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UTILIZING LOW-VALUE WOOD SPECIES FROM FOREST RESTORATION PROJECTS IN LOCAL CLT MANUFACTURE AND DESIGN

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ABSTRACT: Years of wildfire suppression and ever-extending periods of drought are fanning the flames of catastrophic wildfires at an unnatural scale. The west coast of the United States has suffered the brunt of these negative impacts as wildfire seasons are becoming increasingly worse every year. The abundance of small-diameter trees and dry fuel accumulating in forests is reinforcing the need for better forest management practices as human activity in the last century has proven to be detrimental to the global climate. The goal of this research is to examine the relationship between collaborative forest restoration and local mass timber production to showcase the use of mass timber as a means to improve wildfire resilience and push the United States toward developing its mass timber industry at a local scale. The use of low-value species, harvested from forest restoration projects, in mass timber panels can create a symbiotic relationship between forestry, architecture, and the respective local economy. This project addresses the utilization of low-value species (Ponderosa pine) from forest restoration projects in the Sierra Nevada forests of California to manufacture mass timber locally that, in return, can provide the material for public lands facilities as demonstration projects in parks affected by wildfires.

KEYWORDS: CLT, Ponderosa pine, wildfire management, forest restoration, public lands facilities

1 INTRODUCTION

Forest management policies in the western United States are worsening the effects of climate change and, thus, causing forests to suffer. Years of wildfire suppression due to human intervention has caused forests to become increasingly vulnerable to unnatural fire behaviour [1, 2] Although forest restoration projects, including thinning efforts, are effective at creating forest resiliency, these efforts are often expensive ventures and harvest low-value wood species that are used for low-yield profit products such as biofuel and paper pulp; this results in immense expenditure losses that government agencies are typically burdened with. Mass timber products offer an alternative for lower-grade species as they can be engineered to enhance the wood's structural capabilities. Unfortunately, the production of mass timber, such as CLT (cross laminated timber) panels, can require significant investment in expensive equipment in an industry that is still developing in the United States. For this reason, mass timber production has been largely unattainable for small-scale production. All of these intersecting issues lead to the primary research question: how can forest restoration and thinning, used to reinforce wildfire resilience in forests, create local benefits by using mass timber production generated from associated local forest restoration endeavours? Addressing this question can expand the narrative of the possibilities of mass timber production in the United States while also tackling the issue of wildfire vulnerability in forests.

1.1 WILDFIRE THREATS TO PUBLIC LANDS

Public lands, such as national and state parks, in the western U.S. are facing increased wildfire activity driven by severe drought and an abundance of small diameter trees and dry fuel. The KNP complex fire in Sequoia National Park decimated an estimated 3-5% of California's giant sequoias and, in the past two years, 20% of all sequoias have been lost due to fire activity [3]. In addition to ecosystem devastation, the built environment is also severely affected. In August of 2020, Big Basin Redwoods State Park, the oldest state park in California, suffered catastrophic losses as a result of the CZU complex fire; nearly all of the park's facilities were destroyed leaving only charred remains of the park's historic structures. Lassen Volcanic National Park fell victim to the 2021 Dixie Fire, the second largest wildfire in California history, which not only devastated significant acreage in the park, but also laid ruins to the nearby communities of Greenville, Warner Valley, Canyon Dam, and Indian Falls, amongst others; wildfire threats are not isolated on public forest lands, but also the communities that surround and exist within them. As climate change continues to worsen wildfire seasons, we can expect to witness more and more environmental destruction, both natural and built. For these reasons, this

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project explores the designs of typical public forest lands facilities to address the replacement of these structures that are in the most vulnerable wildfire regions.

1.2 FOREST RESTORATION AND MASS TIMBER

Wildfire and forest management are complex issues that are becoming increasingly urgent to address due to catastrophic fire behaviour. With each fire season becoming increasingly worse on the U.S. west coast, creative solutions involving collaborative measures are beginning to unfold [4]. Forest restoration collaboration projects are currently underway such as the A to Z Forest Restoration Project in Colville, Washington. This project is a collaboration between Vaagen Timbers and the US Forest Service that focuses on allocating harvesting from restorative operations to Vaagen Timbers in order to offset the costs that the US Forest Service would typically be responsible for funding [5]. In return, Vaagen is able to utilize the harvested timber to create mass timber products and sell them for a profit. However, not many projects like this exist. Additionally, a small number of companies are beginning to venture into small-scale mass timber production such as Stoltze Timber in Montana and Timber Age Systems in Colorado. Timber Age Systems (TAS) is producing CLT made of Ponderosa pine, a species that has generally been deemed as low value for construction uses. The company is the first CLT producer in the U.S. Southwest and is capitalizing on the need for healthier forests and more sustainable construction materials [6]. The Sierra Institute for Community and Environment in Taylorsville, California is also developing small-scale, local mass timber production in tandem with their forest restoration projects which often result in harvesting lower-value species of timber [7]. The intersection between forest management and mass timber production has the potential to create a synergetic relationship that addresses multiple issues at once: the need for forest thinning and a sustainable mass timber market in the United States.

2 APPROACH

This project is a demonstration of the use of small-scale, Ponderosa pine CLT that can be harvested from forest restoration projects in the Sierra Nevada mountains of California and used to replace public forest lands structures that were destroyed in wildfires. The intent of this design demonstration is to show a variety of typical park buildings that cover a range of spans, sizes, and levels of complexity as well as to exhibit the unique relationship between forestry and architecture. The designs of these buildings reflect the redefining of park architecture in the U.S. to demonstrate a more contemporary approach, versus a more conventional rustic one, that celebrates the use of modern technologies and natural materials. The use of timber from forest restoration-harvests also provides the opportunity for local mass timber production. The basis of this design project makes use of TAS's production processes, structural data, and 152cm x 305cm Ponderosa pine CLT panels.

2.1 TIMBER AGE SYSTEMS PONDEROSA PINE CLT

TAS utilizes Ponderosa pine harvested from forest restoration projects to produce vacuum-pressed CLT panels that are 152cm x 305cm and 76mm or 127 mm thick for 3-ply and 5-ply panels respectively; the company has invested approximately 1.2 million USD total into their operations and functions under a vertically integrated system from log hauling and milling to kiln drying and pressing. The panels they are currently producing have been accepted for local building department permitted use and have undergone evaluation from a local university engineering department, with validation by an external engineering peer review, to demonstrate that they meet the requirements of IBC 2018; TAS is currently seeking ANSI PRG 320 certification for their CLT panels. This project demonstrates the design opportunities for the use of forest-restoration-harvested Ponderosa pine CLT panels manufactured using this vacuum press process by showing their design application in a series of typical public lands' facilities, which are more typically constructed of light wood frame and/or heavy (sawn) timber. The central question regarding the application of these CLT panels is the following: What are the implications of the Ponderosa pine CLT panel sizes and structural characteristics (e.g., what is the best way to address connections and openings for windows and doors, and long span conditions)?

2.2 PUBLIC LANDS BUILDINGS

Public lands are home to various types of buildings that serve a multitude of purposes. After an in-depth evaluation of the types of buildings found in public lands, the following building types were chosen as a representative sample of typical scales, spans, and details that could be applied to not only the building types they represent, but also other park facilities of a similar nature: a visitor center, information center, restrooms, cabin, and entrance fee station.

3 DESIGN DEMONSTRATION

In the proposed designs, both dimensional lumber and heavy timber sourced from Ponderosa pine are used in tandem with the Ponderosa pine CLT to achieve larger roof spans; the intention is to maximize the use of forest restoration-harvested Ponderosa pine and maintain its connection to the local communities that will manufacture these products. However, the dimensional lumber and heavy timber are not limited to strictly Ponderosa pine; other species harvested from forest restoration projects that are structurally appropriate can also be used. Glulams were intentionally not chosen for additional structural members to avoid sourcing that may not be local and employs a different technology. Strategies for windows, doors, and other details were also developed. With structural engineering guidance from Professor of Civil Engineering Mikhail Gershfeld of California State Polytechnic University, Pomona, it was determined that no more than two panels should be stacked vertically

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without additional structural support to avoid buckling at the horizontal splines.

3.1 DETAILS FOR PANEL APPLICATION AND WILDFIRE RESILIENCE

Systems for typical details were developed as standards for the application of Ponderosa pine CLT panels and wildfire resilience strategies. The wall assembly in Figure 1 maximizes the use of bio-based materials such as CLT, wood fibre insulation, wood furring, and wood siding. Ideally, all of the wood-based products can be sourced from forest restoration-harvested timber including species that are not Ponderosa pine. This idea reinforces local sourcing, manufacturing, and maximum wood utilization. Fire resilience is also a critical aspect of these structures. Although the intent is to maximize the use of low-value wood from forest restoration projects, metal siding can also be used in place of wood siding to increase fire resilience. Other fire resilience strategies include minimal roof overhangs, metal roofing, mass panel wall construction, and fire-resistant insulation. Eaveless roofs prevent flames and embers from catching underneath overhangs, which can cause the entire building to combust. The CLT wall and roof panels also create a continuous envelope that are intended to improve thermal performance and mitigate fire spread. Similar to CLT panels, wood fibre insulation carbonizes when exposed to fire which helps to insulate the rest of the assembly from fire spread [8]. Wood fibre insulation treated with borate provides fire protection [8]; however, mineral wool insulation can also be used for increased fire resistance.

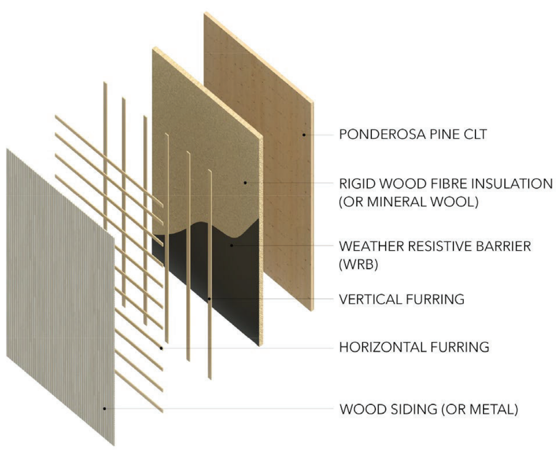

Figure 1: *Typical wall assembly*

Strategies for window and door openings were also developed. Although openings can be cut directly out of a panel, best practice is to avoid cut out openings due to the panels' small size and to minimize waste. Where appropriate, windows should fit between panels as illustrated in Figure 2. Additionally, windows that are carried to the underside of a CLT roof can use the roof panel itself as a header. This approach also prevents waste from panel off-cuts. Small skylight openings should not be cut from the centre of the panel, but rather at the ends of a panel to maintain structural properties. It is important to note, however, that these strategies may not be appropriate for every building. Openings are dependent on a building's program and may require other configurations.

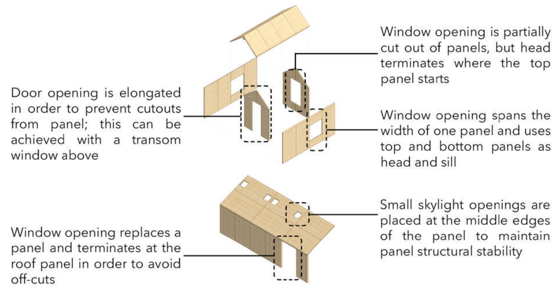

Figure 2: *Strategies for panel openings*

Because these structures could be located in a variety of landscapes, two different foundation systems were developed to accommodate possible site constraints. A concrete foundation with a concrete floor, as shown in Figure 3, would be an appropriate application in larger scale buildings, restrooms, and any building requiring a permanent foundation with few site challenges.

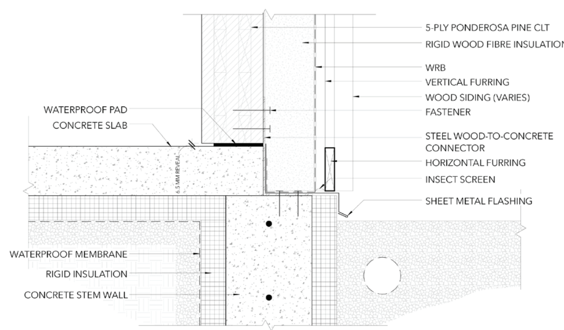

Figure 3: *Concrete foundation with concrete floor detail*

A pier foundation, as seen in Figure 4, would be appropriate for buildings in difficult terrain; the pier system enables the building to be lifted above grade and placed where necessary on its respective topography, which may be appropriate for cabins.

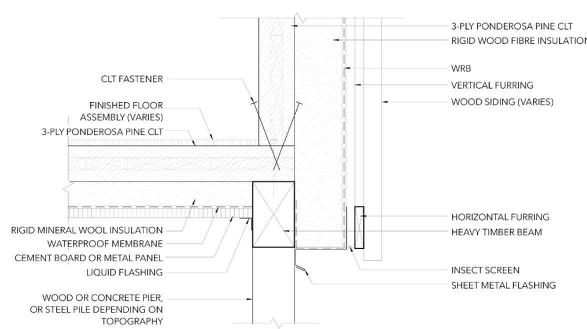

Figure 4: *Pier foundation with CLT floor detail*

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3.2 VISITOR CENTER

Figure 5: *Visitor centre rendering*

The visitor centre is intended to accommodate different site variations by dividing the program into three separate buildings: an exhibit area, gift shop, and cafe. Restroom facilities for guests are a separate building type that can be placed near the visitor centre. Each building is connected to the others through a breezeway that can either be open air or enclosed depending on the climate.

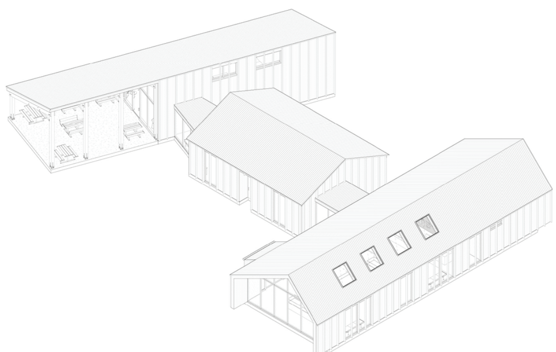

Figure 6: *Axonometric of visitor centre*

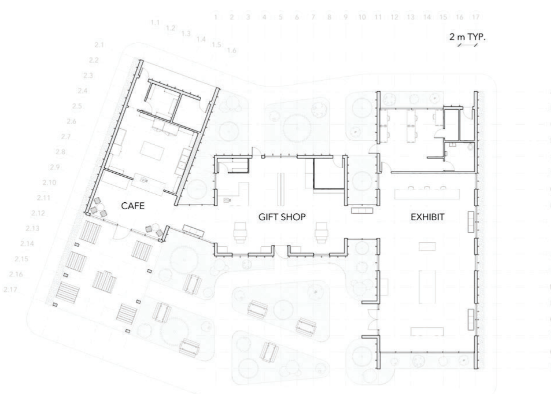

Figure 7: *Floor plan of visitor centre*

Due to roof span structural demands, the buildings have Ponderosa pine beams. The gable roofs of the exhibit area and gift shop require beams and steel collar ties, while the shed roof of the cafe requires beams with knee braces. These building types can also host different programmatic functions depending on the needs of the park; for example, the cafe can also be used as park ranger headquarters. In brief, the intent of this programmatic composition is to allow for the most amount of flexibility with straightforward construction solutions. Five-ply CLT is used for the walls and roofs of these structures and light-wood-frame is used for walls that require plumbing for toilets and sinks.

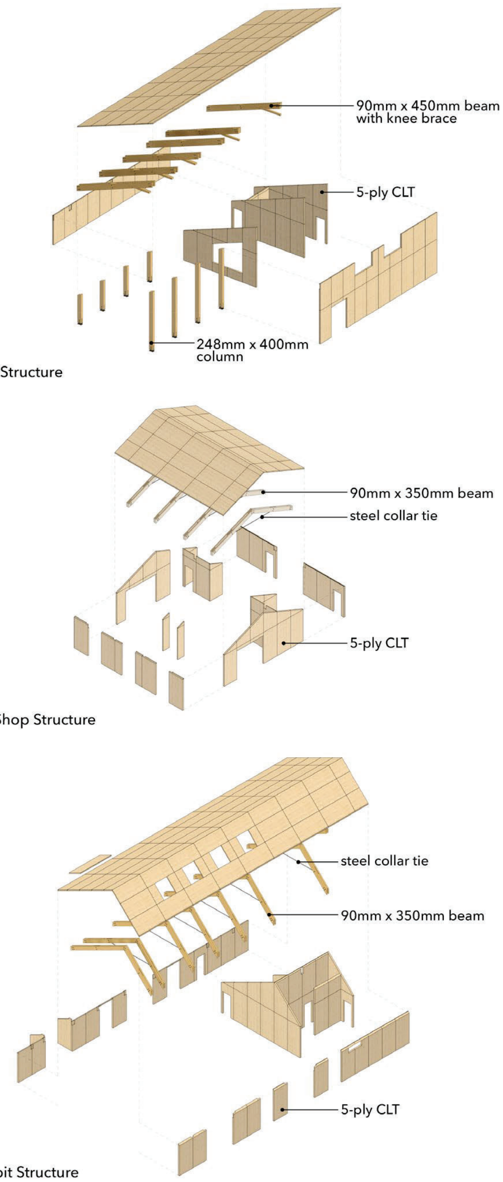

Figure 8: *Visitor centre structure*

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3.3 INFORMATION CENTER

Figure 9: *Information centre rendering*

The information centre is intended to be used near park entrances and/or operate as a ranger station. The program features an information desk for guests, restrooms, and an office for park staff.

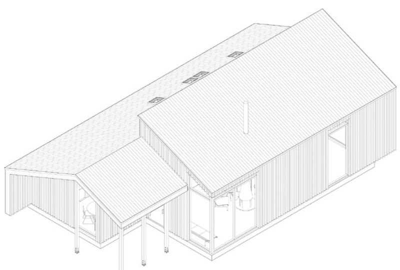

Figure 10: *Axonometric of information centre*

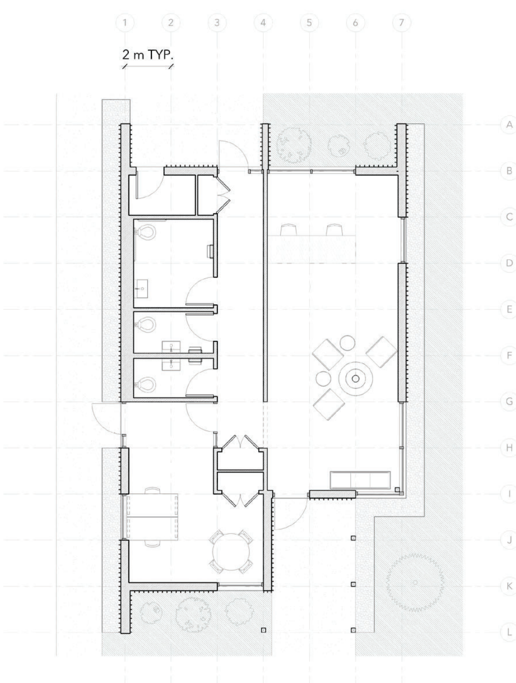

Figure 11: *Floor plan of information centre*

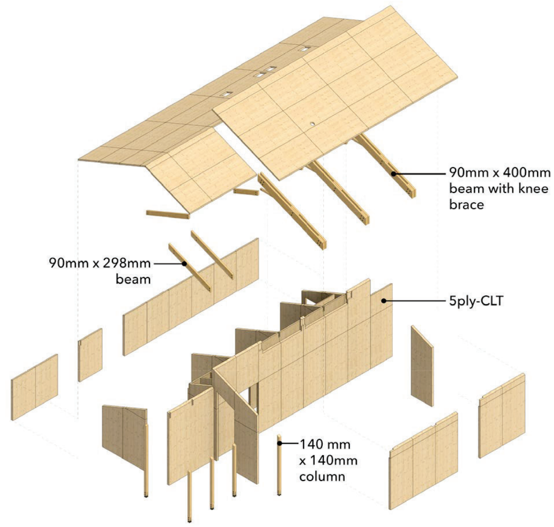

Figure 12: *Information centre structure*

Due to the building's small footprint, simple beam systems are used to span the roof with knee braces where necessary. Five-ply CLT is used for the walls and roof of this building and light-wood-frame is employed for walls that require plumbing for toilets and sinks.

3.4 RESTROOM FACILITIES

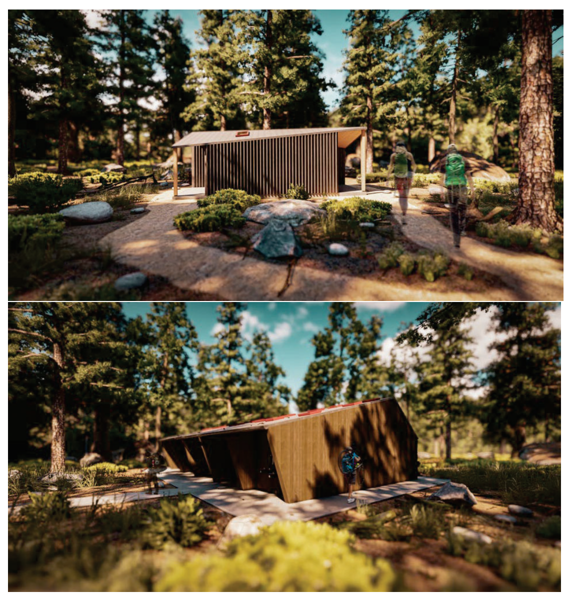

Figure 13: *Restroom renderings*

This building type consists of two different designs: small restroom structures intended to be scattered throughout a park and larger restroom facilities for busier parts of a park and its campgrounds. The small restroom facility is constructed with 3-ply CLT and utilizes a Ponderosa pine column where the roof cantilevers. The program consists of two private accessible stalls and a small utility closet. The larger restrooms are comprised of a flexible program that allow it to be adapted to different needs of a park. For example, showers can be added to the building to accommodate a campground and stalls can be added to the floor plan as needed. This facility is also constructed of 3-ply CLT and does not require additional structural members to support its roof. Light-wood-frame is used for walls that require plumbing for toilets and sinks. Due to the nature of this building type, the roof and wall assemblies do not need to be insulated and the building does not need to be conditioned which significantly simplifies construction.

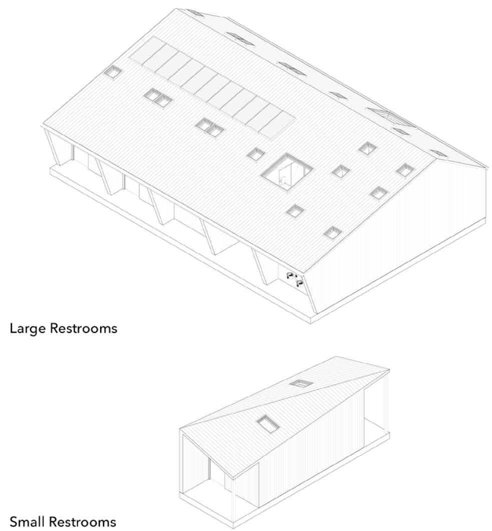

Figure 14: *Axonometric of restrooms*

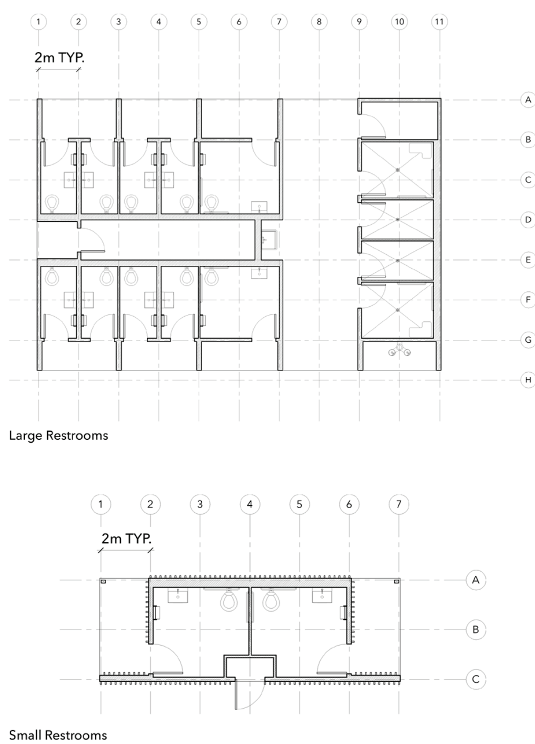

Figure 15: *Floor plan of restrooms*

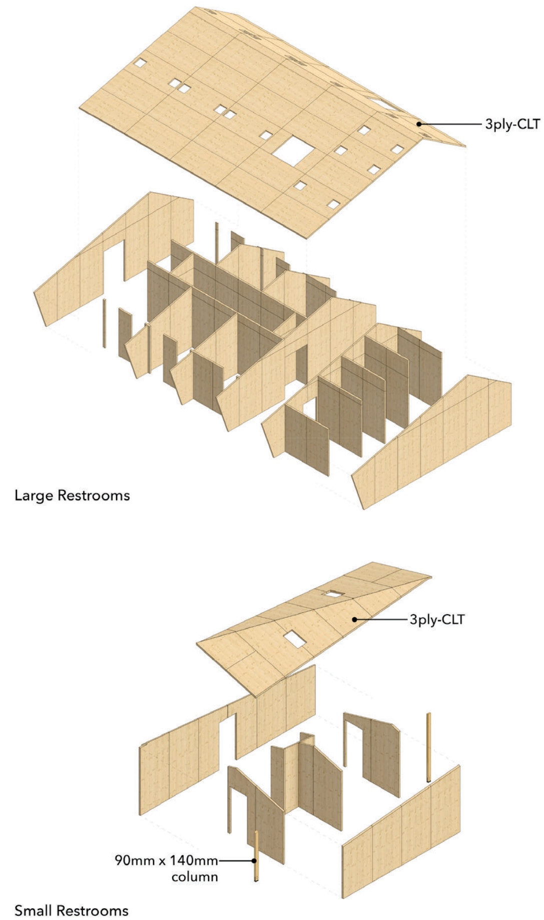

Figure 16: *Restrooms structure*

3.5 CABIN

Figure 17: *Cabin rendering*

The program for this building type is a one-bedroom space with designated sleeping, lounging, and eating areas. This structure requires 3-ply CLT, a ridge beam, steel collar ties, and a column to support the roof cantilever. The cabin is intended to be placed in nearly any condition and can be supported on a simple pier or pile system.

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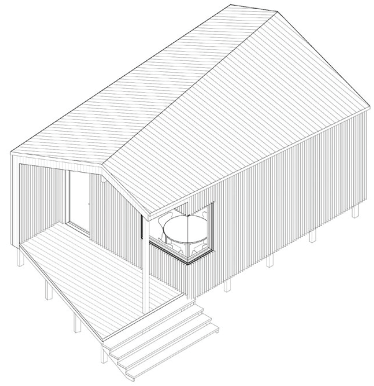

Figure 18: *Axonometric of cabin*

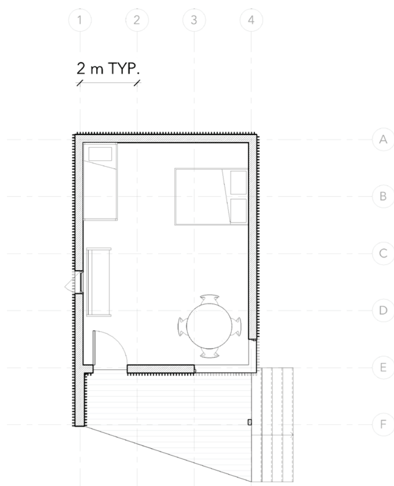

Figure 19: *Floor plan of cabin*

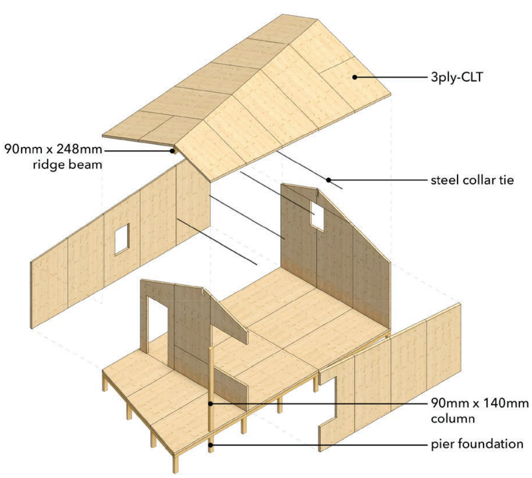

Figure 20: *Cabin structure*

3.6 ENTRANCE FEE STATION

Figure 21: *Entrance fee station rendering*

This small-scale building has a simple structure. Due to its small loads, the roof can be spanned using only 3-ply CLT and a ridge beam at the roof. This program features adequate space for 2-3 park employees and drive-up windows for incoming guests.

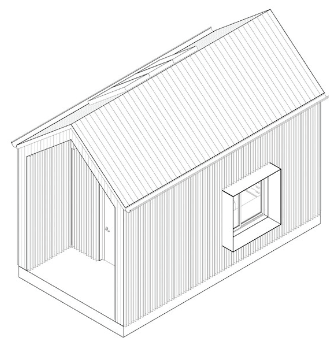

Figure 22: *Axonometric of entrance fee station*

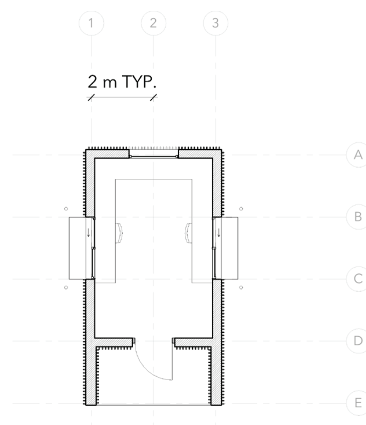

Figure 23: *Floor plan of entrance fee station*

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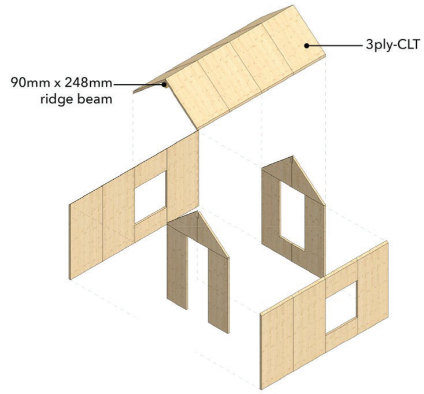

Figure 24: *Entrance fee station structure*

4 CONCLUSIONS

Although the structural properties of Ponderosa pine are less robust than some other wood species such as Douglas fir, Ponderosa pine CLT panels can be an effective structural system with proper detailing and an understanding of small mass timber panels. Unlike most CLT panels on the market, 152cm x 305cm Ponderosa pine panels require integrating other structural systems to carry longer roof spans. These secondary structural systems can also be sourced from Ponderosa pine, but may not necessarily be Ponderosa pine or from forest restoration projects; heavy timber and dimensional lumber can either be sourced from a productive site, other low-value species, or can be recovered from past burn sites; it is important to note that Ponderosa pine can reach a diameter of 66cm in 30 years and diameters of 76cm to 127cm are not uncommon for the species [9]. These CLT panels also have significant height restrictions; because they are only 3 meters tall, panels need to be stacked vertically to achiever taller wall heights. However, it is advisable not to stack more than two panels to maintain structural wall stability. Furthermore, compared to conventional light-wood-frame and heavy timber buildings typically found in public lands, the Ponderosa pine CLT allowed for greater design flexibility in terms of architectural expression. Because the structures do not require conventional wood framing, the panels can be prefabricated to create expressive forms that can be rapidly assembled. CLT also provides opportunities for faster construction time, less construction waste, off-site pre-assembly, and less on-site labour when compared to other construction types. In conclusion, the exercise of designing public lands facilities from small-scale, low-value species mass timber panels sourced from forest restoration proved to be a viable construction type for replacing buildings in wildfire vulnerable areas.

In addition, this project addresses only one timber species and one CLT manufacturing process. There is much more research that can be done on alternative low-value species mass timber products from varying regions across the U.S. and Canada as well as on a variety of manufacturing processes (dowel-laminated timber, interlocking timber, etc.) that can make up an array of different mass timber products for local applications in the future. White fir, for example, is a low-value species that only has preliminary structural data, but could potentially be used in a similar application to Ponderosa pine in CLT. There are several recently completed and planned low-value species testing projects undertaken at the TallWood Design Institute and Oregon State University on Oregon-harvested Ponderosa pine in collaboration with Vaagen Timbers, and, additionally, California white fir and Alaskan spruce using a more capital-intensive process with a large timber press; there is growing interest in the structural and commercial possibilities for these materials, along with the increasing local, less-capital intensive efforts as noted above [10–12]. Furthermore, continued development of construction details and the application of these panels to other building types, such as housing and multi-story structures, is a potential area of study. Much more work in this area should be coming in the near future and this project should become part of the growing efforts to create a sustainable mass timber industry in the U.S. supporting forest restoration efforts.

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REFERENCES

[1] S. Liang, M. D. Hurteau, and A. L. Westerling, “Large-scale restoration increases carbon stability under projected climate and wildfire regimes,” *Front Ecol Environ*, vol. 16, no. 4, pp. 207–212, May 2018, doi: 10.1002/fee.1791.

[2] A. P. Williams *et al.*, “Observed Impacts of Anthropogenic Climate Change on Wildfire in California,” *Earths Future*, vol. 7, no. 8, pp. 892–910, Aug. 2019, doi: 10.1029/2019EF001210.

[3] L. Sediman, “How the KNP Complex fire devastated one giant sequoia grove - Los Angeles Times,” *LA Times*, Nov. 26, 2021.

[4] A. A. Ager, K. C. Vogler, M. A. Day, and J. D. Bailey, “Economic Opportunities and Trade-Offs in Collaborative Forest Landscape Restoration,” *Ecological Economics*, vol. 136, pp. 226–239, Jun. 2017, doi: 10.1016/j.ecolecon.2017.01.001.

[5] R. Vaagen, “A to Z Forest Restoration Project.”

[6] “Timber Age Systems, Inc.” www.timberage.com

[7] L. Redmore *et al.*, “Mass Timber and Other Innovative Wood Products in California: A Study

https://doi.org/10.52202/069179-0485

of Barriers and Potential Solutions to Grow the State's Sustainable Wood Products Sector," 2021.
[8] "FAQ - TimberHP by GO Lab." https://timberhp.com/faq/
[9] "Ponderosa Pine (Pinus ponderosa)," *University of California Agriculture and Natural Resources*.
[10] S. Jahedi, S. Bhandari, L. Muszynski, and M. Riggio, "Investigating a potential for utilization of low value Ponderosa Pine lumber in CLT modular structures," 2021.
[11] S. Bhandari, S. Jahedi, M. Riggio, L. Muszynski, Z. Luo, and A. Polastri, "CLT modular low-rise buildings: a DfMA approach for deployable structures using low-grade timber," 2021.
[12] I. Macdonald, J. Dettmer, B. Miyamoto, C. Barkley, P. Mann, and T. Deboodt, "Cross-Laminated Timber Layup Tests Using Western Wood Products Association (WWPA) White fir Species Group," 2021.