World Conference on Timber Engineering Oslo 2023

RE:SOURCE PAVILION – EXPLORING THE CIRCULAR USE OF WOODEN BUILDING MATERIALS

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ABSTRACT: The pavilion as a building task is a contested typology as both its functional life span and constructive durability tend to be limited. However, this ephemerality makes the questions of the materials' origin and the construction elements' later reuse a pressing issue which is of great importance for rethinking architecture of greater scale as well and render the pavilion a suitable format for study and exploration. This paper describes the conception, design and planned mounting of a timber pavilion as part of a master studio taught at The Oslo School of Architecture and Design. The pavilion is planned to be built and exhibited parallel to the World Conference on Timber Architecture 2023 in Oslo. Special focus is directed towards the implication of "disregarded" wooden materials for architectural design and constructive solutions. "Disregarded" wooden materials include cut-offs and cut-outs, materials found on waste sorting plants, pre-used materials from buildings soon-to-be demolished or erroneous deliveries. Specifically, the focus is on joining smaller members or members of varying sizes to larger load-bearing elements or to indoor and outdoor planes and surfaces. The paper discusses the insights this design task provided, highlights new questions that arose during the process, and suggests how these may inform timber architecture in general.

KEYWORDS: Timber construction, reclaimed wood, engineered wood, circular architecture, design for disassembly

1 INTRODUCTION

1.1 THE PAVILION AS A CONTROVERSIAL DESIGN TASK

The dichotomous demands towards sustainable building materials to be both permanent and ephemeral become overly apparent in pavilions as a building typology – permanent as materials are supposed to last long, and ephemeral as materials are supposed to be compostable (or combustible for energy production) instead of ending in landfills [1].

For many, the pavilion is a contested building task. As its function tends to be limited and its construction less durable, the pavilion may be criticised for its use of resources. However, the pavilion may also serve as a test bed for new architectural and constructive ideas and exhibit these to the public [2]. Bringing together the necessary expertise for non-standard design and construction endeavours may even initiate future collaboration.

When its materials have been pre-used or would have been discarded otherwise, and when the pavilion's functional and constructive conception allows for a relocation after its primary exhibition phase – in parts or as a whole, the critique of wasting resources is less apposite. Both using pre-used materials and designing the pavilion for later disassembly and reassembly may on the contrary provide an important opportunity to explore circular construction concepts that are not possible, feasible or common in full-scale buildings at present – either for logistic challenges, due to clients' short-time perspective and corresponding budget, or owing to expectations for the materials' visual and performative properties. The pavilion's focus on circular materiality also brings these issues to a broader public awareness, and if designed in an education context, equips future architects with a corresponding mindset and skills that they can bring to future projects.

1.2 FOUR CIRCULARITY FOCUS AREAS

Even when employing renewable resources that in addition store carbon, such as timber, the environmental benefits are maximized when the materials are in use as long as possible and when their use is planned in a cascading circle – not ending in a landfill[3] but feeding into energy or soil production [3]. This cascading circle may be understood as a perpetual succession of four use stages, or focus areas, that each tries to minimize material or energy losses along the way.

- *"Plan A":* The first focus should always be on extending a building's life span. This is supported by the construction's durability, the building's maintenance, the layout's and surfaces' adaptability and the building's overall lovability and acceptance [4].

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[3] Since 2009, landfills with biologically degradable materials such as wood are not allowed in Norway.

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- *"Plan B":* If at some point, the building needs to be taken down, it should be possible to reuse it as a whole, or its components with the least modification and the least loss of material possible (design for disassembly) [5]. The re-use of building components is eased by access to their documentation or information about previous approval details (e.g. catalogued in a database). It furthermore requires the space and the logistics of storing and marketing them.

- *"Plan C":* When building components do not allow any further reuse, their materials' recycling will give them another life. Even when flagged as "upcycling" however, this new life is sometimes a dead end, for example when the materials' treatment only allows for later disposal in a landfill. The recycling of materials is supported by their non-toxicity and their separability into components.

- *"Plan D":* Materials should always be treated in a way that does not impede their later composting for soil amendment or their combustion for energy production. However, some paints or impregnations turn wooden materials into hazardous waste, and composites are often impossible to separate into their organic and inorganic constituents.

While previous "Timber Studio" courses at The Oslo School of Architecture and Design (AHO) have mainly dealt with "Plan A", this course's task has been designed to predominantly address "Plan B" and "Plan C". Focussing on wooden construction materials, the course paid special attention to their provenience (e.g. pre-used, cut-offs, waste, left-overs) and to their afterlife (not impeding composting or combustion). It furthermore engaged in design for disassembly and scenarios for subsequent uses.

2 METHODS

2.1 A DESIGN-BUILD MASTER STUDIO

The master's studio course *Re:Source Pavilion* was taught during the fall semester 2022 at AHO. It has developed the concept, program, design, construction, details, production and assembly plans of a wooden pavilion that is planned to be exhibited on a city-centre site during the World Conference on Timber Engineering 2023 in Oslo. Its 21 students from Norway and from abroad were at different stages of their master studies. The teacher team had special expertise in architectural design and theory, timber construction, parametric design, and static engineering. Both at a midterm review and at the final review, invited guest critics provided critical feedback.

The students worked with a variety of individual and group tasks, and in changing group constellations. Each student wrote one lecture report, presented one precedent analysis, and shared photographs of their favourite details from a study trip to Switzerland.

The students' playful first design task was individual as well. Each student got 1m of AHO terrace boards that had been retained when the school's deck got shifted during summer vacation. Only by subtracting material (grinding, sawing, cutting, sanding etc.), the students transformed their boards into something new, and formulated their thoughts in a short poem. The ensuing discussions among the entire group introduced a wide range of topics with relevance to the course's focus on wooden materials and their repeated use.

The students then suggested pavilion concepts in groups of 2, voted for which ones to refine, worked on pavilion designs in groups of 4, voted for which ones to continue with, and in groups of 7 contributed to develop the 3 final conceptual, spatial, and constructive pavilion designs that will be described more in detail in this paper. The diagram in

Figure 1 illustrates each student's path through the semester's group constellations.

Several efforts were made to foster the sense of contributing to the entire group's knowledge gains instead of individual achievements. As an example for the sharing of ideas across projects, when voting for the projects to continue with, the students would also point out ideas or aspects they would like to see followed up in later designs, without the project the ideas originated from claiming exclusive ownership to these. In the large final groups, each student developed an individual field of "nerd expertise", diving deeper into the different aspects of the project (e.g. parametric modelling; detail drawing; the logics of prefabrication, transportation, assembly and disassembly; or building and mounting 1:1 mock-ups).

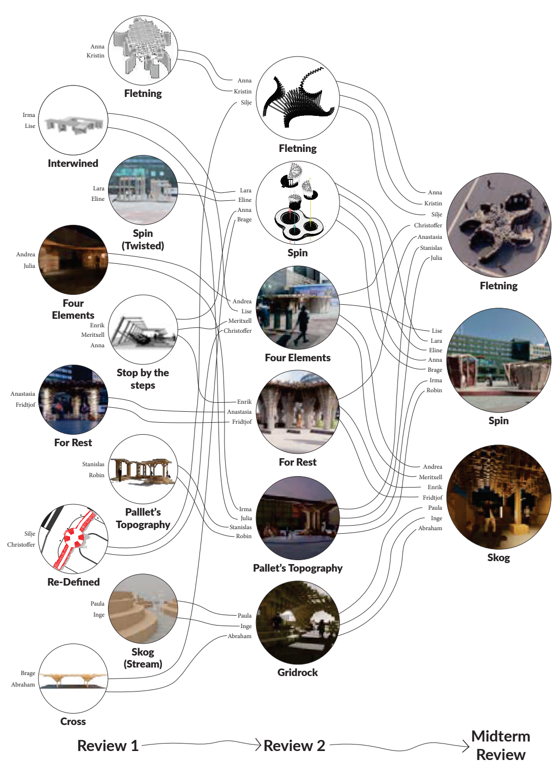

Figure 1: *21 students contributed to the projects in varying group constellations (Illustration: S. Corbevin).*

2.2 WORKSHOP EXPERIMENTS

A series of experiments in 1:1 scale was conducted at the school's workshop hall. In a first session, "disregarded" wooden materials reclaimed from waste facilities, a CLT producer and a disassembled, obsolete barn were joined into larger construction members.

The students' suggestion *Leftover Ceiling* created dowel-laminated slabs consisting of leftover boards with different formats and surface qualities, their edges aligned to a flush surface on one side and with a varied relief on the other side, imagining that the irregular side could remain visible in the room underneath (Figure 2).

To Glue or Not to Glue tested glue and wooden dowels as alternatives for joining pallet boards into thicker and longer elements that were used in a block construction and a cross-laminated floor slab (Figure 3).

Pillar and Beam made use of rescued plywood pieces to vertically join old components to longer columns. The plywood pieces were joint horizontally by adding simple top- and bottom flanges that only needed few screws to be held in place, resulting in wooden I-beams (Figure 4). This was also imagined to be a way to vertically join the ancient columns from pre-industrial barns that had been retrieved for this workshop.

Gradient Wall explored varying degrees of transparency by inserting plywood pieces in gradient angles between a top and a bottom beam made from CLT parts that had been cut out of CLT walls to create openings (Figure 5).

Stacked Triangles explored ways of joining boards into triangular segments and stacking these or connecting them in one plane (Figure 6).

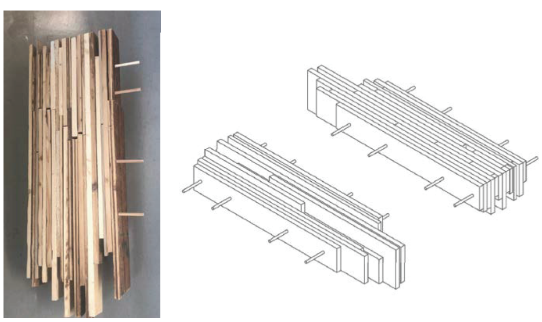

Figure 2: *Leftover Ceiling*

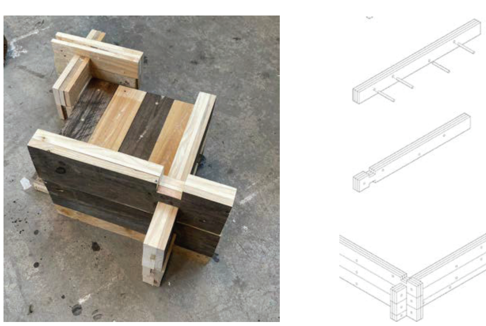

Figure 3: *To Glue or Not to Glue*

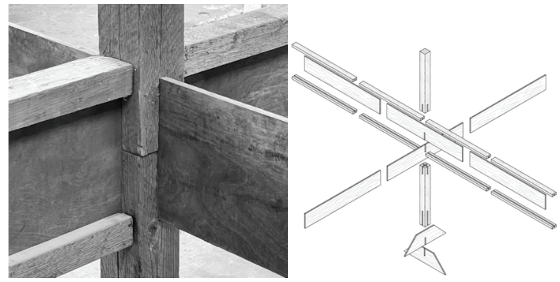

Figure 4: *Pillar and Beam*

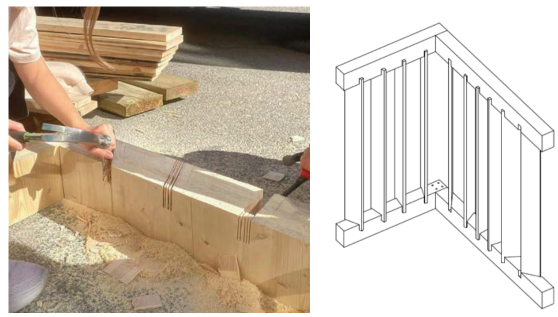

Figure 5: *Gradient Wall*

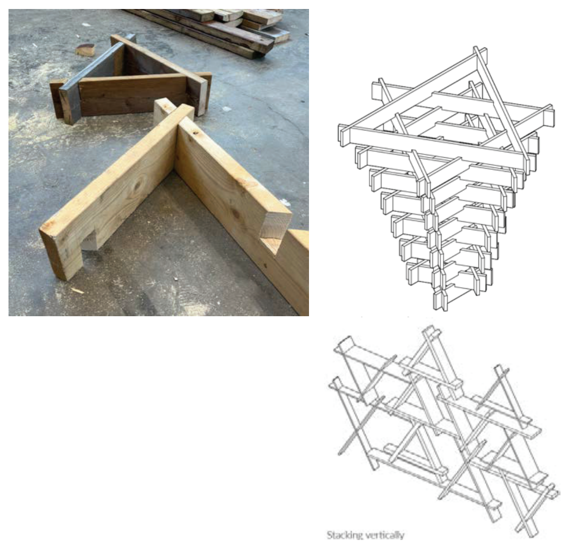

Figure 6: *Stacked Triangles*

As part of a later task, the students' pavilion designs were tested in 1:1 detail models, and a section of each of the three final pavilion designs was built as a full scale mock-up for the final review and exhibition at the AHO gallery (Figure 10, Figure 14, Figure 18).

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3 RESULTS

3.1 FINAL PAVILION PROJECT 1: SKOG

"Skog" means forest in Norwegian, and the project departed from the wish to recreate the experience of being under a forest's treetop canopy, with the light filtered through different layers of leaves and branches, and an undulating forest floor beneath (Figure 7). From the outset, this intention was formulated and explored through hand drawings, a poem, various model iterations and digital visualizations.

The final project consists of 13 trees with a wooden gridwork symbolizing the tree crowns. The trunks consist of four square parts that are anchored in a base plate which is hidden in a modular stepped landscape. The landscape can be used as an informal sitting amphitheatre or during presentations and other events, and indicates areas for the exhibition of objects or prints (Figure 8). Due to the limited possibility of clamping the trees at the base, they were also connected to each other at the top. This creates a so-called social static system with a frame effect. In the case of local overload, the stress peaks are taken over by the neighbours.

The physical mock-up was made from left-over materials (2'x2' battens) after another course's concrete workshop at AHO (Figure 10). While the physical and digital models suggest standard 2'x2' formats in defined lengths, one can also imagine members with varying cross sections and/or lengths as well as surface qualities, especially in the places where these are only attached to the gridwork on two sides.

The students considered options to protect the gridwork's end-grain parts, either with a translucent roof plate or with small caps covering the horizontal cut faces. They finally decided to leave the wood unprotected and to embrace and exhibit its degrading process – possibly even at a secondary site in the forest where the construction materials originally came from (Figure 9).

Figure 7: *Light filtered through the trees' canopy (rendering).*

Figure 8: *The existing stairs at Oslo S may extend the pavilion's sitting landscape (rendering).*

Figure 9*: Imagining the pavilion returning to its materials' place of origin, re-entering the biological cycle and decomposing in the forest.*

Figure 10: *The students built a quarter of one tree as a 1:1 mock-up.*

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3.2 FINAL PAVILION PROJECT 2: SPIN

Spin consists of three pavilion segments that can be rotated in order to create a wide range of spatial constellations that facilitate different activities, such as lectures, presentations and concerts, a pathway along the pavilion's differently treated panels or other smaller exhibitions, large audiences, smaller groups and coincidentally attracted passers-by. The rotation is made possible by mounting the pavilion segments onto the slewing rings from disused excavators. These are hidden in a stepped base plate construction (Figure 13).

With the wood stemming from an obsolete barn close to Oslo, the pavilion's dimensions are conditioned by the materials available. The students were able to make use of pre-existing 3D data of the barn's elements in order to maximize material efficiency. Former beams and columns make up the pavilion's load bearing frames (Figure 11). Wooden dowels are used for the pavilion's permanent connections, with rescued plywood parts reinforcing the joints (Figure 14). Demountable parts are joined by steel dowels. The old cladding makes a reappearance in the pavilion's vertical spaces between the frames. They are treated (sanded, oiled, painted, engraved, etc.) in various ways in order to show the wealth of options for processing or upgrading pre-used materials. Disused surfing sails are used to protect the wood from rain and to add colour to the design (Figure 12).

Figure 11: *An obsolete barn's construction members constitute Spin's main materials (rendering).*

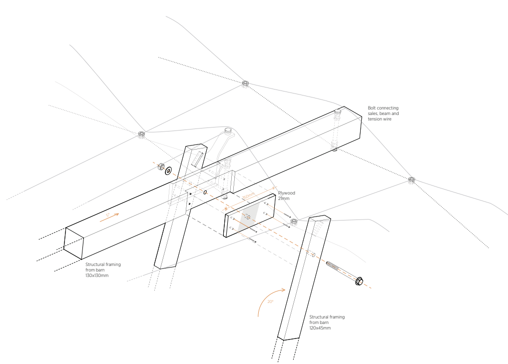

Figure 12: *Old surfing sails protect the wood.*

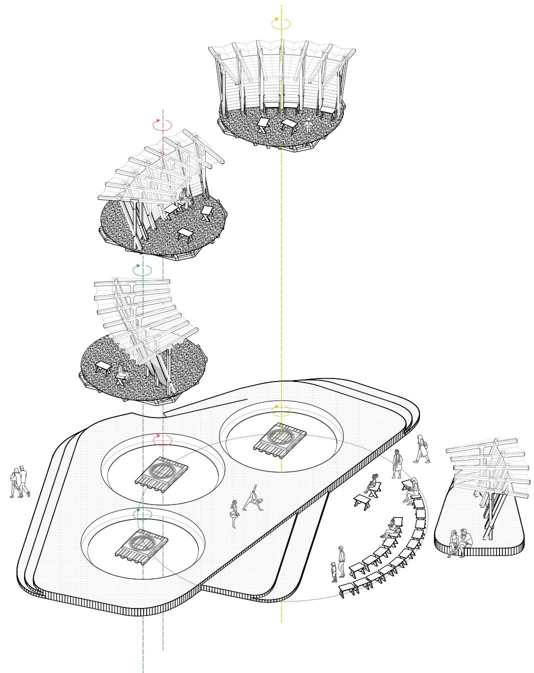

Figure 13: *Mounted on disused slewing rings, the pavilion's segments can be turned to create a variety of spatial constellations on and around the "connective tissue" base.*

Figure 14: *Plywood parts reinforce the wood dowel connections (1:1 mock-up).*

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3.3 FINAL PAVILION PROJECT 3: FLETNING

During the processing of wood into standardized industrial building materials, wood loses one of its original qualities, namely the organic shapes of the tree and its parts. This pavilion project's ambition was twofold: to create organic shapes with highly standardized industrialized wooden materials, and to mainly use short dimensions as more readily available from wood waste and cut-offs.

"Fletning" means weaving in Norwegian. By stacking rows of short, offset 2'x4' pieces ("wood bricks") with altering angles, the resulting semi-transparent walls allow glimpses through the construction that vary with every step when passing by (Figure 15). Towards the wall's top, the pieces gradually increase in length and create a cantilevering canopy (Figure 18). In some places, other walls' tops complete the geometry of an archway. Three such walls are arranged in a curved geometry that both ensures stability and creates subspaces for smaller exhibition sections, sitting areas or a podium. The structure's geometry has been parametrized in a digital model for full flexibility in the form-finding process. In order to compensate for the laterally projecting walls' lack of weight, the students suggest a disk-shaped roof element that is filled with earth for weighing down the pavilion against wind forces. It is clad with disused offprint metal sheets that mirror the construction and visually continue the pavilion's central space (Figure 16). Another option could be to omit the roof plate and to hide sandbags in the two podiums instead. The wall itself is made up of smaller ca.1m wide blocks that consist of 11 wood brick layers and weigh about 38kg each. They are joint by long wooden dowels that create a loose fit with the middle layers' holes and a tight and permanent connection with the outer layers. Stacks of these blocks are held together with steel rods, and these segments are joined with other stack segments (Figure 17).

Depending on the "re:source's" provenience – either from a waste facility or collected at a production facility – the materials' surface will either be weathered or more or less pristine. In contrast to most conventional products with the exposed surfaces aligned with the wood fibres' direction, here the end-grain's cut fibres face the visitor. If most pieces are cut to length, only a few weathered pieces will mix up the frontal view's colouring, but due to their angled placement, also the lengths' surfaces will be discernible. As only parts of the pavilion are protected by a roof, its walls will weather differently and increase the walls' visual homogeneity.

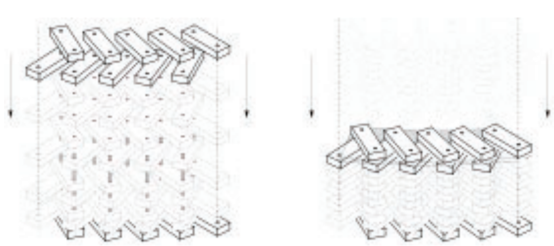

Figure 15: *"Wood brick" layers are joined into a block and then stacked. Altering in orientation, they create varied transparency.*

Figure 16: *Fletning's organic curves visually continue as a reflection in the roof disk (rendering).*

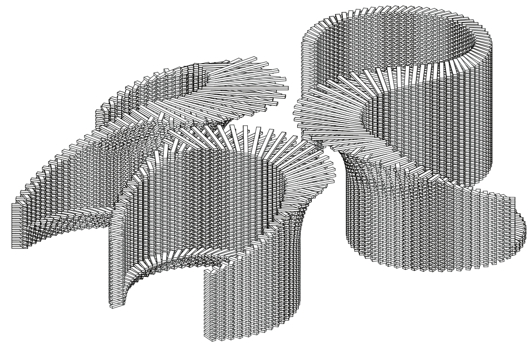

Figure 17: *Wall segments are assembled into curving walls for stability and spatial differentiation.*

Figure 18: *The "wood bricks" increase in length to create a sitting bench and to extend into a partial roof (1:1 mock-up).*

4 DISCUSSION AND CONCLUDING COMMENT

The work on the pavilion projects and the course's accompanying tasks addressed a number of issues that are specific for the design with "disregarded" wooden materials.

4.1 STRATEGIES TO JOIN SMALL PARTS INTO LARGER CONSTRUCTION MEMBERS

There is an element of unpredictability of the available sizes and qualities when harvesting disregarded materials. The students realized that shorter pieces were more common to find than long boards, panels, beams or large plates.

Different products were aimed at when joining small parts into larger construction members and thereby creating larger surfaces or increasing lengths and spans: planes (slabs), linear members (columns and beams), gridworks and bent surfaces with varying degrees of transparency.

Availability, fabrication, logistics and assembly on site were discussed and are mirrored in the resulting connections.

4.1.1 Permanent and disassemblable joints

The projects made a differentiation between permanently assembled construction members and joints between such members that need to allow for repeated assembly and disassembly.

Permanent connections typically involved glue or wooden dowels in places where a later dismantling was not considered relevant. For the wooden dowel connections, dried wooden poles were inserted into slightly more narrow pre-drilled holes. When the wooden poles adapt to the ambient moisture and expand, they permanently lock the parts together. It is difficult to dismantle connections with wooden dowels without destroying them. For example, the wooden dowel connections in *Spin* can only be removed by sawing them or by drilling them out. The wooden dowels permanently join beams and pillars into parts that still fit into a container and that can be raised by manpower.

Steel bolts in the connection details between these segments can be attached and detached repeatedly.

In *Fletning*, wooden dowels connect 11 layers of "wood bricks" into permanently joint blocks. Weighing about 38kg each, these can be handled by manpower. The stacked blocks are joined with removable steel rods and attached to other stacks.

4.1.2 Including diverging dimensions while minimizing cuts

Some of the workshop studies addressed the issue of minimizing adjustments to obtain equal formats when found materials differed in cross-section and/or length. Among the preliminary workshop experiments*, To Glue or Not to Glue* avoided the problem by basing their proposal on the components of standardized pallets. *Leftover Ceiling* aimed to expose the differing heights and lengths of the included reclaimed boards on one side, aiming to activate the visual and narrative potential of their product. *Stacked Triangles* also suggested versions where the boards circumscribed equal triangles while continuing outwards according to the found lengths.

Many of the pavilion projects were initially imagined with freely defined formats as usual in conventional projects where one can choose from a range of available formats and looks, and only later turned to embracing the unique and unpredictable qualities and dimensions of reclaimed wooden materials. However, also the final projects all have some potential to integrate found formats to a greater degree.

Skog: While the students aimed for a clear overall geometric shape and envisioned the pavilion with identical 2'x2' profiles, the canopy's construction system would also allow for integrating different lengths, resulting in a geometrically less controlled underside or top (or both). In contrast to other parts in the crowns' gridwork, its (at present) shortest pieces are only attached on two sides, which would allow for attaching other formats than 2'x2' cross sections as well. Visual consequences could be studied in the pavilion's digital model that served for visualizations and for a VR tour of the project.

Spin: The dimensions of an actual obsolete barn considered suitable as re:source co-defined the size and shape of the pavilion. As described above, the use of pre-existing 3D data of the barn's elements allowed the students to maximize material efficiency. With longer or shorter members available, for example from another obsolete barn, the pavilion's parametric model can be adjusted accordingly.

Fletning: Confronted with the complexity and laborious production of their pavilion, the students highlighted that 70% of their "wood bricks" were identical, while the rest differed in length. However, the key invention in mastering the complexity may lie in using the same drilling stencil with a defined distance between the holes for the dowel connections in all wood pieces, no matter their length (or even height if it is the same for an entire layer). Precision in the distance between these holes is of key importance for the pavilion's assembly, while – as is the case in *Skog* as well - precision in the components' length only matters visually.

The flexibility to include different formats (as long as they have the same height per layer) might alleviate one fallacy: the pavilion's design is based on cut-offs in the most common dimension, as these are most likely to find at waste facilities. However, this universally applicable format also makes these the most sought-after pieces. The further refinement of the design could integrate pieces that are less attractive for subsequent users.

Catering for a greater variety of lengths when minimizing cuts, one could align the pieces in a different way than in the students' project, for example creating several partial covers over each curve instead of the central area between the three curves, or creating random reliefs on one or both sides of the walls. Using the same basic design as the student's proposition but with random (found) lengths, the increasingly cantilevering walls would create vaults and

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archways of a less regular geometry. These geometrical options may be explored in the pavilion's parametric model.

4.2 WEATHER PROTECTION

The pavilions feature different ways of handling the protection against weathering and decay. *Skog's* student team explored several options, but favours to expose the pavilion fully to the elements. *Fletning* suggests partial coverage, and *Spin* provides protection of all upright elements except for the base.

If the pavilions are no longer used as a temporary structure, adequate structural wood protection must be provided. The roofs should be constructed in such a way that the joints are not directly exposed to the rain.

4.3 ADDED WEIGHT

On an exposed site, high wind-induced uplifting forces occur. In order to compensate for wood's light weight and the lack of foundations in the temporary constructions, weight is added to the pavilions' roof or floor construction: the designs allow for adding sandbags, earth or other heavy materials in *Skog's* landscape, in *Spin's* base or in *Fletning's* roof plate or podiums. The added weight helps to fix the temporary pavilions in place against strong winds without the need of fastening them to a foundation on site.

Connecting several elements like in *Skog* or arranging connected frames in a half circle like in *Spin* additionally stabilizes the construction.

4.4 PROVENIENCE AND PROVENANCE

The re:sources' provenience as their place of extraction, or more precisely, retrieval, has been important – both as a justification for the pavilion as a building task, and as a specific area of investigation, as the materials' previous function, use, treatments, removal (cautious or careless) and storage all condition their visual and performative qualities as well as choices for their later processing and according use of tools in a technical perspective.

The material's previous life entails yet another dimension than just the performative one, which has been embraced in different ways in the student projects. In contrast to provenience as the exact location of retrieval, the term provenance is used to address the detailed history of an object, for example the different owners and exhibition or storage circumstances of an artwork. The materials used by the students all witness of their history, for example with traces of axe cuts from times before other tools were invented, with different layers of paint, with insect holes, with the overall roughening effect of weather exposure or the locally smoothing effect of repeated touch.

How these signs of previous life were valued differed – in some cases, they were consciously preserved and exhibited (e.g. in *Spin's* frames and parts of its cladding, or in *Fletning's* wood bricks), in other cases, they were ignored, evened-out or removed (e.g. in *Skog's* gridwork or in other parts of *Spin's* cladding).

The materials' provenience and provenance were of particular interest when discussing the use of obsolete barn materials, some of them from preindustrial times. The abundance of disused barns all over rural Norway most often leads to their demolition – in some cases, they at least serve for fire brigade exercises before turning to waste.

If the oftentimes quite solid materials can be used in constructions instead, even when just hidden between gypsum boards, they can still play an important load-bearing role and replace more harmful materials or ease the pressure on fresh wood. The same is true when cutting or planing the material to obtain parts that are straight or equal. Then, the old traces may still be discernible in part, while including the retrieved components mostly untreated will expose these qualities more fully.

In order to access a greater part of these narratives than only the visually accessible ones, some circular building projects label the materials with QR-codes for the visitor's information. This additional information beyond the architecture's mere atmospheric experience may even change the appreciation of the architecture's visual, experiential and functional qualities. What may be criticized in other cases is potentially valued when associated with the materials' previous life and the intentions behind their reuse.

4.5 PROJECT STATUS

The three final projects, together with the terrace board exercise and the workshop experiments, have been exhibited at the AHO gallery in December 2022 and are planned to be shown again during the conference.

It had been the wish of the WCTE arrangers to erect one pavilion at Oslo's Central Station during the World Conference on Timber Engineering in the summer of 2023. Out of the three final projects, a jury recommended *Fletning* to be built in full size for this purpose. The jury consisted of the course's external censor (Siv H. Stangeland from Helen&Hard), the course's teachers (3 architects and one engineer), a representative of WCTE and a representative of the engineering firm that was going to act as the responsible applicant (Sweco). The assessment criteria collectively agreed upon were the projects' poetic and conceptual approach, experiential qualities, functionality, resource use, originality and innovation, feasibility, disassembly and reuse options, and transferability of research insights.

At the point of this paper's submission deadline, the process of realizing the winning proposal has not started yet; an update will be included in the conference presentation.

4.6 EXPECTED CHALLENGES

A number of challenges are expected when realizing the winning proposal. *Fletning* is considered to be buildable, but intermediate storage and timing are expected to be the main challenges.

The manual assembly of *Fletning* has been tested by students in 1:1 mock-ups; it is relatively simple and can be done by untrained workers, but time-consuming and difficult to estimate for the pavilion's entirety. All larger pieces must be prepared in advance and their assembly well-planned and tested, as the time window for mounting the pavilion on site is short. Possible unevenness of the site may complicate the pavilion's assembly somewhat. The storing of gathered materials and assembled parts will require adequate storage space over longer time. Security issues and possible vandalism need to be addressed carefully. The pavilion's after-life is not decided at the point of the paper's submission.

4.7 CONCLUDING COMMENT

The results of AHO's master's course *Re:Source Pavilion* showcase that vast architectural variety is possible when basing the design on readily available, disregarded wooden materials. Joining smaller and irregular pieces into larger construction members will be relevant for larger building projects as well. In the load-bearing parts of conventional projects, the formal and atmospheric potential of disregarded materials such as waste wood, cut-offs, cut-outs from CLT production and materials directly retrieved from obsolete buildings may not be fully taken advantage of.

The narrative and associative potential of discernibly reused materials may elevate their value for some, especially when their visually accessible qualities are complemented by information on their previous location(s), function(s) and modification(s).

In more rational (purely functional) assemblies, disregarded wooden materials may still play an important role in replacing more harmful materials and reducing the need for fresh wood, while at the same time maximising the life cycle and thus carbon storing benefits of wooden construction materials.

The necessary labour and related need for storage and transportation need to be carefully assessed in order to avoid the latent risk of promoting circularity for its own sake [6]. However, what is not established and competitive today (both budget-wise and in a LCA perspective) may become easier to achieve and more feasible in the future – both due to more established routines and systems, and potential legal changes.

ACKNOWLEDGEMENTS

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