WORLD CONFERENCE ON TIMBER ENGINEERING 2025
BRISBANE, AUSTRALIA
Advancing Timber for the Future Built Environment

ADVANCING INTEGRATED DESIGN EDUCATION AND CIRCULAR ECONOMY IN WOOD CONSTRUCTION: KIT-OF-PARTS FOR FAST-DEPLOYABLE AND RELOCATABLE STRUCTURES

Mariapaola Riggio[1], Nancy Yen-wen Cheng[2]

ABSTRACT: This paper presents the development of an educational initiative aimed at equipping future professionals in the wood construction sector with expertise in integrated design approaches. In this context, a diverse group of students contributes their disciplinary expertise to the design of reusable wood-based kits-of-parts for rapidly deployable structures. The 11-week course underscores the role of technology, wood science and engineering, simulation, physical prototyping, fabrication and construction, describing approaches to designing with and for wood reuse. A progressive collaboration model is used, beginning with low-stakes small-group case studies to break down disciplinary biases. Modeling and analyzing case study examples support skill-building and tectonic understanding prior to employing these capabilities in design. Activities are staged to foster the partner trust that is needed as the class steps from small groups to a single coordinated prefabrication and on-site assembly team. In kit-of-parts design, the traditional top-down approach—moving from the overall concept to the details—is reversed, enabling earlier engagement of diverse expertise in the process. Designing for reuse requires evaluating the durability of connectors and elements over multiple cycles, redefining the approach to structural design. Different course iterations reveal a trade-off between more playful lightweight experiments and more functionally oriented constraints.

KEYWORDS: wood kit-of-parts, design for disassembly and reuse, parametric design, digital fabrication, integrated design teams.

1 – INTRODUCTION

The circular economy is a crucial strategy for addressing climate change by minimizing environmental impacts throughout a product's life cycle, optimizing resource use, and reducing waste. This approach focuses on maximizing the value of buildings and materials at every stage of their life. The most effective strategy is extending the physical and functional service life of buildings, including adaptive reuse that repurposes structures for new functions. When full building reuse is not feasible, salvaging and reusing materials—from large structural components to smaller finish elements—ensures that valuable resources remain in circulation, reducing the need for new raw materials and lowering embodied carbon. Design of new structures should consider this hierarchy of reuse and as long enshrined in sustainable standards such as LEED Integrative Process [1], all parties should participate in early pre-design for better building for circularity.

In designing reusable building systems, architects can plan modules that can be effectively reconfigured for different settings. Engineers should ensure that these designs meet structural requirements across various configurations. Manufacturers and fabricators play a crucial role by providing a portfolio of products suited to different system components and advising on the most effective strategies for their use, ensuring efficiency and minimizing waste. Finally, builders can optimize assembly and disassembly processes to facilitate reuse.

Given the crucial nature of this interdisciplinary dialogue in the wood construction industry, students need to learn early how to productively discuss and negotiate with interdisciplinary colleagues [2]. But classes that mix students from different majors are rare, especially within

[1] Mariapaola Riggio, Wood Science and Engineering Department, College of Forestry, Oregon State University, Corvallis, OR, USA. mariapaola.riggio@oregonstate.edu. https://orcid.org/0000-0002-9013-7304

[2] Nancy Yen-wen Cheng. School of Architecture & Environment, University of Oregon, Eugene, OR, USA. nywc@uoregon.edu

https://doi.org/10.52202/080513-0517

disciplines such as architecture and engineering with strict accreditation requirements. Partnerships may need to cut across scheduling and bureaucratic challenges to put heterogenous students in the same classroom. This paper describes a class that immerses students into the process of integrative design and construction with the most recent focus on Design for Adaptability and Reuse.

2 – COURSE AND PROJECT DESCRIPTION

The Timber Tectonics in the Digital Age class is a collaboration between Oregon State University (OSU) and the University of Oregon (UO). The course is open to advanced undergraduate and graduate students from OSU's Wood Science and Engineering, Civil and Construction Engineering, and Architectural Engineering and UO's Architecture. The course replicates a real-life scenario, where inter-disciplinary collaboration is activated at an early stage of the creative process. Wood science, engineering and architecture students, embodying the three roles of manufacturer/fabricator, engineer and architect, work in integrated design teams, thus developing critical hard and soft skills essential to today's forest products and wood construction industries. The course focuses on the intersections of material science, technology, architecture, and engineering in wood tectonics, emphasizing teamwork and interdisciplinary communication. The class also exposes students to the challenges of integrating digital modeling and fabrication, structural simulation, and wood construction into a design and build project. Principles of design for manufacturing, assembly, and reuse are taught through digital experimentation and physical prototyping.

Throughout the various iterations of the class, students are tasked with designing kits of parts for various applications, including seasonal pavilions that can be disassembled and relocated, and emergency housing that can evolve into more permanent rural shelters. These types of projects contribute to developing an understanding of designing wood system for the circular economy, by creating temporary, reusable or upgradable systems. Wood products are chosen for their lightweight properties, allowing for easy handling by hand or light equipment, and for their suitability for straightforward CNC cutting or manual processing. The design challenge limits the number of component types and types of connections to ensure that standard elements can be easily reused and reconfigured in various setups. In all cases, the challenges are to minimize waste, maximize the flexible use of components within the current project, and enhance the future reuse of components or materials.

In sequential years, reciprocal frames and stressed skin panels using plywood and dimension lumber as primary materials have been investigated to create the modular components. Alternative approaches have been prioritized for timber connections: first CNC-fabricated notched connections, which introduce students to digital fabrication, and in the following year, bolted connection systems, which rely on widely accessible off-the-shelf fasteners. In both cases, the primary focus is to evaluate their effectiveness for deconstruction and repeated reuse to foster circular economy approaches.

The design project evolved from an initial focus on the structural system, particularly reciprocal frame systems, in 2022 and 2023, to incorporating the building skin and interior space in the 2024 iteration, to address the challenge of emergency housing design.

Figure 1. Example of a student reciprocal frame system.

2.1 RECIPROCAL FRAME SYSTEM

For two consecutive years, students in the course developed proposals for a reciprocal frame system using veneer-based engineered wood products. In the first iteration, Fall 2022, the absence of specific constraints—such as material type and CNC specifications—resulted in highly varied proposals pursued by individual teams without converging on a final common design. In the second year, Fall 2023, stricter requirements were introduced, specifying the use of 19-mm thick Douglas Fir plywood and wood-to-wood notched connections, with CNC cuts limited to perpendicular angles to the panel faces to simplify fabrication. Additional constraints were set by the project's client, who required a seasonal park canopy that could be disassembled and removed during the wet season. Emphasis was placed on designing a minimal set of elements that could be used to construct the entire structure while also allowing for alternative configurations for future applications (Fig. 1)

2.2 STRESSED-SKIN PANEL SYSTEM

In Fall 2024, students were tasked to develop the structure for a lightweight modular shelter system that could be rapidly deployed and further extended and aggregated. The elements needed to be pre-fabricated,

https://doi.org/10.52202/080513-0517

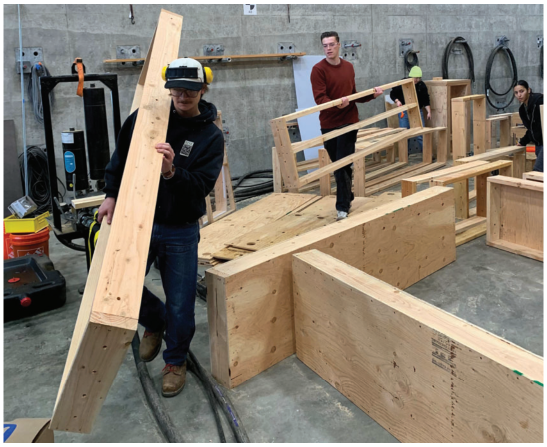

Figure 2. Fabrication of stressed-skin panels

transportable in a cargo van, and easy to assemble, allowing a small crew to construct the shelter without heavy equipment, ensuring that even untrained individuals could build it in the aftermath of a disaster. The students were tasked with considering also two post-emergency scenarios. The first scenario involved designing a system suitable for transitional shelters. This system would be adaptable for future upgrades to increase its physical longevity, either by disassembling parts and replacing them with more durable components or by reinforcing existing parts to withstand prolonged use. It would also need to allow for aggregation and modification into larger structures. The second scenario focused on creating a temporary shelter designed for full reusability. In this case, the shelter's components would be fully disassembled and reused in different contexts multiple times. Emphasis was placed on designing a system rather than a single building, ensuring that the same kit-of-parts could be adapted to create various configurations and unit types with minimal component variations. Students focused on designing and fabricating wall, roof, and floor using double-skin stressed-skin panels from Douglas Fir plywood, 2440 mm x 1220 mm x 12 mm in size, and dimension lumber (38mm x 90mm) for the internal stringers and edge beams (Fig.2). While students were encouraged to explore alternative forms for the SSPs, they were advised that minimizing cuts and reducing waste would be beneficial for both cost savings and environmental impact. Structural connections had to meet the required standards while utilizing off-the-shelf materials that allow for disassembly and reuse. An emphasis was put on designing a limited amount of connection types for all the different required connections.

3 – DESIGN AND BUILD PROCESS

Over the first four weeks of the term, the class project evolved through a structured approach, beginning with an analysis of case studies and culminating in small group proposals. Students in interdisciplinary groups were encouraged to adopt a convergent design approach that combines bottom-up and top-down strategies. The bottom-up approach emphasized the detailed design of kit-of-parts components and their integration to create the intended design and explore potential variations. In contrast, the top-down approach focused on aligning these components with the overall design objectives (Fig. 3 Course Structure). After the week 5 midterm review and feedback from professionals and academics, the class selected the most promising proposal for further design development. In this phase, students were reorganized into specialized teams, with each focusing on specific aspects of the design, such as the overall architectural and engineering design, enclosure design, fabrication specifications, the connections, and the development of a construction plan. At the start of this new phase, the teams developed a work plan to identify dependencies between their tasks and those of other teams, recognizing the need for coordination and communication. A separate communication and management team was formed to handle material orders, budget tracking, coordination across teams and with instructors, and communication with the public. During these weeks, students immersed themselves in the woodshop and laboratory, working on full-scale prototypes, testing solutions, and addressing any issues prior to building the prototype structure. The final deliverables included the completed prototype, construction, deconstruction and storage guidelines, an engineering report, and recommendations for ongoing maintenance and future upgrades. Students participated in the construction of the full-scale prototype at the end of the course.

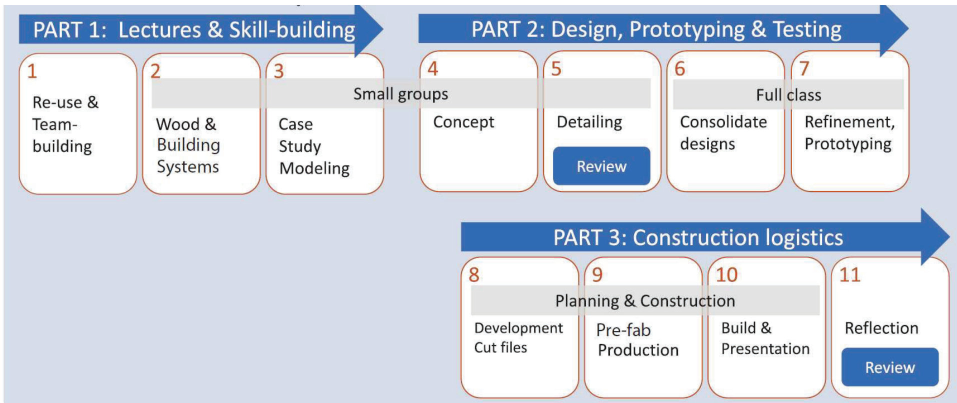

Figure 3.Course structure

3.1 RECIPROCAL FRAME KIT-OF-PARTS

In the first week of the Fall 2023 term, students were introduced to reciprocal frame systems and tasked to analyze an exemplary project. Built examples included Kengo Kuma's Geibunkan Museum [3] and Kodama Pavillion [4], Franz Masereel Cultural Centre [5], Gramazio & Kohler's Future Tree [6], and Siza & Souto de Moura Serpentine Pavillion 2005 [7]. Additionally, findings from the literature were shared, exploring various aspects of reciprocal frame designs, including panelized reciprocal framing [8], and examples of connection systems suitable for disassembly and reuse [9]. The design process began with developing a basic reciprocal frame module, focusing on member connections while addressing material and fabrication constraints. The resulting module was then used to develop a proposal for the overall structural and architectural configuration of the canopy. Although reciprocal systems have traditionally relied on beams or rods, opting for plywood instead of lumber or linear wood products prompted the exploration of polygonal shapes for the framing components. The constraint of using a CNC router bit perpendicular to the panel surfaces directed the projects toward 4-fold rotational patterns, featuring orthogonal rather than angled notched connections. Fig. 4, left illustrates examples of components developed during the initial design iteration, along with their respective jointing systems. Following the first review, a proposal was selected for further development. The proposal drew inspiration from the roof of Kengo Kuma's Geibunkan Museum, which showcases a planar reciprocal frame made of notched triangular members. In the students' proposal, the triangular members were adapted into a 90-degree pattern with 4-fold rotational symmetry. In the initial connection design, half-lap notches were placed on the top edges of the triangles, allowing the elements to rest on their symmetrical corners. Structural analysis revealed that these notches weakened the elements, with

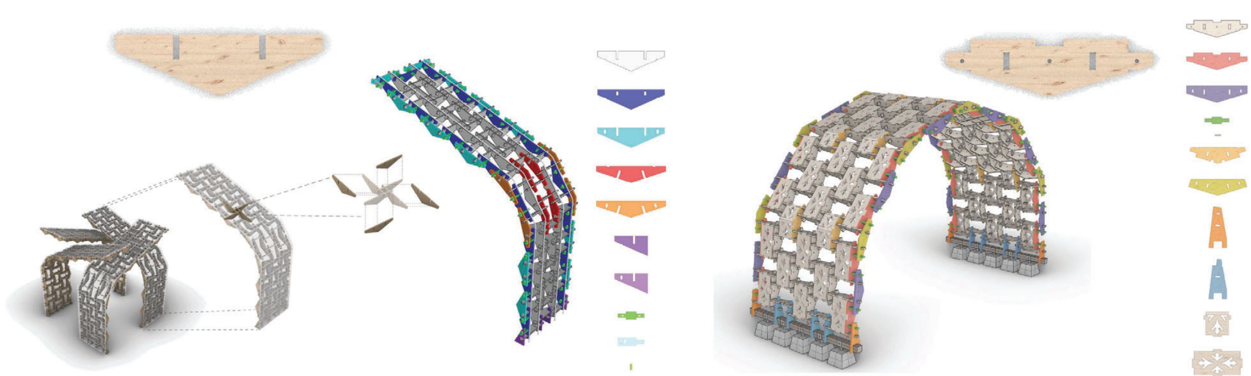

Figure 4. Original small group design with half-lap notches (left) vs. final arch with mortise and tenon joints (right)

https://doi.org/10.52202/080513-0517

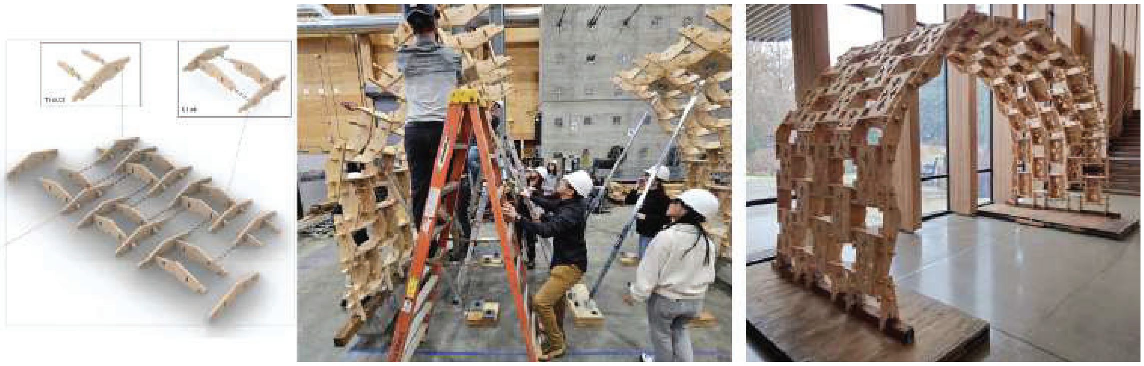

Figure 5. Modular units facilitated quick assembly of first (middle) and second (right) installations

some depths exceeding recommended ratios, and that the partially constructed system lacked stability against wind uplift. The design evolved by replacing the original half-lap notches with mortise and tenon joints, inspired by the 2005 Serpentine Pavilion, to improve stability (Fig. 4, right).

The final kit-of-parts included five variations of the triangular elements from the reciprocal frame module: one for the standard module configuration, one for the internal corner transitions of the arch, and three for the end conditions along the arch’s sides. Additionally, two half-triangular pieces were included for the base elements—one for the external and one for the internal conditions. Additional components included plywood stiffening plates, integrated into the reciprocal frame grid in alternating patterns to reduce wind uplift pressure on the arch surface while stabilizing the system. Concrete blocks were added as removable anchors.

Pre-assembling the frame into modular sections was recommended to streamline construction and disassembly, enhancing reusability and reducing material damage. During construction, several issues arose after removing the shoring, including joint rotation, settlement, and imperfect supports. Joint rotation occurred during sectional assembly, with even tusked joints remaining loose. This was addressed by shimming each joint. Settlement was evident after removing the shoring, with the upper section sagging most noticeably. This was attributed to the structure's overall lack of stiffness and the local joint rotations. Proposed solutions, though not implemented, included adding tension elements between the peak and the elbow of the arch, and compression elements between the elbows and the base of the structure. An unexpected issue arose where the bottom members meet the 4x4 footing timber. The member, slotted over the 4x4 and bolted with Simpson-Strongtie HR33 brackets, was assumed to behave as a perfect pin in the structural model. However, deformations caused the member to rotate, jamming the plywood slot against the 4x4 and creating a moment connection. This introduced internal forces not considered in the original design, but it seemed to improve the structure's stability.

After the arch was completed and stood for a few days, measurements were taken to assess deformation at each corner between linear segments and compared to a 3D Karamba model. By adjusting the rotational stiffness at reciprocal frame joints in the model, the measurements were roughly matched, yielding a stiffness of 0.8 kN·m/rad. Additionally, differential deflections were observed between arch planes. The center plane deflected 23 mm more inward than the outer planes at the first corner, and 46 mm more outward at the crown,

Figure 6. Components repurposed as a partition wall.

indicating the stiffest load path in the arch resembled an "X" from end to end [10].

The need for shims in the notched connections and the settlement of the structure posed challenges during deconstruction. Mallets were required to disassemble the parts, leading to localized damage such as fiber crushing. Despite this, deconstruction was efficient, and the components were successfully reused to rebuild the arch at a new location as a temporary wall. (Fig. 5-6).

3.2 STRESSED-SKIN PANEL KIT-OF-PARTS

In the first week of the Fall 2024 course iteration, students were assigned emergency shelter case studies and tasked with creating an instruction manual to guide construction. This manual included a kit-of-parts diagram detailing all necessary components and their quantities, as well as assembly instructions specifying required tools, hardware, and personnel. The objective of this exercise was to analyze a built example, compelling students to investigate its fundamental components and the methods used to assemble them. Analyzed precedents included the Liina Transitional Shelter developed by the Aalto University's Wood Program [11], Shigeru Ban Paper Log House [12], the Wikihouse Shelter [13] and Veneer House projects [14].

From the second week onward, students focused on developing their own proposals. The initial phase involved simultaneously designing a shelter form and breaking it down into a set of multi-functional stressed-skin panels to create a flexible, adaptable kit-of-parts. This iterative process allowed for continuous refinement of both the SSP designs and the overall shelter layout, aiming to optimize the individual components as well as the overall spatial arrangement. Students addressed panel dimensions and shapes by considering fabrication constraints and material optimization to minimize waste, as well as construction constraints to design lightweight panels that could be easily handled by a small crew without the need for heavy equipment.

Week three emphasized the design of connection systems to integrate SSPs into a cohesive shelter. Students developed in-plane connections for walls,

Figure 7. Module connection experiments.

floors and roofs, as well as wall-to-wall, wall-to-roof, and wall-to-floor corner connections. The connection systems prioritized ease of installation and disassembly, versatility, and reusability for varied configurations. The groups explored opportunities to minimize the number of connection types, aiming to apply them across multiple elements of the shelter. Off-the-shelf fasteners were incorporated to enhance accessibility and cost-effectiveness. During this phase, physical prototypes of connections were developed, enabling assessments of fabrication ease, installation accessibility, and overall robustness (Fig. 7). Concurrently, the shelter design was further developed to consider any modifications necessary to enhance the compatibility with the designed connection system.

The fourth week integrated moisture control strategies, thermal insulation, and air circulation. Moisture control strategies included designing foundations to prevent direct floor-to-ground contact, avoiding moisture traps in connections, and incorporating effective drainage paths. Temporary tarps and end-grain protection were also considered, along with accommodations for differential material movements. For thermal insulation, the integration of natural fiber (hemp) mats within the two skins of the SSPs was considered. Shelter enclosure designs were refined to rain deflection, and climate adaptability for wet-cold, humid-hot, and hot-dry conditions to enable adaptation to different climate conditions. To integrate other elements of the shelter's enclosure, additional components of the kit, such as windows and doors, were designed in this phase.

One challenge faced by all the teams was designing an interior space that offered comfort, privacy, and the flexibility to accommodate various functions, all within a limited footprint and using a straightforward construction system. While initial explorations involved pyramidal shapes and polygonal base areas, these more intricate options led to challenges in optimizing `materials, space, and connection design. After the midterm review, the class established key strategies and design criteria for moving forward. For the overall shelter design, they opted for a simple rectangular base. The design included a single-slope roof and a fixed clerestory above the 2440 mm high longitudinal wall section. For the kit-of-parts, the strategy involved using 610 mm wide SSPs without internal stringers, except for floor components, to reduce self-weight. For the foundation, 90mm x 90 mm treated lumber girders supported by cinder blocks were chosen for their light weight and versatility. To simplify construction, it was decided that each610 mm wide transverse section of the

https://doi.org/10.52202/080513-0517

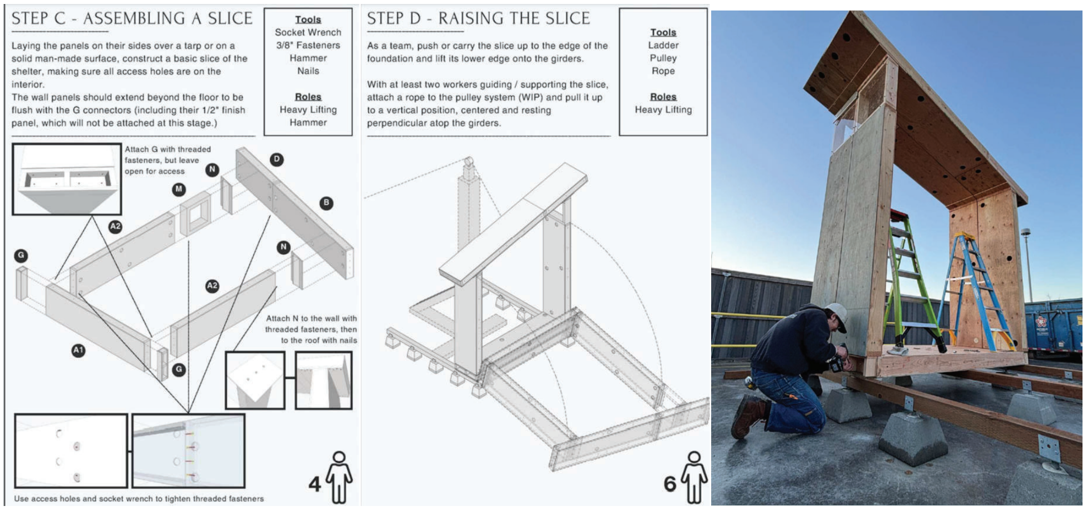

Figure 8. Construction Manual – "slice assembly"instruction (left and center) Assembly of the prototype on site (right)

shelter unit—including the floor, roof, and two walls—would be assembled flat on the ground and then tilted upright onto the foundation girders, allowing the shelter to be constructed one slice at a time ((Fig. 8). Bolted connections were chosen to ease assembly and disassembly, using threaded inserts in place of nuts on one side to reduce access requirements. Staggered pre-cut holes in the SSP were also added to improve accessibility to the connections (Fig. 9) . Additionally, an intermediate prefabricated component was introduced for corner connections to minimize SSP variations (Fig. 10 – left). To address thermal bridging at the corners, the enclosure team developed a specific solution for the intermediate connection component (Fig. 10). The decision to use roof overhangs to deflect rain from the shelter added complexity to the design of the connection between the wall and the roof, as the standard corner connection could not be applied in this case (Fig. 10 - right). For short-term exposure, two coats of an oil-based, waterborne wood stain in a semi-transparent color were applied off-site to provide moisture and UV protection for the exterior faces of the prefabricated SSPs. On-site, a UV-resistant

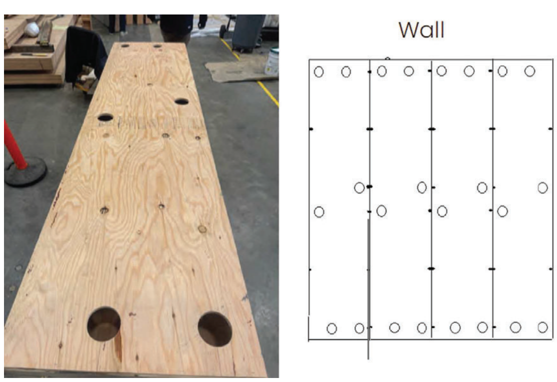

Figure 9. Openings for bolts in panel to panel connections

waterproofing tape was used to seal the seams between the SSP wall sections. For the emergency roofing system, options such as reusing pool covers, trailer covers, and other recycled tarps were considered. Following a circular economy approach, the door was sourced from a second-hand store. The operable window was custom-built using a wooden frame and a polycarbonate panel.

Given the budget and time constraints, the decision was made to construct an 'emergency sleeping core unit', with a width matching the length of a plywood panel (2440 mm) and a length as a multiple of the plywood width (610 mm), as a practical solution to test all the parts of the kit.

4 – OUTCOMES AND REFLECTIONS

4.1. ADVANCING INTERDISCIPLINARY LEARNING AND COLLABORATION

The course's challenge is to pack in parametric design thinking, structural analysis, timber detailing and construction within a quick design/build project. Because of a wide range of student backgrounds, it is difficult to provide all students with baseline skills in these areas. Rather than asking all students to do the same work and develop the same proficiencies, specialization occurs in the class, as it happens in professional offices. Additionally, students experience will vary, with novices learning by observing those with more expertise.

At the beginning of the course, architecture students tend to dominate the partnership, as they are more familiar with the course content and design studio format. Additionally, their sketching and digital

Figure 10. C-shaped connector boxes for corner connections (two images on the left).Roof connection (two images on the right)

visualization skills give credibility to their ideas. However, as the course progresses and the focus shifts to realizing designs, the dynamic changes—material and structural knowledge and construction skills become more critical, reshaping the group dynamics.

This shift in group dynamics underscores the importance of technical skills as they are applied and developed within the context of the project. By embedding skill-building within the larger design/build process, students learn to see technical competencies—both their own and those of their partners—not as isolated tasks but as critical tools for realizing their ideas.

Skill-building is woven into the course's iterative process. Case studies play a pivotal role in both skill development and fostering collaboration in the design process. For example, students apply digital fabrication and woodshop skills to produce models of precedent case study buildings and project designs at various stages. Physical models help them understand component connections and overall stability, while digital modeling and analysis provide practice with software tools, supporting parametric exploration and element substitution. As students move from modeling to full-scale prototyping, they experiment with component variations and expand the kit with new elements. In preparation for the build, a small group takes a deeper dive into structural analysis using Karamba, further reinforcing the integration of design and engineering within the course framework.

In previous iterations of the class, collaboration dynamics and the roles' significance and responsibilities were introduced later in the course. Moving forward, presenting these aspects upfront is expected to better align student expectations.

4.2. ADVANCING THE DESIGN OF A CIRCULAR KIT-OF-PARTS

The course project requires students to design a system rather than a specific building, prompting a shift in mindset. Architects are typically accustomed to designing a particular building, while engineers focus on verifying that design. In this project, the bottom-up approach is particularly emphasized, where students begin with the system and its components, considering how they can be configured and applied across multiple buildings. This fosters a deeper understanding of how systems configure space, fulfill specific functions, and meet the structural requirements for each permutation. It also involves specifying the use of particular wood products, hardware, and finishes in prefabricated components.

One of the biggest challenges in the project is developing reusable connections without relying on special connectors or proprietary systems. To streamline the shelter's kit-of-parts, the connection systems are integrated into the kit, minimizing the number of variations in the standard parts, such as the wall and floor panels. This approach typically requires multiple prototyping iterations at different scales, testing solutions for various system connections, including in-plane connections between floors and walls, as well as angled connections between floors and walls, wall-to-wall, and wall-to-roof. Engineering knowledge plays a crucial role in this process, helping to reduce reliance on trial-and-error by supplementing physical prototyping with calculations and structural analysis.

Connection design and fabrication-controlled tolerances have proven to be the main bottlenecks in both project experiences, necessitating on-site adjustments and additional revisions to enhance overall stability.

Designing a kit-of-parts system with a limited number of components rather than a building requires a different kind of creativity that works with material constraints for fabrication optimization. Offering students viable examples can foster self-exploration. In Fall 2023, the constraint of cutting only perpendicular to the plywood surface led the students to study more similar

https://doi.org/10.52202/080513-0517

precedents, and generate ideas with similar 4-fold tessellations. In contrast, in 2024 fewer precedents were provided that used stressed skin panels for shelter design. While the small group solutions had some similarity, it was difficult for either the class as a whole or the delegated three students to resolve the design. The three students felt torn between the need to be practical by fully utilizing 4'x8' (1220mm x 2440mm) plywood sheets and the interest in innovating by developing various spatial and functional permutations of the system. In the future, narrowly defining the problem and providing strong precedents could reduce the small group variations and lead more seamlessly to a consolidated project.

4.2. CHALLENGES AND OPPORTUNITIES IN ADVANCING INTERDISCIPLINARY COLLABORATION AND CIRCULAR DESIGN THROUGH DESIGN-BUILD STUDIOS

Short-duration design-studio courses, like our 11-week program, present several challenges, particularly in balancing rigorous learning objectives with practical execution. The steep learning curve requires students to quickly grasp new concepts, while the compressed timeline limits opportunities for design refinement and testing. Rapid decision-making under pressure can be demanding, and effective teamwork is crucial despite the limited time available for developing strong group dynamics. Additionally, technical and fabrication logistics may restrict design experimentation, requiring students to adapt their ideas within material and process limitations.

The success of these courses depends on careful coordination of scheduling and logistics to ensure a smooth workflow. This includes procuring materials, securing appropriate spaces for production, construction, and storage, and ensuring access to specialized tools and technical support. In interdisciplinary settings, logistical challenges become even more complex, as collaboration across disciplines requires integration of different workflows, schedules, and technical expertise.

In dispersed teams, such as in our interinstitutional course, collaboration relies heavily on online communication platforms, digital whiteboards, and video conferencing tools. Remote collaboration with these digital tools competes for time with the location-based physical prototyping, fabrication, and construction. These hands-on activities require in-person direct interaction with materials, tools, and physical spaces, making coordination more demanding.

While the course already breaks typical boundaries, fully embracing the circular economy could add further complexity. Designing projects that incorporate salvaged or reconditioned wood and reusing course products for future applications require careful planning for storage and transportation. Managing these logistical aspects ensures that circular design principles are not only integrated conceptually but also implemented. Selecting a project type that enhances the learning experience is crucial. There is a trade-off between ensuring feasibility for completion and maintaining relevance for practical applications. Comparing the 2023 and 2024 projects, the reciprocal frame arch had a much smoother production process. While reciprocal frame structures are not very practical due to the system's relative instability and difficulty of enclosure, small and lightweight elements make it easy for many to participate in manually prefabricating and disassembling sections. In contrast, the stressed skin panel shelter is a more realistic building system. Our shelter's scale, weight and complexity prevented the class from completing it within the allocated time. However, the greater complexity of the shelter project provided a valuable opportunity to examine the interconnections between structure, building enclosure, and functional requirements, emphasizing the need for expertise from multiple disciplines. These interdependencies also introduced more intricate challenges and considerations for circularity, requiring a deeper exploration of disassembly strategies and long-term adaptability.

5 – CONCLUSIONS

In recent years, designing for increased circularity has become essential for transitioning from a linear to a circular economy, with renewable, bio-based materials such as wood playing a key role. Achieving circularity, however, requires rethinking traditional design approaches, including the adoption of bottom-up methods and the creation of modular systems and kit-of-parts. It also calls for a shift in how experts are involved, necessitating early interdisciplinary collaboration and integration throughout the process.

The experience gained through this course highlights the critical importance of such collaboration, emphasizing how early and ongoing involvement from diverse experts is key to navigating the complexities of the project and ensuring its success at every stage.

This collaborative approach becomes especially evident when translating a design from drawing to built form,

https://doi.org/10.52202/080513-0517

which presents both the greatest challenge and the most rewarding experience in the building industry. The course encourages even novices to engage with digital workflows and hands-on tasks in the shop, where, through observation and participation, they gain a vivid understanding of interdisciplinary collaboration in action.

Furthermore, the course demonstrates how critical planning is for a digital design-build experience. Course content must be ruthlessly edited so that each step builds on the next, contributing to the final result. Orchestrating such an interdisciplinary design/build course brings many unexpected trials, but these challenges ultimately provide invaluable learning opportunities, preparing students to face the complexities of real-world design and construction projects.

6 - ACKNOWLEDGEMENTS

We acknowledge the contribution of the students of the Fall 2023 and Fall 2024 Timber Tectonics in the Digital Age course, and teaching assistants Alireza Yari and Grayson Wright (2023) and Nastaran Hasani (2024). Our effort was partially supported by the U.S. Department of Agriculture's Agricultural Research Service (USDA-ARS), Agreement N. 58-0204-02-143, and by the 2023 and 2024 UO Sustainable City Year Programs. USDA Borlaug Fellow Marco Aurelio Rebaza Rodriguez, supported by the USDA Borlaug Fellowship Program – Softwoods, Architectural Technology and Structural Design, collaborated in Fall 2024. Roseburg Forest Products donated materials to build the demonstration project in Fall 2023. Timber Pro Coatings USA donated the water resistive coating in Fall 2024. TallWood Design Institute assisted with CNC fabrication and installation.

7 – REFERENCES

[1] U.S. Green Building Council. LEED v4: Reference Guide for Building Design and Construction. Washington D.C.: U.S. Green Building Council, 2013.

[2] Riggio, M. and Cheng, N.Y.W., (2021). Computation and Learning Partnerships: Lessons from Wood Architecture, Engineering, and Construction Integration. *Education Sciences*, 11(3), p.124.

[3] Kengo Kuma Associated Architects (2013) Annex 2 for the Kyushu Geibun Kan Museum https://kkaa.co.jp/en/project/kyushu-geibun-kan-museum-annex-2/

[4] Kengo Kuma Associated Architects (2018) Kodama Pavilion. https://kkaa.co.jp/en/project/kodama-pavilion/

[5] Bergis, L. and Rycke, K.D., 2017, September. Reciprocal frame for the roof of the Franz Masereel Centre. In Proceedings of IASS Annual Symposia (Vol. 2017, No. 7, pp. 1-10). International Association for Shell and Spatial Structures (IASS).

[6] Apolinarska, Aleksandra Anna, Mathias Kuhn, Fabio Gramazio, Matthias Kohler. Performance-Driven Design of a Reciprocal Frame Canopy - Timber structure of the FutureTree. (eCAADe 2021)

[7] Gouw, HI (2011) The Serpentine Pavilion 2005 Case study. https://issuu.com/hizkiagouw/docs/serpentine_pavilion_2005

[8] Bavarel O, Pugnale, A (2014) Reciprocal Systems Based on Planar Elements: Morphology and Design Explorations. Nexus Network Journal.

[9] Bowne, X., Larsn, O.P. and Castriotto, C., 2020, June. Utilising waste wood through reciprocal frame systems. In *Proceedings of IASS Annual Symposia* (Vol. 2020, No. 5, pp. 1-10). International Association for Shell and Spatial Structures (IASS).

[10] Passarelli, R.N., Riggio, M., Cheng, N., Winkels, P. and Knapen, E., 2025. Designing for timber circularity: Potential challenges and approaches from the lens of two educational design/build projects. *Architecture, Structures and Construction*, *5*(1), pp.1-17.

[11] Wood Solutions (2011) Aalto University Wood Program, Liina Transitional Shelter. https://www.woodsolutions.com.au/case-studies/liina-transitional-shelter

[12] Ban, S., 2014. Shigeru Ban. In *Humanitarian Architecture* (pp. 19-30). Routledge.

[13] Open System Lab. The WikiHouse Project. The Shelter (2022). https://www.wikihouse.cc/featured-projects/the-shelter

[14] Kobayashi, H., 2017. The Veneer house experience: the role of architects in recovering community after disaster. *Rethinking Resilience, Adaptation and Transformation in a Time of Change*, pp.365-385.

 https://doi.org/10.52202/080513-0517