: Studio Mid Review of student work, Summary. Source: (Studio Collective, Tyler Sprague 2022)

Along the way, the studio defined core values that guided the decision-making:

- Wood is a local, regional, grown material
- Wood represents a relationship to the land (native tribes, foresters)
- Wood is not a uniform material (with grain, knots, etc) and not all wood is the same
- Wood is flexible in thin sections, but can be made stiff through geometry
- Structure can respond to support conditions, constraints
- Dis-assembly and re-use are vital, and must be considered from the beginning

These values were then operationalized through three strategies: 1) Make Structurally Efficient Use of Material, 2) Create a Unique Spatial Experience, and 3) Design for Disassembly.

3.4 Final design approach

After considering many options, the studio converged onto a single design approach. This approach was a synthesis of design ideas, rather than a selection of a specific option, rooted in shared values for the project. The approach was rooted around the idea of a timber chain, consisting of predetermined 'links' of wood connected by round dowels. These chains could be assembled, and then hung from the elevated bridges on either side of our site. The hanging chain would develop a materially-efficient form as a pure tension structure, such that when inverted, would become a compression arch. In order to capture the geometry, the spaces between the rotated links could be filled with an angled 'voussoir' – which would work as a compression block.

The pavilion could then consist of a series of different-sized arches – made only from the donated 2x4s - rising from a common platform. The platform would be made of only 2x6s, with tension tie between the ends of the arch. The arches could then be connected by thin, flexible strips cut from the 2x3 boards, and fastened to the arches.

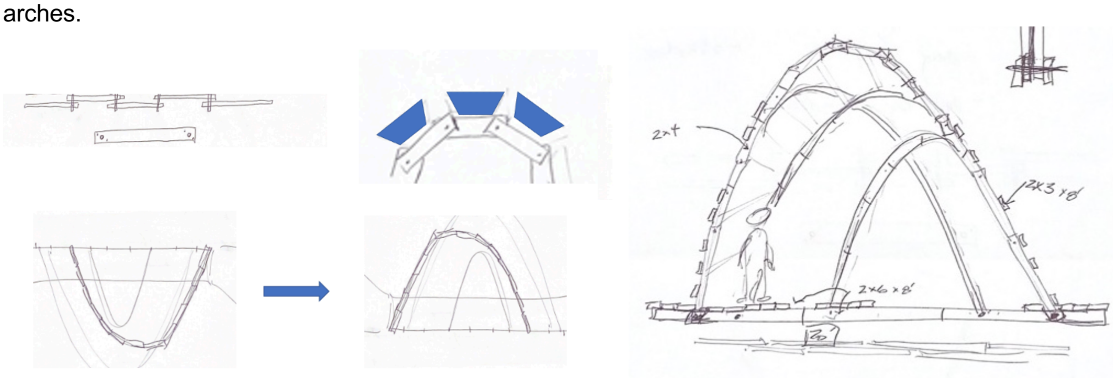

Figure 5: Final Design, diagram of hanging chain inverted to be compression arch. Source: (Tyler Sprague, 2022)

With only doweled connections in the arch, and minimal processing needed, the material of this pavilion could be disassembled, and re-made into furniture as a second life.

3.5 Working groups

With the project direction decided, students took on different tasks in several groups of 3-4 students. Groups were focused on BASE (layout and detail), ARCH (hang links, solidify), LATTICE (cut strips, fasten), MODEL (model ideas physically and digitally as rapidly as possible) and FURNITURE (propose possible). With such inter-connection between groups, check-ins at the start of studio were essential.

Student self-selected and utilized different design skills in their individual work. The BASE group was charged with defining the on-site condition, and the direct contact with the grass below. Utilizing the sectional orientation of the 2x6 members, the group defined paired members (on end) to by-pass and receive the arches with a single, wooden pin. On top of these arch 'ties', the group specified 2x6 laid flat as decking, or walking surface, elevated above the ground. This platform was doweled to the arch ties below, being mindful to not create too great of span or overhang.

The ARCH group defined the height and size of the different arches, and developed a strategy for erection. With the links and 'voussoirs', each arch was two-boards wide. Once hung from the bridges, the arches were marked with pencil and corresponding 'voussoirs' were cut and doweled in place (on the ground). Each arch was then separated into two halves, wrapped with a rope to keep all the pieces in place, and doweled into the base. The two halves were then lifted up and re-joined at the peak of the arch.

The LATTICE group determined size and pattern of the connecting lattice work. This began with the ripping of 2x3 boards into 3 widths (roughly 3/8" thick), and determining a fastening system to connect to the arches. The 8' strips defined the maximum distance between arches, but also required a diagonal pattern to assist in the bracing of the arches against each other. This lattice was essential in creating shell, or membrane behavior, across the structure as a whole, while also defining the interior space and exterior pattern/ texture.

The MODEL group ran parallel to the other groups, providing design feedback as each fabrication and installation process developed. This group worked with both physical and digital models, allowing the groups to visualize the synthesis of all the different components and make high-level design choices together. Physical models gave a tactile sense of the structural behavior – instructing the group on the importance of the shape of each arch (not too steep or shallow) and connecting the arches together (for stability as a whole). Digital models provided rapid feedback on larger spatial possibilities, where the relationship between arches and the pattern of lattice could be quickly altered and evaluated.

The FURNITURE group worked to rapidly prototype furniture options, based on the dimensions and materials used in the pavilion design. With the goal of losing the least amount of material, the group prioritized use of un-cut pieces taken directly from the arches or lattice design. Students developed a variety of chairs, end tables, and stools, designing at an accessible, human scale.

Figure 6: Hanging Chain to Standing Arch, Assembly. Source: (Tyler Sprague, Stephanie Cote 2022)

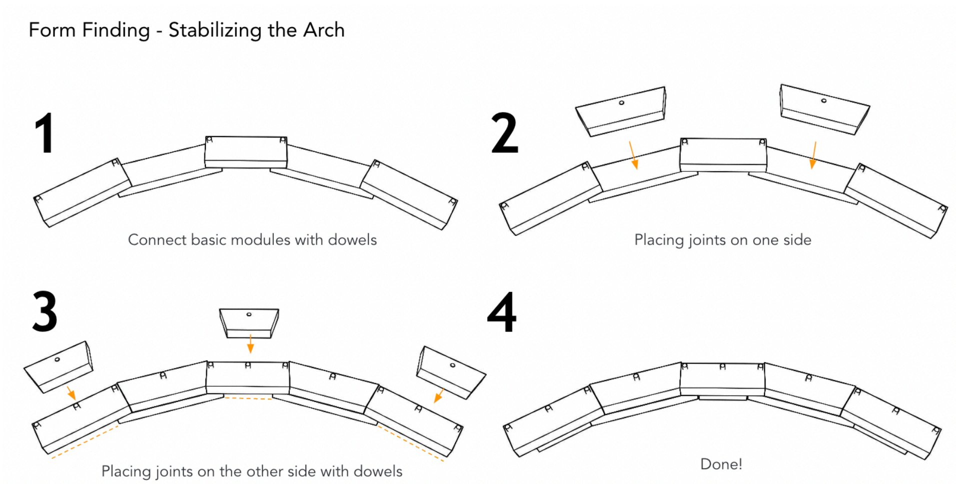

Figure 7: Stabilizing the Arch, Source: (TJ Gassaway, 2022)

4. FINAL INSTALLATION

Over the last week of the quarter, final installation took place on Gould Lawn. The pavilion attracted significant attention from students, and became a popular place to study, or rest. The pavilion remained until mid August, when students dismantled the structure and stored the material. Over the next few months, different students gradually assembled different pieces of furniture. As intended, the pavilion then dispersed among the population, taking a second life in people's homes. In the end, this studio was successful in its attempt to both challenge the existing logics of timber construction, and deeply consider the material consequences of architectural design – from acquisition through dispersal.

Figure 7: Final Installation. Source: (Sprague 2022)

Figure 8: Final Furniture. Source: (Tyler Sprague 2022)

5. EVALUATION

5.1 Final Review

At the end of the quarter, a final critical review of the project was held – with members of the architectural, engineering, academic and forestry communities. Representatives of all foresters who donated lumber were on hand to observe and critique the results. The reviewers broadly praised the transparent connection between material sourcing and structural form – providing evidence of the material transformation that good design leads to. The foresters also remarked about the community of students, instructors, and critics that came together to create such a transformation. This community, for them, mirrored the community of people that produced the initial dimensional lumber. People like arborists, timber harvesters, equipment operators, truck drivers, administrators, and managers. This project made evident the community-led transition from tree to product to architecture. Criticisms of the project largely resided at the level of detail, specifically the connection of the lattice to the arches. The rapid pace at the end led to a structurally stable solution, be left something to be desired aesthetically.

5.2 Student Evaluations

After the quarter, students completed a course evaluation with useful feedback on their experience of the studio, with 7 out of 12 students completing the evaluation. The overall "course as a whole" was rated 4.8 out of 5. When asked about various aspects of the course, students ranked "Feedback from my peers was valuable" first, reflecting the group nature of the course. This was followed by "Instructor encouraged me to acquire new skill and approaches", reflecting the experimental nature of the design and construction process. Unsurprisingly, the statement "Instructor encouraged me to think independently was ranked last.

In the next category of responses, there was a consensus on the top skill the course helped develop: "Develop your ability to work in fluid or ambiguous situations." This response reveals the occasional anxiety among students that "everything would work out." Most students were used to a much more established design process, with lower stakes on the output. The physical structures - experimental yet absolutely must not fall over - at times felt like a high bar to clear in a 10-week, collaborative studio.

Students also responded with written comments, asking if the course was mentally stimulating, what contributed most to learning, aspects that detracted from learning, and suggestions for the future. Comments were positive, with the exception of the speed we were required to work towards the end of the quarter.

6 CONCLUSION

This studio advanced a distinct perspective in its approach to timber – producing a collaborative, site-specific, hand-made installation, with minimal material waste and a potential second life. The structural form was both efficient and spatially compelling, and three large lessons emerged:

- Students adopting common priorities for the project, early on, made collaboration between easier. Overall, the studio was successful in following the priorities established for the design: 1) Make Structurally Efficient Use of Material, 2) Create a Unique Spatial Experience, and 3) Design for Disassembly. Early, consensus-building group work (accomplished around mid review) paid off
- Clearly defined roles allowed everyone to contribute to the project in a distinct and definable way. This was important for assessment (grading) but also stressed the dual nature of group work: gaining the advantage of everyone working together, while maintaining individual accountability.
- Remaining flexible – with clear communication between groups – and the baseline assertion that the design will change, was very important. As groups uncovered different aspects of their work, the design would change, requiring each group to contribute and adapt. Check-ins before each studio session, with the whole class, was very important.

Future work could extend both the group-structured process and the efficient form-finding used in timber. A comparison to a conventionally framed space (perhaps by the ratio of interior volume to structural material) would validate the assertion that it is a truly a more- efficient structure.
The design values embedded in this studio are needed within many areas of the architecture, engineering and construction industry. As the industry advances to a less carbon-intensive means of producing buildings, potential direction – like those demonstrated here – must be considered.

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