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THE GIRL SCOUTS OF UTAH INTERLOCKING CROSS-LAMINATED TIMBER SUMMER CABINS

Fig 1: Finished cabins in their natural environment

Research summary

This paper discusses the design, development and construction of three, 600ft^2/56m^2 gross area summer camping cabins for a Girl Scouts' Ranch Camp in the United States of America. When developing the design for the cabins, the authors as the organizing team took an integrated, multidisciplinary design and development approach in which stakeholders, architecture faculty, general contractor and fabricator, engineers, the building department, Girl Scouts, and architecture students were involved. The cabins were designed and built in collaboration with a local timber company that focuses on natural building methods using no glues, binders, adhesives, or products with VOCs. That company, in collaboration with researchers of the local university, has developed an innovative and highly sustainable material called Interlocking Cross Laminated Timber (ICLT) to incorporate locally sourced wood damaged by pine beetle infestation prevalent in the American West into the assembly of solid wooden panels. Utilization of this new material puts the project at the forefront of sustainable construction with findings expected to influence the construction market within the region and well beyond. The paper analyzes the project's construction with a specific focus on experiences and challenges anticipated during the design and construction process when using a material that is new to the US and local building industry.

Keywords: Interlocking Cross-Laminated Timber; Sustainable Design; Design and Education, Participatory Development Process.

1. Introduction

Project:ARCHITECTURE is a new partnership between the Girl Scouts of Utah (GSU) and the School of Architecture (SoA) at the University of Utah, to raise awareness of careers in the built environment for women and to provide opportunities for architecture students to engage in service and creative projects. The inaugural project for this partnership was the design and construction of three cabins for the GSU's Ranch Camp in Provo Canyon. Located on a wooded site at the upper end of a narrow canyon at an elevation of 6,040' (1,840m), the area sits within the Utah Cold Climate Zone with warm and dry summers and cold winters with heavy seasonal snow loads. The camp's use is restricted to summer months only, offering diverse activities during daily, weekend, or weekly camps to the GSU population. The cabins' services are reduced to electricity only; supporting functions such as washhouses, common kitchen, indoor activity areas, additional sleeping opportunities, and meeting and gathering places are provided by the larger camp development that already exists as part of the Ranch Camp. To conform to fire code regulations, the cabins are equipped with a simple fire sprinkler system.

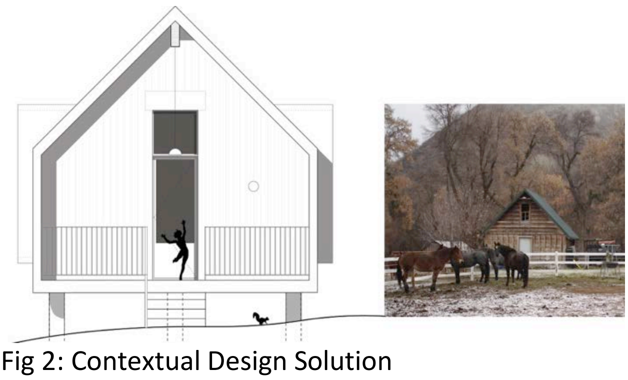

Fig 2: Contextual Design Solution

As a central part of the participatory design process, the authors hosted a yearlong series of outreach events to expose Girl Scouts directly to women practitioners, provide female student mentors in design-related programs, and offer opportunities to visit architecture firms, construction sites and engage with an institution of higher education. The project is based on the collective experience of the design team, the client, stakeholders and all other parties and persons involved – including the Scouts as the project's users. With this approach, it follows Reed's emphasis of a 'conscious process of learning and participation through action, reflection and dialogue' [Reed 2007] and falls into the category of regenerative design, as described by Robinson and Cole [Robinson & Cole, 2014].

2. Design Philosophy

The regionally rooted typology adopted for the cabins is simple, clearly defining the project as highly sustainable from a design as well as a material standpoint. It echoes the regional, functional design of old farm and barn buildings in the canyon, as well as the typology of the Scout's old wooden tent platforms, which were originally erected on simple CMU piers above ground. The concrete piers for the new cabins have been initially chosen for their minimal construction disturbances while simultaneously maximizing land use efficiency. Clad in mild steel, the cabins blur well into the site. In addition, the steel has been chosen for its fire resistance properties, allowing for the reduction of wall thicknesses to the structural minimum for material efficiency.

Each cabin has an inviting, shaded patio that is oriented towards the common fire pit area - the cabin to the north also offering additional outdoor seating on its stairs. Access to the cabins is through this common space, supporting the idea of community and communication among the group members.

Inside, the cabins offer a spacious, day lit, warm, and healthy interior that provides accommodation for 10 scouts. For indoor activities, the bunk beds of each cabin are grouped around a large table, which were designed and digitally manufactured by students at the SoA. A small changing room completes the spatial arrangement. A tall entry door and vertical egress window oppose each other on the short cabin elevations, allowing for a direct view connection into the woods when entering a cabin. The four bay windows on the long sides echo the verticality of the trees and offer a small seating bench in each bay; the arrangement of the upper, operable windows allow for cross ventilation. Similar bays without windows, one on each side of the patio, offer sideway views when outside.

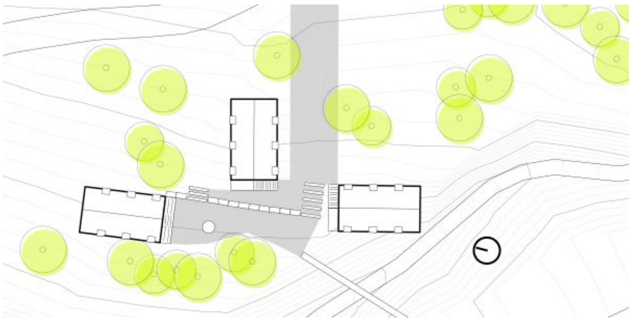

Fig 3: Cabin site plan

Providing a high standard of architectural quality, the regionally rooted, timeless design of the cabins is kept robust and simple, clearly defining this project as highly sustainable from a design and visual expression standpoint. As an already award-winning example of modern regionalism, the design exploits resources onsite such as sun exposure, wind protection, orientation, and preserves environmental quality with the goal to support the local ecosystem through design with nature. The cabins respond to a socially viable environment and reflect the value of the local community. They provide an outstanding case study, and thus a stimulating environment for their users, raising critical awareness of finite natural resources and a sensible use and management of an important natural resource. Within its larger context of the GSU, the project creates a space of communal significance and social value; it inspires the Scouts' human spirit and supports the bonding of their community within and the local neighborhood.

The collective, integrated design and construction process applied by the team consistently included stakeholders, authorities, students, Scouts, contractor, and trades. Through the efficiency of the design and the chosen materials, the cabins provide a long-term economic benefit for the users and GSU as a non-profit organization.

Fig 4: Cabin interior

For the design development, in which many of the schematic decisions were further explored and finalized, groups of students and Girl Scouts were involved in the decision making process to ensure a functional architecture that would not only be rooted in the local context but would also become the most functional solution for its occupants. During those workshop-like meetings, the number and shape of the beds were discussed and re-defined, moving the layout from single beds to spatially more efficient bunk-beds, which also allowed the team to stay within the given construction budget by reducing the overall cabin size by about 25%, at the same time introducing a common space for in-cabin activities. The importance of a porch for each cabin was discussed, and the need for a large table in the center of the cabin emerged. After consultation with stakeholders and the client, all of those measures were successfully implemented into the scope and design of the project.

3. Cabin Materials

Interlocking Cross-Laminated Timber (ICLT) was the primary building and construction material used for the cabins built in collaboration with Euclid Timber LLC, a local company that focuses on natural building methods using no glues, binders, adhesives, or products with VOCs.
Originally developed in Europe, Cross-Laminated Timber (CLT) uses glue adhesives or mechanical fasteners to assemble solid softwood timber stock into structurally sound, cross-laminated building components and panels. Solid wood components are also available without the use of glue adhesives or metal fasteners – the Dowel Wood Wall System (Dübelholzwand) uses dried spruce soft wood boards, which are layered and then fixed into solid component by use of dry beech wood dowels. After pressing those into place, the dowels absorb the moisture of the soft wood and swell, thus creating a very strong, force-fit connection [Greve 2014]. ICLT is a similar, prefabricated cross-layered solid softwood wall panel that is fabricated from two or more layers of alternating direction pine stock. Different to regular CLT, the wood is milled from waste or beetle-killed pinewood, using a robust, CNC-controlled process. Beetle kill pine is abundant in the Mountain West. For example, Colorado State University reports that two million acres of national forest in Colorado in 2008 were subject to pine bark beetle, doubling the number just two years earlier, equating to 44% of Colorado's national forests being infested with this pest, which is deadly to trees.

Instead of using the material for low-value application such as burning it as fuel, it is more desirable to use it for higher value products, such as construction for commercial structures, storing CO_2 in built works and applying the residual to energy. By binding the CO_2 content of this already dead wood into a long lasting, low maintenance product, ICLT has a low environmental impact over any project's life cycle. Euclid Timber, with research support from the Integrated Technology in Architecture Center ITAC at the University of Utah, has developed this innovative and highly sustainable material to incorporate the locally sourced damaged wood.

Fig 5: ICLT and Brettstapel assemblies

Simple dovetail connectors join the pine stock elements, utilizing no fasteners and no adhesives within each panel. This system reduces overall capital cost for either stainless fastener purchase and install or press purchase and set up associated with glue lamination [Smith 2010, 2011]. Mechanical fasteners are used for the assemblage of the panel modules onsite, which means that capital cost can be reduced by increasing the actual size of such components to the point where size is limited by the access to the construction site, availability of equipment, and transportation restrictions. As one of the major advantages of utilization of ICLT, the team identified its time-savings potential: the building components were pre-manufactured in the contractor's controlled environment, utilizing a construction sequence that involved a highly-detailed computer model from which the solid wood wall components had been milled on a CNC router. The individual pieces were joined together in 'chunks' in the shop to form manageable modules that were delivered to the site where they were assembled and fastened together. In parallel, the site and foundation work was prepared and finished to allow for relatively short assembly phases on site, which on the other hand allowed constructing the cabins over the winter.

The ICLT system presents a new approach in construction technology, material process, and assembly methodologies; it is a low embodied energy material. The cabins provide long-lasting, healthy and useful buildings that conserve finite resources and fossil energy by using this durable, recyclable, and renewable natural material. Utilization of this material puts the project at the forefront of sustainable construction with findings expected to influence the construction market along the Wasatch Front and beyond.

4. Development and Construction Process

An integrated design process was utilized to design and develop the cabins. The authors worked closely with the contractor and engineer, the trades, component manufacturers, the building department and fire marshal of the jurisdiction. Utilizing ICLT as a new solid wood component system in one of the first times in practice, the design and construction process was more complex for these simple cabins than it would have been for a standard building. After the first and very schematic design of the archetype of the cabins, the architects met with the contractor to discuss buildability of the chosen scheme with regard to the possibilities and limits of ICLT. Topics such as transportation, accessibility of the site, weight limit of each panel, assembly and other factors influenced the following design development process. Noteworthy challenges and changes have been experienced through the collaboration with the jurisdiction - when a new fire marshal came in towards the end of the construction phase, the team was able to abstain from the required metal skirt around the cabin's pier structure. The new marshal allowed an exposed underside of the 9.75" thick solid wooden floor slabs, which made the cabins float above ground as it was originally intended.

Another initial target, to use concrete piers to minimize site disturbance, could not be achieved when the structural engineer added oversized footings due to the dead load of the ICLT panels, and his caution in working with a new system. The oversized footings required significantly more excavation than originally anticipated.

To better accommodate for dead, live, and snow load requirements on the roof and the floor, the assembly method of choice for such components was adjusted during the design process and through collaboration with the contractor and structural engineer: the 9.75" thick horizontal floor and 7.25" thick sloped roof panels were assembled in Brettstapel construction, in which softwood timber boards are connected in parallel with hardwood dowels. More load-intensive locations, such as the floor slab ends, where the gable walls carry their loads into the slab and the solid wooden beams below, were finished in Laminated Veneer Lumber (LVL). The covered patios that define the entrance area of each cabin were constructed as regular wooden decks, allowing water and humidity to easily run off. As a consequence to meet fire code, one additional fire sprinkler had to be installed underneath the deck of each cabin.

Road transportation limits would have allowed prefabricating entire cabin wall, roof and floor panels to be delivered to the site and erected with a larger crane. However, very limited site access in the mountainous camp area restricted the maximum weight of each component to a size that would be transportable by 2 persons over a short distance, resulting in 6-board wide floor and roof panels that could be carried to the site and assembled by hand.

Echoing the fastener-free ICLT strategy, wooden pegs, shims and wedges were milled into the edges of components to allow a friction-locked and force-fit connection, which was additionally supported by 12" long ¼" log screws for final assemblage. A similar method was applied to fix the entire floor structure to the concrete piers: the solid floor beams were fit over a metal tube with fitting slots, through which a metal wedge ensured a frictional connection of both components. Being erected in a seismic zone D, which corresponds to buildings and structures in areas expected to experience severe and destructive ground shaking but not located close to a major fault, this and other measures were necessary to fulfill all safety requirements for the buildings.

Structural loads required simple 5.5" thick two-layer ICLT panels for all walls, which supported the concept of using minimum resources for the cabin construction. Local fire code required either a fireproof cladding or a minimum solid wood thickness of 8", thus walls and roof were clad in 12-14 gauge milled steel plates. Only the wooden entrance façade had to be constructed from three layer 8.25" thick ICLT to conform to code requirements without additional metal cladding. To ensure protection from the elements, the cabin roofs were clad in Grace Ice and Water Shield, which is a self-adhered roof underlayment that protects the buildings from wind-driven rain and ice dams. Its rubberized asphalt formulation has the ability to maintain a watertight seal around fasteners used to attach roof coverings, which was important when the roof panel fasteners penetrate the layer.

The simple, mountain-regional design of the cabins asked for the natural material to be exposed to the interior, with no fasteners or installation visible on the inside. As a result, electric wiring was placed within the ¾" cavity underneath the exterior metal cladding with the openings for receptacles and switches carved into the solid wood walls. Linear grooves were CNC-milled into the solid roof panels and the ridge beam to hide all sprinkler pipes from sight. This clean but unusual design solution was developed in close collaboration with the sprinkler system installer since cavity dimensions had to allow for enough space to weld the pipes together inside the groove. To allow for a consistence appearance of the exposed front wall, electric and sprinkler conduits were CNC-milled into the wooden boards before the actual panels were assembled. The final result shows all receptacles and switches flush-mounted, and only the sprinkler heads themselves projecting into the space.

The tall window dormers of the cabins allow for maximum amounts of daylight in the wooded settings. As an architectonic element, they extend beyond the eaves and into the roof, mimicking the verticality of the tree trunks. By mounting the windows flush to the outside, 2' wide and 18" deep seating benches were created on the inside window sills, allowing Scouts to sit in the dormers to watch the surroundings or to read. The lower, larger glass pane is made from tempered, fixed double glazing units to provide the necessary safety protection; the upper, smaller lite is operable from the inside through a crank, providing effective cross ventilation during hot summer days. Two similar, windowless dormers frame the patios.

The mild steel façade cladding was partially donated by a local metal company. The 4x8 feet rough sheets were shear-cut to specific cut sheets before they were numbered and delivered to the site. On site, a detailed plan allowed the roofers to install the components in a predetermined order. On the roof, the panels overlapped horizontally to allow water to run off; for the vertical seams on the roof and the walls, a 2.5" wide metal strip was mounted onto the furring strip first, with the panels mounted side by side onto the metal strip. The overlapping of the material caused some issues during the mounting process: coming from surplus material, the steel was delivered in two different thicknesses – 12 and 14 gauge (2.80 and 2.10mm). When overlapping in up to three layers, the thicker material was hard to penetrate even with self-drilling screws.

Before cabin completion, the interiors were sanded, cleaned, and the floors were treated with two layers of linseed oil. Bunk beds, lamps and reading lamps, fans, curtains and the tables were installed to finish up construction. Landscaping included gravel surfaces for the common fire pit area and a small gabion retaining wall that provides additional outdoor seating opportunities for the Scouts. An issue that needs to be mentioned is caused by the dropping of natural resin from the walls and the ceiling. It stopped after the first year of operation, but should be taken in to consideration when using the exposed ICLT panels and components for any high-end application.

5. Conclusion

The participatory and integrated design, development and construction process applied by the author team consistently included all stakeholders – building authorities, students, scouts, contractors, and trades – to efficiently provide a long-term economic benefit for the users and non-profit GSU. According to du Plessis' [2012] 'philosophical departure points', it can be argued that the cabin design and development process was a generative design and development process because:

- The human system of the Scouts and their education became an integral part of the ecosystem at the site;
- The human activities incorporated in the process contributed positively to the ecosystem function and evolution;
- The human endeavors were informed by context-specific aspiration;
- Ongoing participatory and reflective processes were and still are applied in the design and development of the GSU cabins as a regenerative place.

Already during and shortly after completion, the project received six important design, collaboration, and diversity achievement awards. The success of the project was extensively covered in the regional media. The authors are confident in stating that the project overall has been a tremendous success in its intention to serve as an outreach, teaching, and research initiative that links faculty and students in architecture, Girl Scouts, and female practitioners with industry to create learning opportunities about architecture through sustainable building design and construction projects.

As of mid 2015, the cabins have been occupied through 1 ½ summer seasons of operation, serving the community of Girl Scouts very well. Occupants love the simple architectural expression of the buildings, their spaciousness, solidness and feel of protection. With maximum daytime temperatures of up to 95°F/35°C during the summer, the solid wooden cabins stay effectively cool during the daytime due to their thermal mass. Effective nighttime cross ventilation removes additional heat stored in the wood – an effect that is directly perceptible - teaching the Scouts the impact of well-designed buildings.

The authors also believe that the project has had a significant impact on the community, which includes the general public in the form of GSU, parents, and troop leaders; the academic community of students and faculty who volunteered for the project; and the professional community who engaged in mentoring the GSU and architecture students by sharing their expertise. This impact includes both a sustainable focus as it relates to the ICLT material utilized for the cabin design as well as a social focus as it relates to female architects. This partnership will be continued through the development of an "Architecture Badge" in collaboration with the GSU, which will formalize a series of events and activities related to architecture that will impact an even broader audience. Furthermore, the authors discussed with the GSU leadership future projects on other campsites in the region.

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