Design Follows Availability

Affordable Dwelling Units based on reclaimed materials in San Antonio

UTSA
The University of Texas at San Antonio

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Affordable Dwelling Units based on reclaimed materials in San Antonio

Prepared for:

CITY OF SAN ANTONIO
OFFICE OF INNOVATION

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Table of Contents

7 Introduction

- Accessory dwelling units
- Material Innovation Center
- Purpose of the Study

19 Case Study: New, Reclaimed, and Salvaged Garage Doors

- New Lumber Garage Door
- Reclaimed Garage Door
- Salvaged Garage Door

41 Access to Materials

- Material Origin
- Salvaged Demolition Materials
- Reclaimed Deconstruction Materials
- Recycled Construction Waste
- Recycled Fabrication Waste

59 Evaluating Materials

- Evaluation of Recycled Materials
- Compression Testing

89 Case Study: ACCESSORY DWELLING UNITS FROM REUSED LUMBER

- Framing with Reclaimed Materials
- Modular Truss from Reclaimed Lumber
- Stack For Reuse

131 Innovative ADU Designs from Reclaimed Materials

- A Student's Perspective
- When One Door Closes Another One Opens
- Post & Beam - Bundled Wood
- Reused Views
- Steel Yard Prefab
- Re-Timber
- Diy Reclaimed Kit Homes
- Once Removed Prefab
- Scrap. House

157 Recommendations and Conclusion

172 References

174 Acknowledgments

175 Impressum

INTRODUCTION

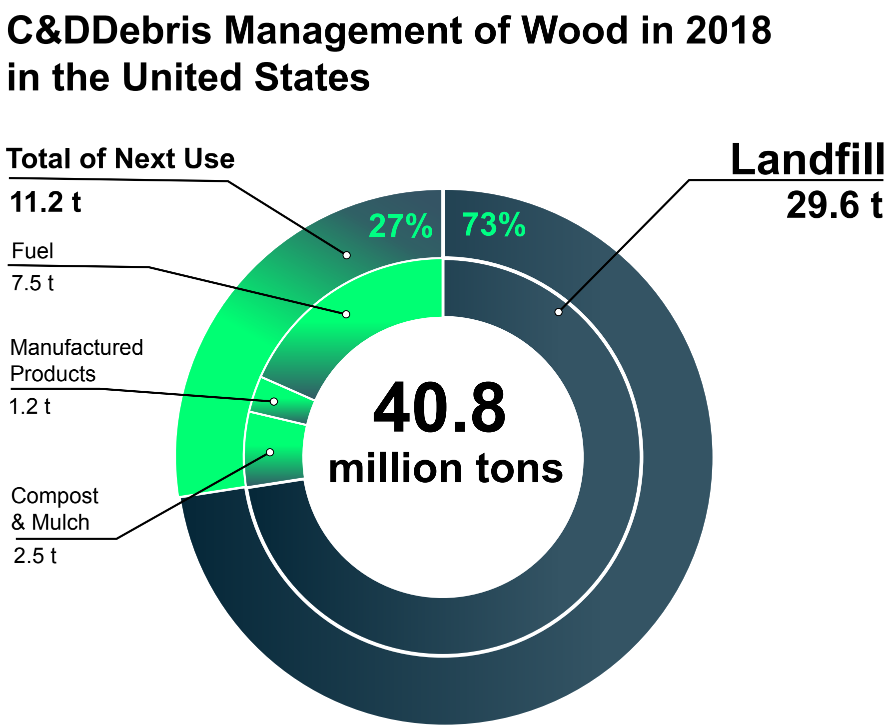

Figure 1 C&D Debris Management by Material and Destination, 2018 (in millions of tons) (based on EPA, 2019)

Wood waste in the United States is a significant issue from a waste management perspective. According to the U.S. Environmental Protection Agency (EPA), wood debris made up about 18% of total construction and demolition debris generated in the United States in 2018 . This high level of wood waste is due in part to the growing construction industry and the increased rate of demolition and renovation of existing buildings. Wood waste is a challenging material to manage, as it can take a long time to decompose in a landfill, and burning it can contribute to air pollution. However, there are many efforts underway to reduce the amount of wood waste that ends up in landfills. For example, some companies and communities have established recycling programs that repurpose wood waste into fuel for boilers, animal bedding, and other products. In addition, the use of salvaged and reclaimed wood has been growing in popularity in recent years, as consumers and builders look for more sustainable building materials. This trend has helped to reduce the amount of new wood that needs to be harvested and has provided an outlet for the reuse of existing wood products. The use of salvaged and reclaimed wood has also been shown to have a number of environmental benefits, including reducing greenhouse gas emissions and conserving forests. Despite these efforts, wood waste remains a significant problem in the United States, and much more needs to be done to reduce the amount of wood waste that ends up in landfills. This will require continued investment in recycling and repurposing programs and increased public awareness and education about the importance of reducing wood waste.

There have been growing efforts to recycle and reuse deconstruction wood in recent years. These efforts are driven by a desire to reduce waste and conserve natural resources, as well as to create more sustainable building practices.

One of the main ways that deconstruction wood is being recycled is through the creation of wood products, such as wood chips, sawdust, and mulch, which can be used as fuel or as landscaping materials (Figure 3). This type of recycling diverts the wood from landfills and provides an alternative source of fuel for boilers and other heating systems. Another way that deconstruction wood is being reused is through the use of salvaged and reclaimed wood in construction and building projects. This trend has grown in popularity as more consumers and builders seek out sustainable building materials. Reclaimed wood has the advantage of being a unique and characterful building material, and it also provides a way to reduce the demand for new wood products, which can help conserve forests.

The process of salvaging and reclaiming wood can also create jobs and support local economies, as it requires specialized skills and knowledge to process and prepare the wood for reuse. In addition, the use of reclaimed wood has been shown to have a

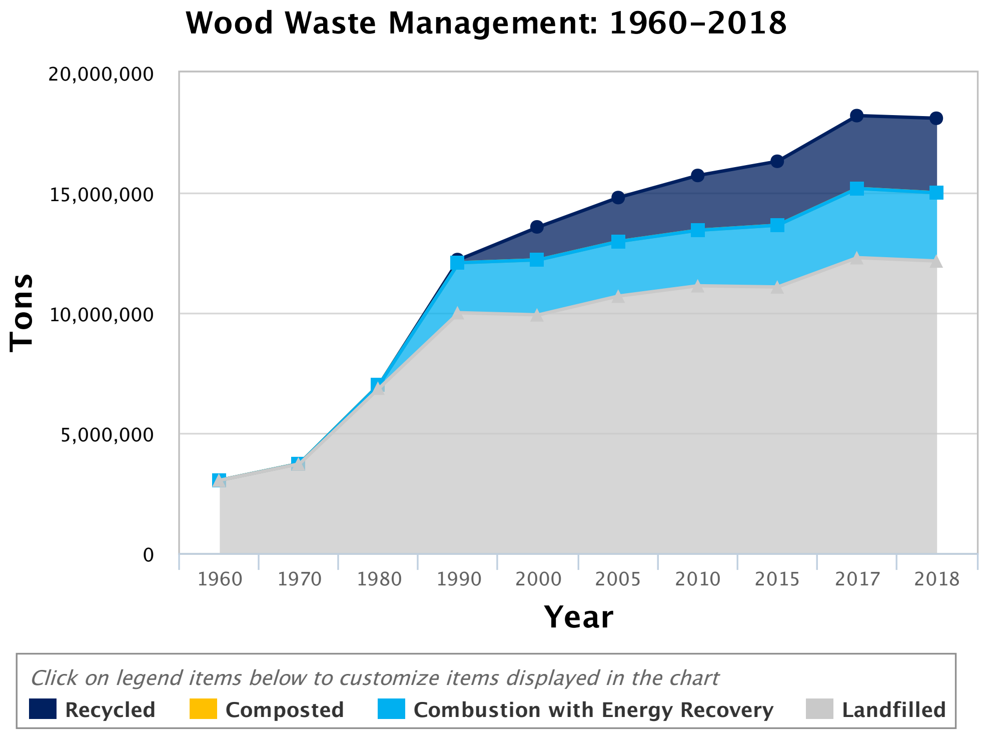

Figure 2 1960-2018 Data on Wood in MSW by Weight (in thousands of U.S. tons) (Wood: Material-Specific Data | US EPA, n.d.)

positive impact on the environment, as it helps to reduce greenhouse gas emissions and conserve energy that would otherwise be used to produce new wood products. Overall, the growing efforts to recycle and reuse deconstruction wood are a positive trend, and they demonstrate that it is possible to create a more sustainable future through creative and innovative solutions to waste management and resource conservation. Reusing deconstruction wood from historic buildings has a number of benefits from a historic preservation standpoint. These benefits include:

1. Conservation of historic resources: Reusing wood from historic buildings helps to conserve historic resources, as it allows the original materials to be used again in new projects. This can help to maintain the character and authenticity of historic structures and to preserve the cultural and architectural heritage of communities.

2. Cost savings: Reusing existing materials can be more cost-effective than using new materials, as it eliminates the need to purchase and transport new materials. This can help to reduce the overall cost of a project, while still providing high-quality building materials.

3. Sustainability: Reusing wood from historic buildings is an environmentally sustainable practice, as it reduces the demandf or new materials and conserves resources. In addition, it helps to reduce the amount of waste that goes to landfills and reduces the carbon footprint of aproject.

4. Unique character: Wood from historic buildingsoften has a unique character and patina that is not found in new materials.This can add a distinctive quality to new projects and help to create aconnection to the past.

5. Community value: Reusing materials fromhistoric buildings can have a positive impact on the community, as it helps topreserve local history and cultural heritage, and supports the local economy bycreating jobs and promoting economic development.

Overall, the benefits of reusing deconstruction wood from historic buildings are substantial and multi-faceted. By repurposing these materials, communities can conserve historic resources, reduce waste, conserve energy, and promote sustainability, all while supporting local economies and preserving cultural heritage.

Reclaimed and salvaged lumber is becoming an increasingly popular material for building and construction projects, due to its potential for reducing waste and conserving resources. In recent years, several studies have been conducted to evaluate the quality and characteristics of recycled wood, including reclaimed and salvaged lumber. These studies have shown that recycled wood can have comparable strength, stiffness, and durability to newly harvested wood, and that it is a suitable material for use in building construction. One study, „Evaluation of the Physical Properties and Durability of Recycled and Reclaimed Lumber" (2007), compared the physical properties of recycled and reclaimed lumber to those of newly harvested lumber. The results showed that recycled and reclaimed lumber had similar physical properties to newly harvested lumber, and that their strength and stiffness were comparable to that of new wood. Another study, „The Durability of Reclaimed Lumber for Outdoor Applications" (2010), evaluated the durability of reclaimed lumber for outdoor applications, such as decks and siding. The results showed that reclaimed lumber had good durability and resistance to

Figure 3 Location of the Material Innovation Center in San Antonio. [photo:Google Earth]

decay and insect damage and that it was a suitable material for outdoor applications.

The use of recycled wood in construction projects has a number of environmental benefits. By reducing the demand for newly harvested wood, recycled wood helps to conserve resources and reduce the carbon footprint of a project. Additionally, repurposing wood from demolished buildings helps to reduce the amount of waste that goes to landfills, further reducing the impact on the environment. Despite its potential benefits, it is important to note that the quality of reclaimed and salvaged lumber can vary, depending on the type of wood and the method of preparation. It is always recommended to have the wood evaluated by a professional before using it in construction, to ensure that it meets the necessary standards and requirements.

Accessory dwelling units

Accessory dwelling units refer to the extra residential units that are incorporated into a pre-existing single-family or multifamily property. These supplementary living spaces can be built attached or next to an already established structure, such as a house or apartment complex. Many cities are adopting policies and programs to make the construction of ADUs more straightforward and more cost-effective as part of a comprehensive, affordable housing strategy. This topic is outlined as a local priority in the Strategic Housing Implementation Plan . For an average-sized home, the lumber salvaged from one deconstruction project could potentially be sufficient to construct the structure of an ADU at a minimum. This project helps inform how San Antonio can develop a Salvage-to-ADU program that utilizes reclaimed building materials to build new affordable housing units. Such a program would simultaneously advance multiple goals: create affordable housing, promote the circular construction economy, and raise awareness of the importance of combating these crises. This would be an opportunity to educate homeowners on how to finance, build, and manage an ADU and an opportunity for education on building with reclaimed materials.

According to the sources, the reuse of timber in construction is currently not widely practiced. This lack of widespread adoption can be attributed to several barriers, including a lack of demand for salvaged materials, absence of standardized design guidelines, and restrictive building regulations. The ease with which a building can be deconstructed for potential reuse largely depends on its method of construction.

In order to ensure sustainability in timber construction projects, it is imperative that considerations are made regarding the deconstruction, reuse, and recycling processes right from the planning stage itself. This approach would enable long-term and material-efficient use of high-quality wood.

To reduce costs associated with constructing stilted buildings or structures while simultaneously promoting innovation in the industry and minimizing environmental impact through efficient resource utilization has been suggested by architects who advocate using alternative reusable and recyclable materials. A study carried out by Osmani and Villoria-Saez further supports this argument as it reveals that employing reclaimed timber could result in an impressive reduction of up to 80% in environmental impact. Reclaimed timbers are

Figure 4 Loading a pickup truck with reclaimed lumber from a reseller

often obtained from demolished old structures or buildings known for their strength. It should also be noted that wood products have the potential for various end-of-life scenarios

This project will address the latter option while informing the following steps on developing a pattern book or design guidelines for ADU construction. To further incentivize property owners, the City could streamline the permit process for constructing ADUs with salvaged materials, which is a critical policy goal of OHP. This project also helps further identify functional components of the Material Innovation Center (MIC) through evidence-based research and development. The project aims to gather information and knowledge on how the Material Innovation Center can fulfill several important roles. These include sourcing and distributing materials for various affordable housing programs in the city, such as the Shotgun Pilot Project, REHABARAMA, and Owner-Occupied Rehab Program. Additionally, it will function as a learning lab where trades education can take place and contractor skills can be developed. The center also has the potential to offer space for retail sales and warehouse management purposes. Moreover, it will serve as a dedicated workshop area for local construction science students and architecture students who wish to gain hands-on experience in designing and building structures using reclaimed materials.

Furthermore, this initiative seeks to support small businesses that focus on material reclamation or reuse by providing them with an incubation platform within the facility. Lastly yet importantly, this center will act as an innovation hub that encourages new practices of transforming salvaged or surplus building materials into alternative uses.

The Material Innovation Center

The city of San Antonio is actively pursuing its way to prevent building materials from landing on landfills and instead works towards implementing reuse. The Treasure in the Walls report was prepared for the City of San Antonio's Office of Historic Preservation and explores the economic and environmental benefits of a deconstruction program. The report includes findings on the building material supply chain, the economic and environmental cost of demolition, the impact of a deconstruction ordinance, and proposed recommendations for implementing a deconstruction program in San Antonio. The recommendations focus on passing a deconstruction ordinance, developing incentives for deconstruction activity, identifying barriers to material reuse, establishing workforce development programs, and creating a City-Incubated Reuse Warehouse.

Figure 5 Opening event of the Material Innovation Center

PURPOSE OF THIS STUDY

The principal objective of this research is to investigate and assess pertinent technologies that can facilitate the use of reclaimed materials in the design and construction of Accessory Dwelling Units (ADUs) in San Antonio. To delve deeper into this process, a comprehensive case study was conducted, examining the life cycle of salvaged materials, starting from the design phase to construction. Due to the complexity of ADUs, a bifurcated approach was implemented: an initial research phase that focused on simpler construction tasks (Stage 1), and subsequently a comprehensive demonstration of an ADU model (Stage 2). Collectively, both stages provided valuable insights into the Salvage-to-ADU process chain across varying scales.

In Stage 1, the focus was on understanding the array of available materials and their impact on the design process. The key project in this phase was the garage door project at the Material Innovation Center (MIC), which demonstrated the potential of incorporating salvaged materials in design. Building materials were sourced from either deconstruction sites or donations, and were stored at the MIC in Port San Antonio. To streamline the design process, a prototype of a digital inventory system cataloguing these materials was developed, providing easy access to pertinent information for designers.

The garage door demonstration included the dismantling of three existing garage doors. The first one was redesigned using existing materials, the second utilized reclaimed materials, and the third incorporated new materials. Efforts were made to document the labor effort and associated costs in each scenario to enable comparative analysis.

In Stage 2, medium-scale models that encapsulate the concept of reclaimed construction materials were designed and constructed. These models aimed to tackle issues relevant to the development of ADUs. Throughout the design, planning, and construction stages of these demonstrations, digital technologies and computational design tools were explored for their potential to enhance efficiency and automation. As a part of this investigation, various design tools, visualization techniques, and construction methods targeting the use of salvaged materials in the design process were developed and tested. The findings have been meticulously documented in this report, supported by architectural drawings, diagrams, and photographs.

The central question this research aims to address is: How can the Material Innovation Center facilitate the development of a Salvage-to-ADU pipeline and influence related housing development policies?

CASE STUDY:
NEW, RECLAIMED, AND SALVAGED GARAGE DOORS

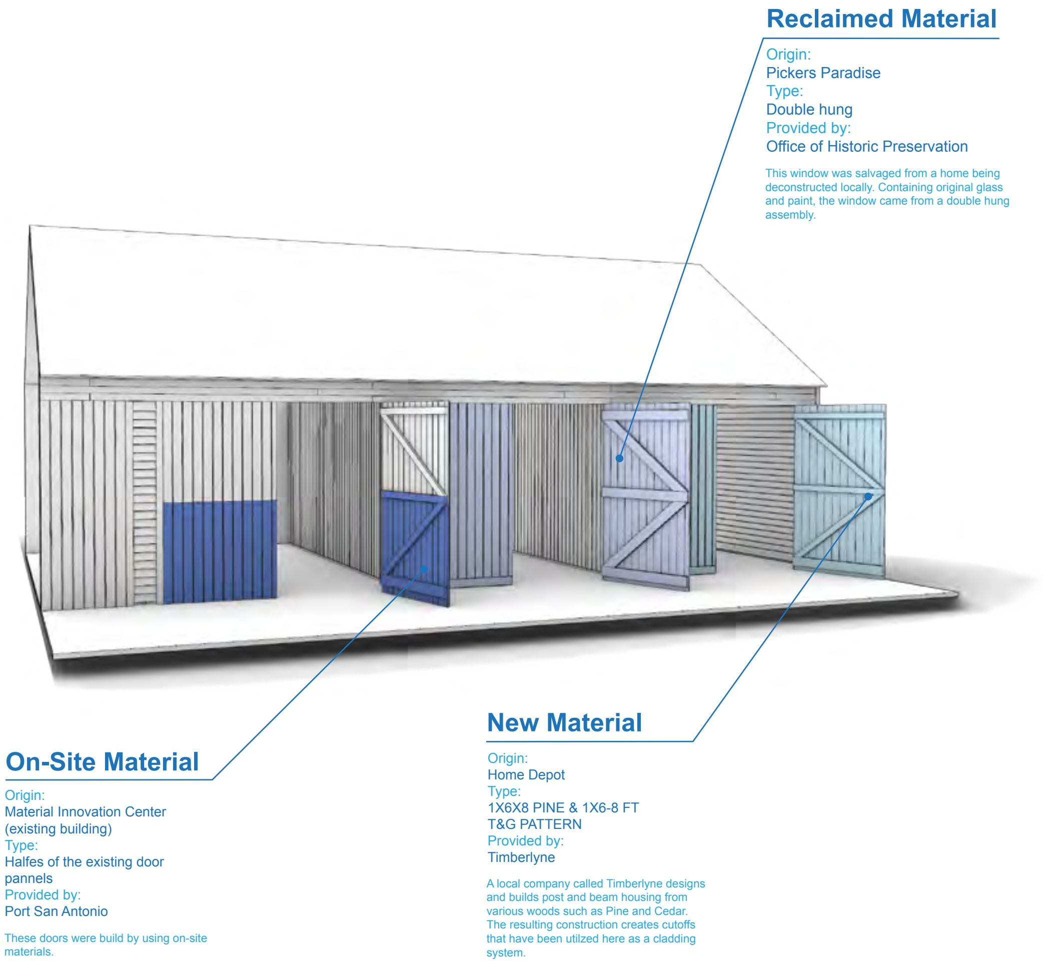

Figure 6 The three garage doors with description of material origin and name of the source

INTRODUCTION

In recent years, there has been a growing emphasis on sustainability within the construction sector. As companies seek to reduce their environmental impact and adopt more eco-friendly practices, one area that often comes under scrutiny is the use of building materials(The Construction Industry Is Getting Greener: Why, How, And ... - Forbes, n.d). Materials used in building construction can have a significant impact on the environment, both in terms of resource depletion and pollution.

The use of sustainable materials in building construction can have multiple positive effects on the environment and overall efficiency of a building. These environmentally-conscious building products not only reduce material consumption and solid waste, but also decrease greenhouse gas emissions both during manufacturing and throughout the construction process.

As the development and construction materials industry continues to grow, it is crucial that we consider the impact this has on natural resources and environmental pollution. Key factors to consider include minimizing raw material waste, properly managing disposal processes, promoting renovation over replacement when possible, maintaining building components effectively, and implementing efficient waste treatment during demolition. By adopting a strategy centered around reducing, reusingThis case study aims to examine the efficacy of selected interventions on the sustainability of corporate environmental practices within the construction industry. Specifically, we will be focusing on the reuse of building materials, specifically garage doors. In order to comprehensively analyze the effects of various approaches, a comparative case study was undertaken to evaluate three different types of garage doors constructed from distinct building materials: newly sourced lumber, salvaged lumber, and reclaimed lumber. This study aimed to assess the environmental impact and resource utilization associated with each material choice.

In the first case study, the primary objective is to analyze the complete processes involved in reusing lumber for three garage doors. This includes identifying potential opportunities and challenges related to working with recycled wood. The construction of these garage doors encompasses various aspects such as structural integrity, aesthetic appeal, and integration of hardware like hinges and locks. To compare different reuse scenarios, three doors were chosen: one utilizing salvaged lumber found on-site, another using reclaimed lumber purchased from a reseller, and a third door made from new lumbe,r which serves as a baseline for traditional construction practices.

Figure 7 Garage door bottom deterioration due to rain exposure.

ASSESSMENT OF SITUATION

Figure 8 3D scan in a CAD environment

The current situation of the garage doors was assessed using 3D scanning to allow a highly detailed understanding. 3D scanning technology has become an increasingly popular tool for assessing construction constraints. In this case study, 3D scanning was utilized to quickly and accurately capture the existing conditions of the three garage doors being rebuilt, including the layout, dimensions, and structural elements. This information was used to identify any constraints or limitations that may impact the design or construction of the garage doors.

The use of 3D scanning, in this case, study brought several benefits, such as speed and accuracy of the garage door geometries. 3D scanning allowed for the rapid and precise measurement of the existing garage doors, which saved time and reduced the potential for errors compared to traditional manual methods. Additionally, 3D scanning is a non-destructive method, which means that it does not require any physical alteration of the building, preserving the garage doors intact.

Furthermore, 3D scanning provided detailed and accurate information on the existing conditions of the garage doors, including the layout, dimensions, and textures. This information helped identify any potential issues or constraints that may impact the design or construction of the new garage doors. Additionally, 3D scanning allowed creating a virtual replica of the garage doors, which was used to plan, visualize, and remodel the garage doors more effectively. The use of 3D scanning in this case study proved to be a cost-effective method of building assessment, and it saved time and money.

Figure 9Figure 3v: The garage buidling [photo:Google Earth]

Figure 10 The material stocks from which the three garage doors were constructed

MATERIAL SOURCES

In the field of construction, the terms salvaged, reclaimed, and reused are often used interchangeably, although each carries a distinct meaning.

Salvaged Building Materials

Salvaged materials refer to those that are extracted from a site prior to or during its demolition or renovation with the intent of repurposing them in other projects. Generally, these materials remain unaltered and are preserved in their original form. To illustrate, salvaging lumber may entail removing intact wooden beams, planks, or unique architectural elements from a site set for demolition for future application in other construction initiatives.

Reclaimed Building Materials

The term 'reclaimed' typically alludes to materials that have been sourced from a built environment and undergone some form of processing to render them reusable. Such processing could encompass cleaning, de-nailing, resawing, or other modifications. For instance, reclaimed lumber may originate from old barns, factories, or warehouses and is usually processed — cleaned, treated, planed, and so forth — prior to its reuse in fresh construction projects.

Reused Building Materials

'Reuse' is a broader term, generally encompassing any materials that find multiple applications, regardless of whether they have been salvaged, reclaimed, or used again in their existing form. This may or may not entail significant processing or treatment. For example, lumber that has been directly repurposed in a new construction following the disassembly of a prior structure, without undergoing significant treatment, can be categorized as 'reused.'

In summary, while all these terms reflect strategies to mitigate waste and bolster sustainability in construction, they denote different processes and stages of material use. Salvaged materials are rescued from waste in their untouched state, reclaimed materials undergo processing to facilitate their reuse, and reused materials refer to those that are deployed multiple times, irrespective of their form.

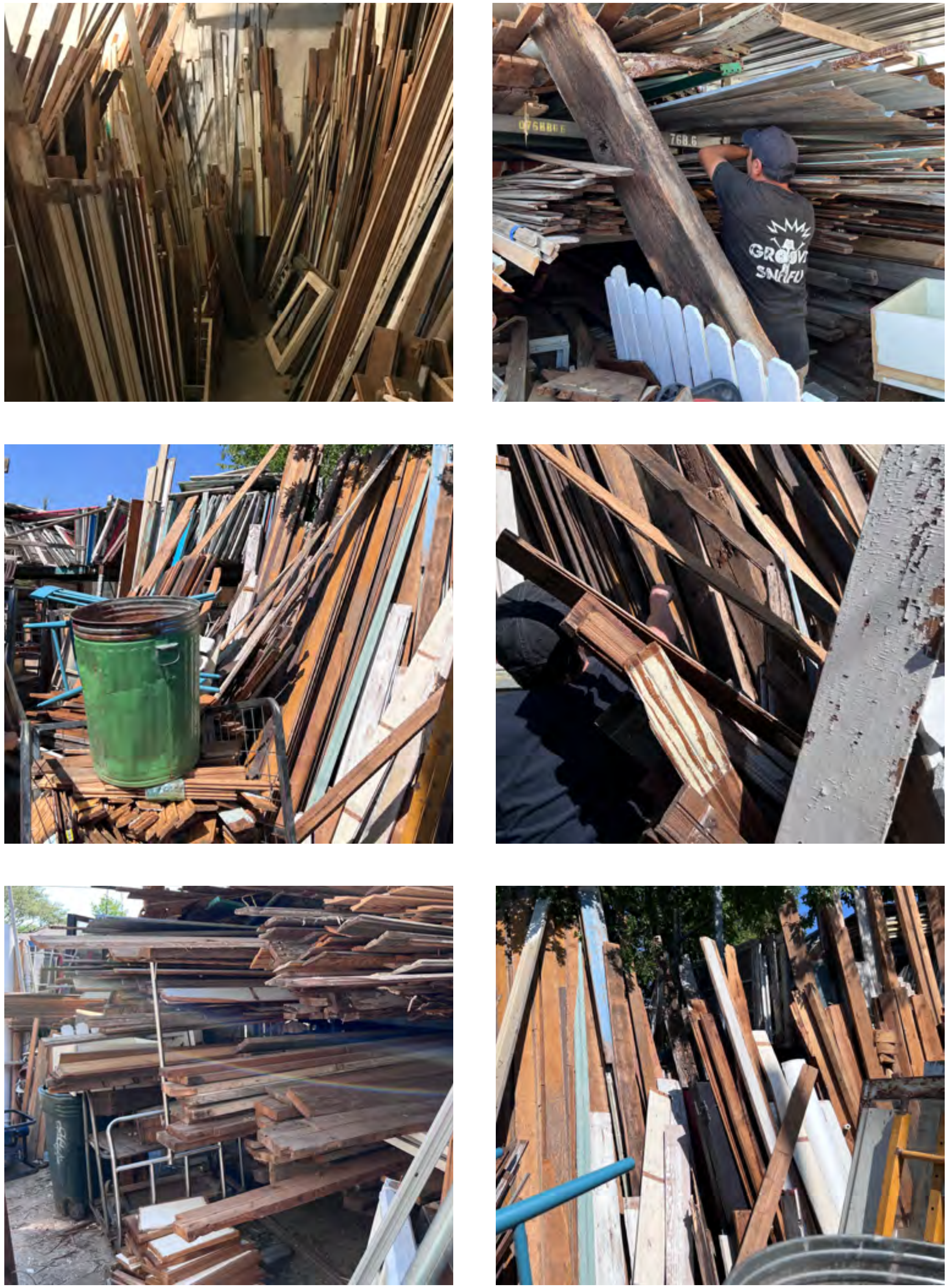

Figure 11 Impressions of a reseller

Figure 12 Purchased lumber loaded on a pick up truck

Figure 13 Purchase and construction process of the door made from new lumber

NEW LUMBER GARAGE DOOR

Figure 14
The new lumber door installed

The conventional approach is exemplified by the use of freshly harvested wood for building garage doors. This method represents the widely adopted practice in which new timber is sourced specifically for construction purposes. While this approach has been traditionally favored due to its availability and ease of procurement,it may not necessarily align with sustainable practices. The newly acquired wood for the project was sourced from a local hardware store and primarily consisted of whiteboard material. However, there were instances where some of the boards had suffered damage during production or transportation. As a result, it became necessary to inspect and sort through the available stock before making a purchase in order to ensure that only high-quality wood was obtained.

This process of sorting serves as an important quality control measure to minimize potential drawbacks caused by damaged or substandard materials. By carefully scrutinizing each piece of wood, builders can identify any defects such as cracks, warping, or other structural issues that could compromise the integrity and longevity of the finished product.

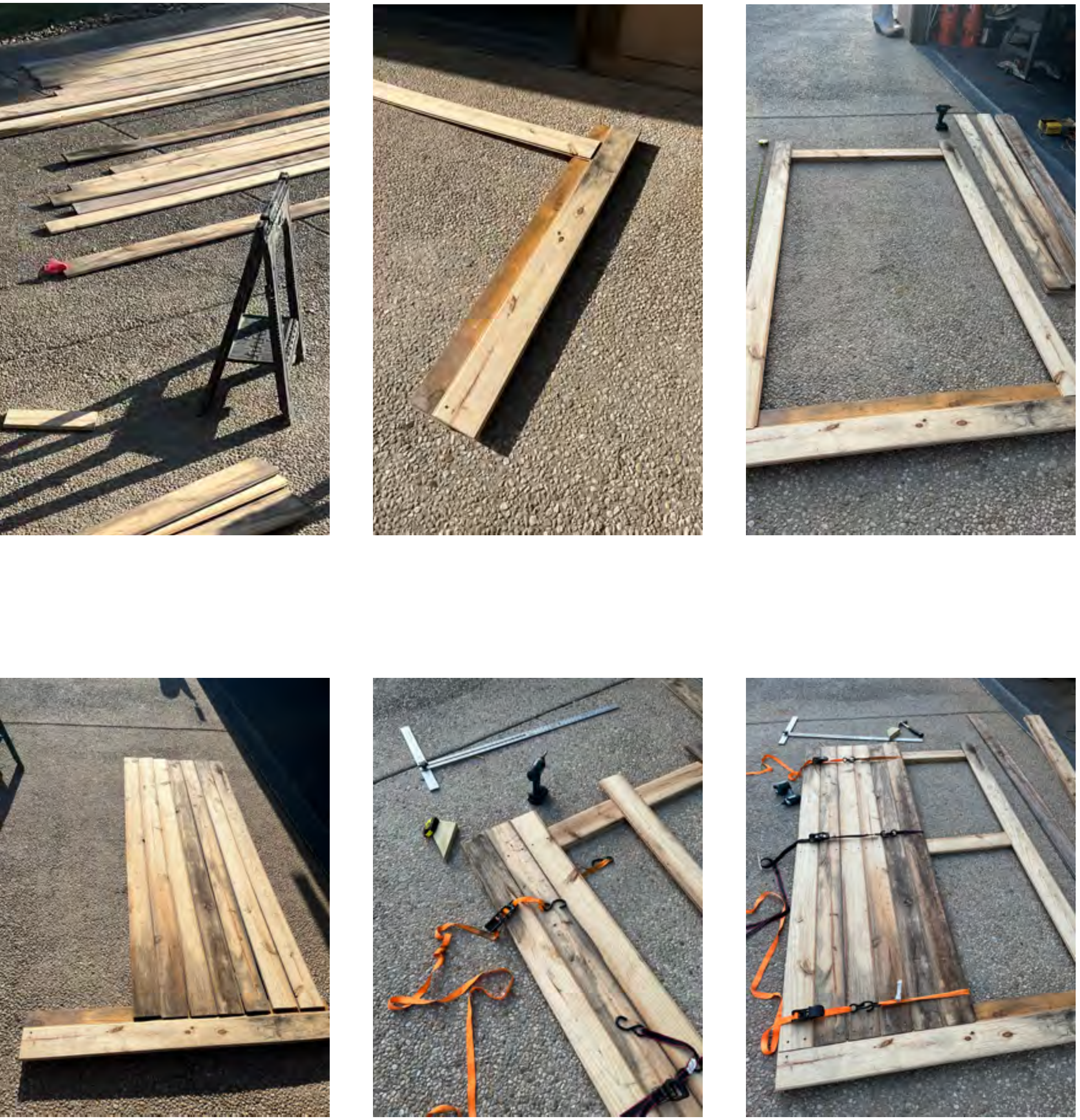

Figure 15 The construction process of the door made from reclaimed lumber

RECLAIMED LUMBER GARAGE DOOR

Figure 16
The reclaimed lumber door installed

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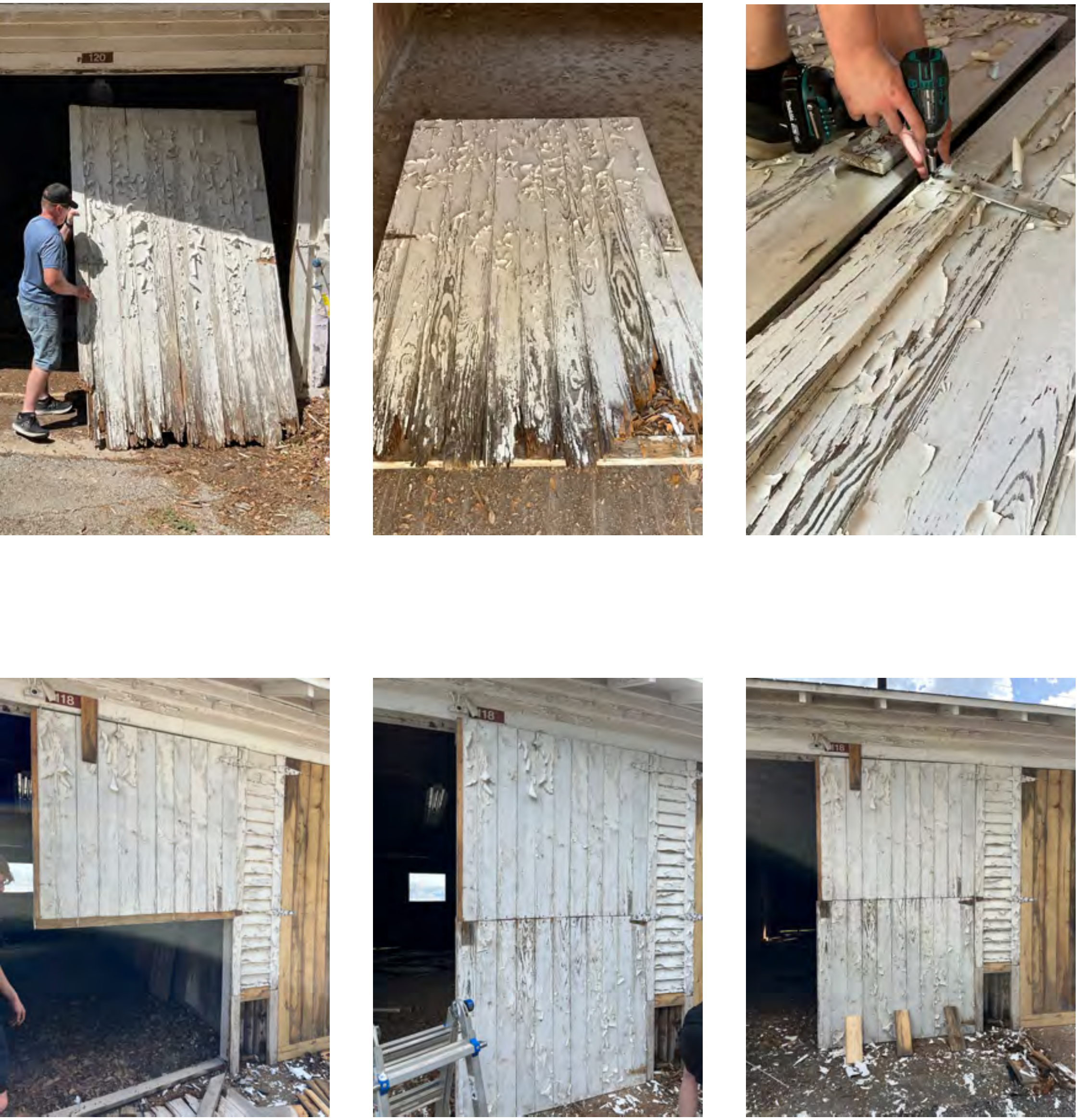

Figure 17 Salvaging and construction process on site

SALVAGED ON-SITE LUMBER GARAGE DOOR

Figure 18 The salvaged door installed

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Figure 19 Installation of the reclaimed door

COMPARISON OF THE THREE DOORS

Figure 20 The three new doors

The comparative study of the three garage doors, one made from new lumber, one made from salvaged lumber, and one made from reclaimed lumber, revealed that there are important considerations to be made when choosing between these different types of materials.

One significant obstacle faced was ensuring the appropriate dimensions and fit of the salvaged timber used for constructing doors. As these materials are often acquired from existing structures or demolition sites, they may not be readily available in standard sizes required for door fabrication. Consequently, additional effort is necessary to meticulously measure and customize them according to specific project specifications. This process proved time-consuming when utilizing reclaimed lumber purchased from a reseller since the board lengths varied.

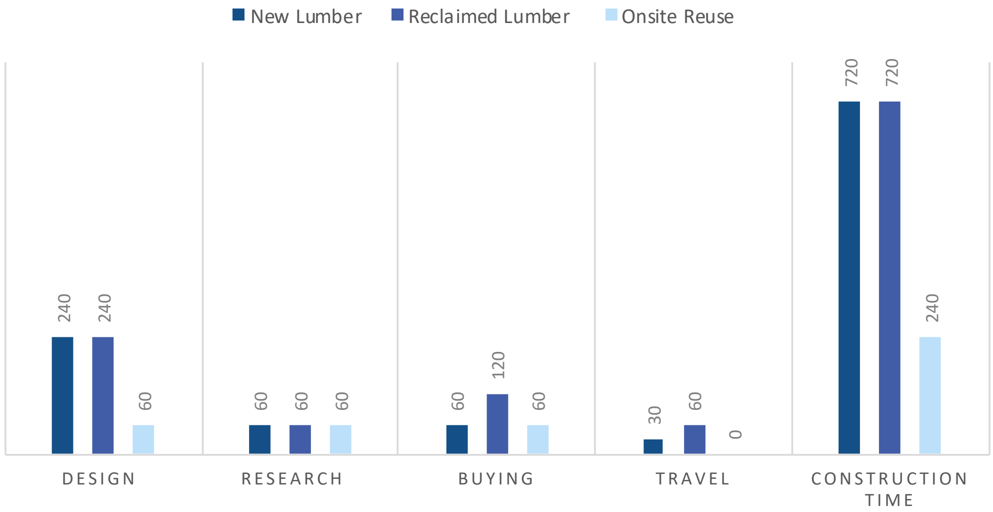

Figure 21 Process times for the three door constructions

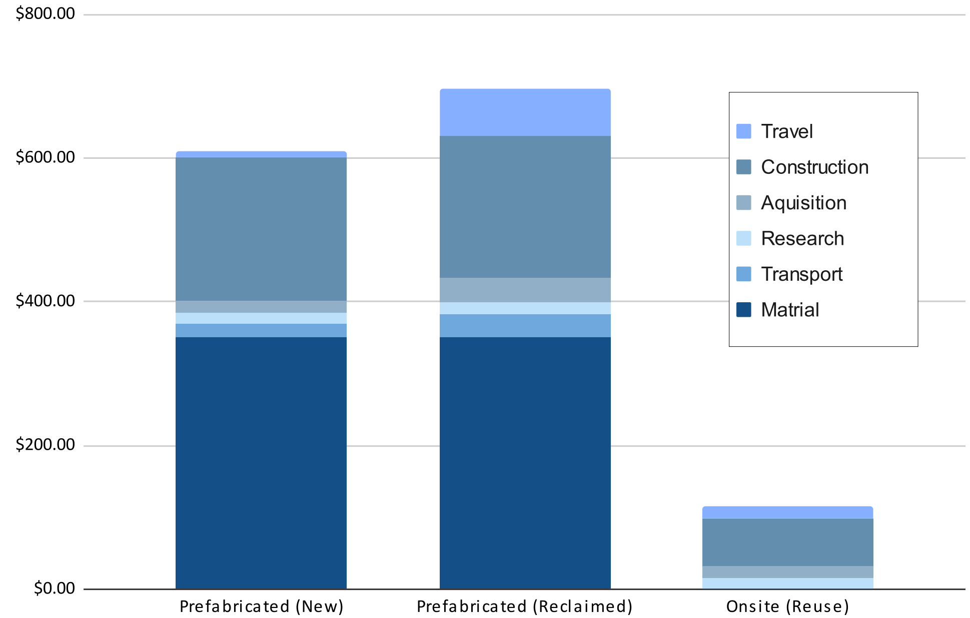

Figure 22 Cost comparision

Furthermore, these pieces exhibited bends which necessitated employing ratchet straps to straighten them out and align them correctly prior to securing with screws. It should be noted that while this challenge mainly applied to reclaimed lumber, even new wooden boards were subjected to similar measurements due to slight bending.

Furthermore, the condition of salvaged materials can vary significantly based on their previous use and exposure to environmental factors. This poses another obstacle as some pieces may need extensive cleaning or repair before being suitable for door construction.

Addressing these issues requires specialized knowledge and skills in working with reclaimed wood. It is crucial that craftsmen possess expertise in assessing the quality of salvaged materials during selection process as well as proficiency in performing necessary modifications such as conditioning timber surfaces or reinforcing weak points through appropriate carpentry techniques.

Further examination revealed that although the salvaged lumber used for constructing doors was conveniently accessible at the site, there were difficulties involved in accurately cutting and preparing these reclaimed materials. Nevertheless, a closer analysis brought to light several obstacles pertaining to the precise cutting and preparation processes required for working with such salvaged materials.

The higher cost of reclaimed lumber compared to new lumber can be attributed to the labor-intensive process involved in its deconstruction and processing. This includes not only a more extensive construction time but also additional efforts during design and material acquisition, resulting in increased costs. The cost calculation for this type of construction takes into account factors such as the average construction laborer salary in San Antonio, which is currently estimated at $16.51 per hour according to data from Indeed.com. Additionally, expenses related to the actual purchase price of materials and fuel required for transportation are considered using the IRS mileage reimbursement rate specific to Texas.

In conclusion, while using salvage lumber holds promise for sustainable building practices including door constructions; it remains imperative that adequate attention is given towards overcoming challenges associated with cutting and preparing these reclaimed resources.

ACCESS TO MATERIALS

Figure 23 Imaginery pile of lumber from a deconstruction

MATERIAL ORIGINS

The practice of resource utilization, particularly in the context of salvaging timber, underscores the broader principles of sustainability and conservation. As the global demand for timber continues to rise, these practices become not just beneficial, but also necessary for resource management and environmental stewardship.

When a building is demolished, the resultant debris often consists of various types of wood, from structural beams to interior elements. Instead of relegating this to landfills, conscientious demolition practices can identify and separate valuable pieces of timber for future reuse. This reclaimed lumber often bears unique aesthetic features and history that new wood lacks, contributing to the character and appeal of the final product.

The act of deconstruction provides a similar but more purposeful avenue for reclaiming wood. Unlike demolition, deconstruction entails the careful disassembly of structures, where the intent is to maximize the recovery of usable materials. This process is often more labor-intensive but results in a higher yield of salvageable timber, which, again, is not only economically advantageous but also environmentally friendly. The extracted timber can be treated, if necessary, and reprocessed for reuse in various ways, such as in building new structures or creating unique furniture pieces.

Construction projects typically generate a substantial amount of waste, including discarded timber from cut-offs, over-ordering, or design changes. By implementing sustainable practices like efficient material planning, site waste management plans, and just-in-time ordering systems, the amount of waste can be significantly reduced. Any surplus or scrap wood that still results can be repurposed or upcycled into smaller items, ensuring the most efficient use of the material.

Through these methods, reclaimed and salvaged timber is obtained from a variety of contexts, each with its unique challenges and benefits. Together, they contribute to a circular economy where waste is minimized, resources are efficiently utilized, and the environmental impact is mitigated. This highlights the importance and value of the timber resource, promoting its sustainable management and conservation for future generations.

Figure 24 Closeup of a reclaimed lumber pile stored by the Office of Historic Preservation in the Kelso House

SALVAGED DEMOLITION MATERIALS

Figure 25 Lumber stored by the Office of Historic Preservation in the Kelso House

The initial batch of timber was sourced from a storage facility located at the Kelso House in San Antonio. These particular timbers consisted of dimensions measuring 2" by 8" and were obtained through salvage efforts following a demolition project conducted at the Pearl. Careful deconstruction methods were employed to salvage these lumber pieces, ensuring their suitability for reuse in the construction of ADU prototypes. The salvaged lumber exhibited some variability in terms of lengths and sections, as is common with reclaimed materials. This variability can present challenges in terms of supply and fitness for purpose in mainstream construction, as reclaimed whole members tend to be shorter in usable lengths and have smaller effective sections. Reclaimed whole members generally tend to have shorter usable lengths and smaller effective sections compared to newly manufactured counterparts(Rose et al., 2018). Furthermore, the salvaged lumber obtained from the storage facility lacked warranties and certifications, which may limit its demand in mainstream construction where certainty and quality assurance are highly valued.

This lack of consistent dimensions may limit their use in traditional construction settings where standardized specifications are highly valued. However, given appropriate design considerations and modifications tailored towards working with reclaimed materials, innovative solutions can be developed.

Figure 26 Salvaged lumber piles at the deconstruction training

RECLAIMED DECONSTRUCTION MATERIALS

The process of deconstruction - carefully dismantling structures to reclaim materials that would otherwise be discarded - offers a valuable opportunity to salvage reusable timber. The Material Innovation Center houses material sourced from a deconstruction training event held in San Antonio in October and November 2022. This event, organized by the Office of Historic Preservation and the San Antonio River Authority, was a Certified Deconstruction Contractor Training program, which was conducted by Re:Purpose Savannah. The program was specifically designed to teach contractors how to deconstruct early 20th-century wood-framed structures.

The structures used for training were originally constructed in the early 1900s as housing for workers and their families from a nearby ranch. As the trainees carried out the deconstruction, they discovered markings on the lumber that provided valuable historical information about the structures and the lumber company involved in their construction, Hillyer-Deutsch-Jarratt Lumber Co. This discovery illuminated not only the history of these particular structures but also contributed to the broader understanding of San Antonio's development history, establishing connections with the individuals who constructed the city's homes and businesses. This kind of information, which typically would be lost during standard demolition, was preserved due to the deconstruction process.

This initiative forms part of the city's Deconstruction and Circular Economy Program. The program's goal is to preserve historical materials and promote sustainable practices. The materials sourced from this training event are now stored at the Material Innovation Center, contributing to the center's mission.

Figure 27 Salvaged lumber piles at the deconstruction training

Figure 28 Deconstruction of a floor slab

Figure 29 A trash container

Figure 30 Piles of reclaimed lumber

Figure 31 Piles of sheeting materials

Figure 32 A peer and beam foundation

Figure 33 Denailing process

Figure 34 A large pile of lumber put in storage at the Material Innovation Center

Figure 35 A large pile of lumber stored outdoors at the Material Innovation Center

Figure 36 Salvaging construction waste

Figure 37 The truck loaded with salvaged construction waste.

RECYCLED CONSTRUCTION WASTE

In addition to demolitions and deconstruction, another potential source of salvaged timber for reuse is ongoing construction projects. The study also included a prominent construction site located on Josephine Street in San Antonio as the third source of materials. This site proved to be a significant contributor of dimensional lumber, which is commonly used for temporary structures like fences and staircases during construction processes.

However, it should be noted that these reclaimed lumber pieces from construction sites are often considered unsuitable for large-scale construction projects that require high-quality materials adhering strictly to structural integrity standards. This is primarily due to time constraints and the potential damage incurred during their previous use.

To address this issue, sustainable practices can be implemented within construction activities by integrating meticulous planning and efficient material usage. By doing so, excess or unused structural elements can be repurposed rather than being disposed of wastefully. Ultimately, the goal is to reduce the demand for new materials by maximizing the use of salvaged and reclaimed lumber in construction projects.

Figure 38 A truck load of waste material from a timber prefab manufacturer

RECYCLED FABRICATION WASTE

The construction industry is progressively shifting towards prefabrication processes, a trend prominently observed in the timber products sector. Prefabrication techniques not only optimize operational efficiency but also minimize timber waste, thereby enhancing business profitability. Despite these improvements, waste material is an inevitable byproduct of these processes. Various strategies are adopted to repurpose this waste, such as transforming leftover pieces from post and beam fabrication into energy resources or farming material. However, a significant portion still finds its way into landfills.

Our study focuses on salvaging the residual cut pieces generated during post and beam fabrication. We noticed that a large quantity of dimensional lumber could be recovered. However, the dimensions varied slightly from standard construction lumber sizes. To ascertain the potential reuse of these lumber blocks, we undertook a systematic assessment of their dimensions and structural functionality.

We harnessed the precision of 3D scanning technology to accurately measure the salvaged lumber blocks. This advanced method provided detailed analysis of each block's structural properties, enabling an in-depth understanding of their potential functionality. With the data collected from the 3D scans, we created digital models of each lumber block within a Computer-Aided Design (CAD) environment. These digital counterparts mirrored the physical stock of lumber blocks, presenting an exact replica of each item.

By utilizing cutting-edge technologies like 3D scanning and CAD software tools, we can perform a comprehensive assessment of reclaimed materials such as lumber blocks. This innovative approach empowers us to explore their potential for reuse in a range of applications, thereby further reducing waste and promoting sustainability in the construction industry.

Figure 39 A 3D scan of the lumber blocks

Figure 40 The digital representations of the reclaimed lumber blocks.

EVALUATING MATERIALS

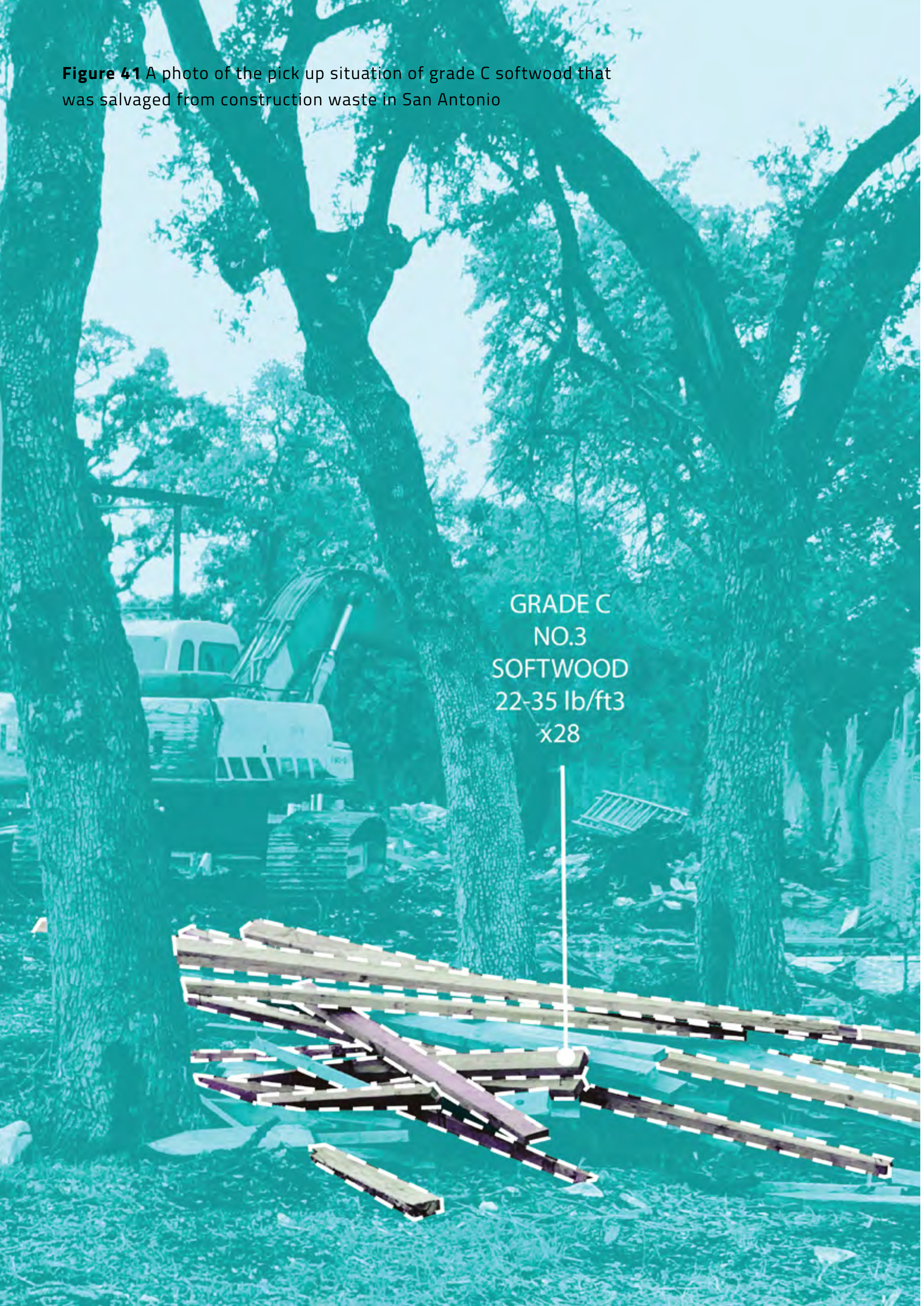

Figure 41 A photo of the pick up situation of grade C softwood that was salvaged from construction waste in San Antonio

EVALUATION OF RECYCLED MATERIALS

In addition to the sourcing of salvaged timber, it is equally important to consider the quality and condition of the materials . The trade and acceptance of reclaimed lumber products greatly depend on rigorous quality control measures. It is important to maintain high-quality standards for recycled lumber to build confidence among stakeholders involved in the reuse of dimensional lumber in construction.

Previous research suggest that heart checks result in a reduction in the modulus of rupture for recycled timber beams, while having minimal impact on the strength of recycled timber columns. It has been observed that dimensional lumber obtained from deconstructed buildings tends to be one grade lower than freshly sawn lumber due to damage incurred during the dismantling process. Since the value of lumber is closely associated with its quality, assessing the grading levels of timber derived from deconstructed structures will prove instrumental in determining potential reuse options and market valuation.

In the United States, the visual grading of lumber is generally conducted according to the standards set by the American Softwood Lumber Standard (Voluntary Product Standard PS 20-70), developed by the National Institute of Standards and Technology (NIST) and the American Lumber Standard Committee (ALSC). This standard covers the sizes, grading rules, and moisture content to which softwood lumber is normally manufactured and is used as a reference for the oversight of the accreditation program by the ALSC. The grades established under this standard depend on various factors such as the species of wood, its intended use, and the visual characteristics of the lumber, including knots, grain patterns, and other natural defects.

However, for reclaimed or recycled lumber, the grading process can be more complex due to factors such as nail holes, saw marks, and weathering. At present, there isn't a widely accepted standard for grading reclaimed lumber. Some organizations are working on developing such stan-

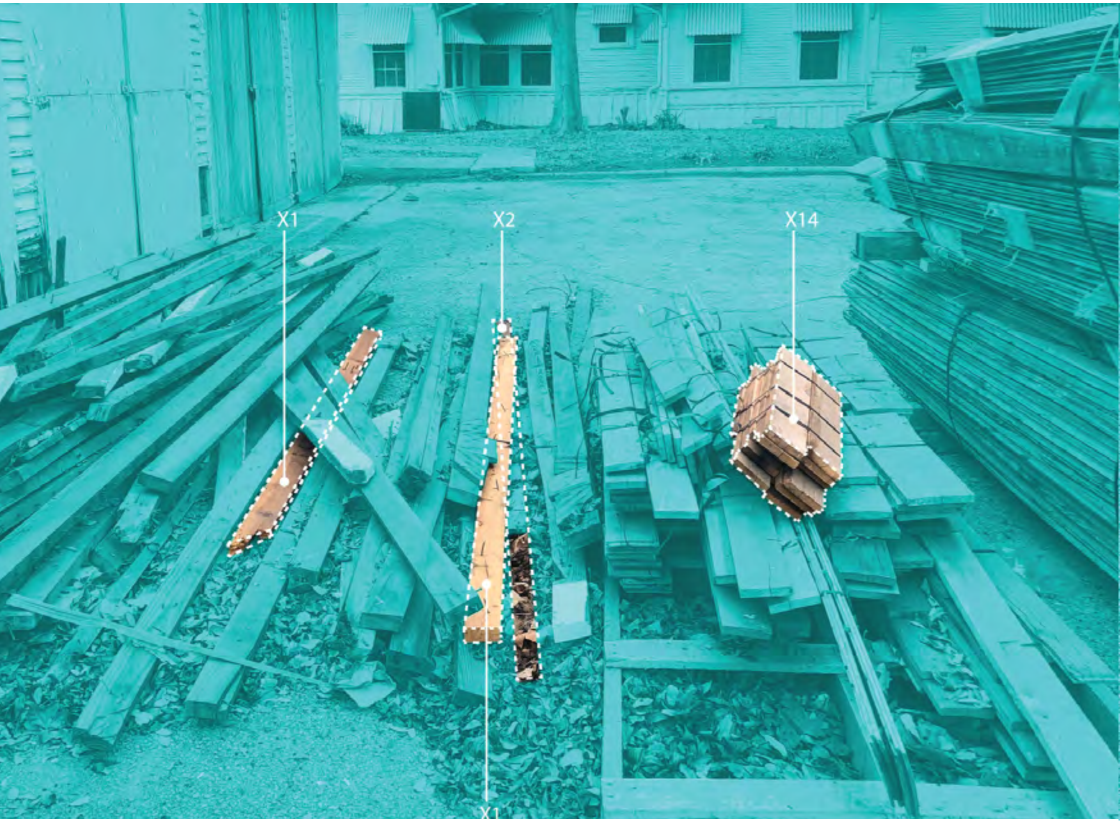

Figure 42 A photo of the pick up situation of at the Material Innovation Center

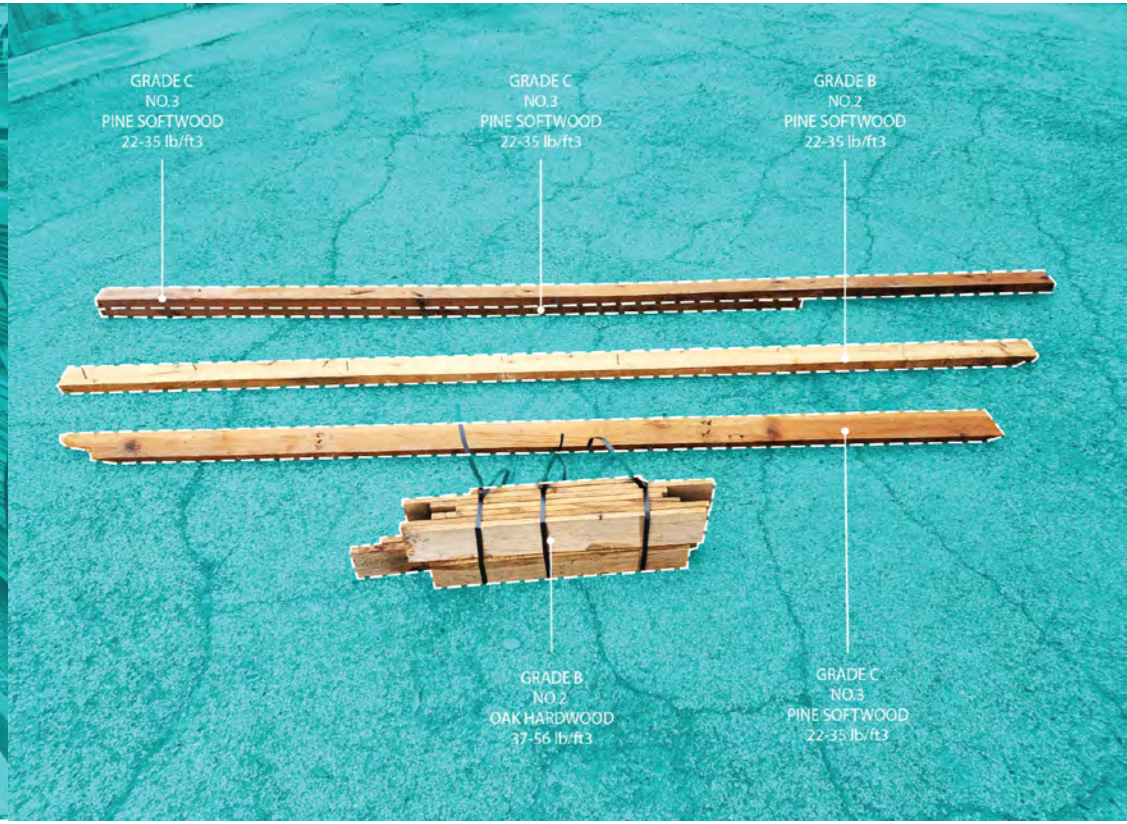

Figure 43 The picked up material with wood species and grading

dards, but in the meantime, the grading of reclaimed lumber often depends on the judgement of experienced professionals in the field.

Several proposed methods for visual grading include creating a distinct "Reclaimed" lumber species group, which would be treated as a unique species within the National Design Specification (NDS) for Wood Construction with design values reflecting the strength reduction. Another approach is applying a reduction factor to current lumber design values based on the strength reduction percentage. Some grading agencies suggest a one visual grade reduction in properties for reclaimed lumber. Alternatively, reclaimed lumber could be included in a lower strength NDS species grouping, as the bending strength of certain reclaimed lumber like Douglas-fir would meet the requirements of the Western Woods species grouping.

The processing of reclaimed wood often involves a series of steps, including de-nailing, cleaning, kiln drying, milling, and installation. These steps help ensure the quality and safety of the reclaimed wood, particularly kiln drying, which is essential for removing moisture and potential pests from the wood. The importance of this step is such that it can distinguish between good and great reclaimed wood. While there might not be specific grading standards for reclaimed lumber, the general principles of wood grading considering aspects like the presence of defects, the size of the wood, and other factors, can still be applied. It's also crucial to ensure the reclaimed wood has been properly processed to ensure it's safe and suitable for its intended use.

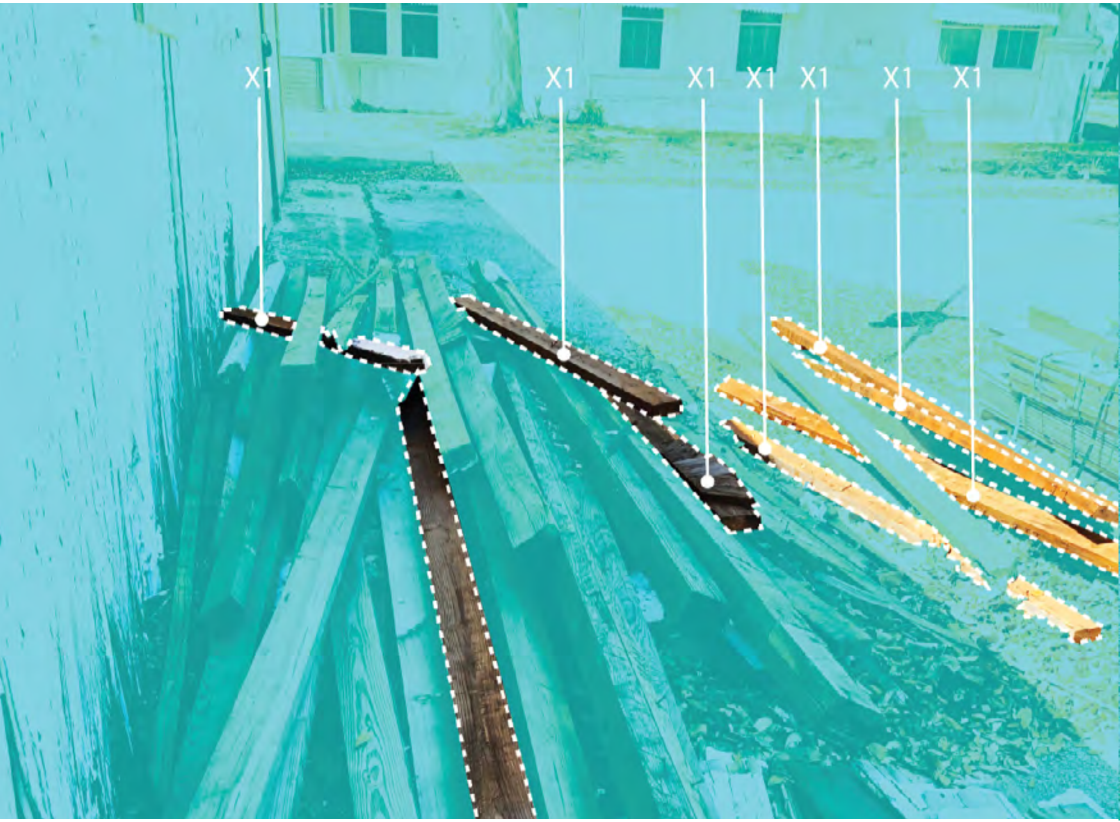

Figure 44 A photo of the pick up situation of at the Material Innovation Center

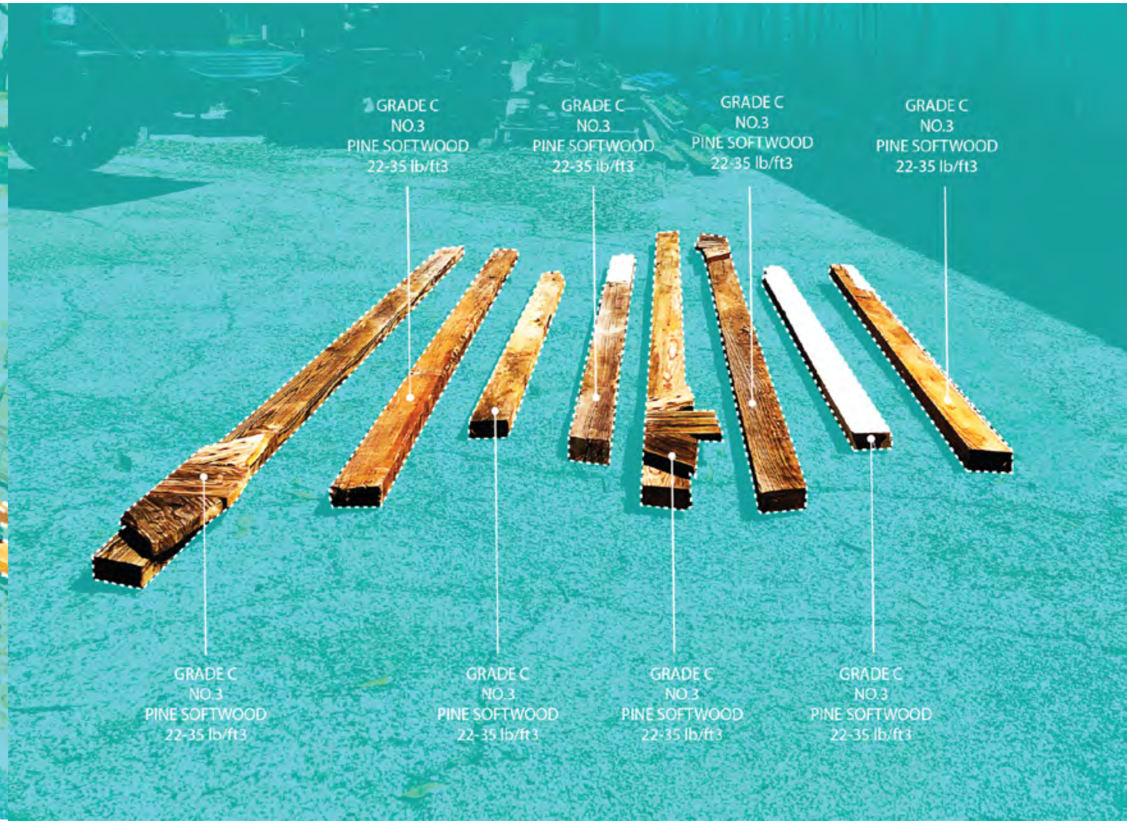

Figure 45 The picked up material with wood species and grading

Figure 46 Different dimensional lumber pieces reclaimed in San Antonio

Figure 47 A lumber piece after failure inside of the compression machine

COMPRESSION TESTING

The lumber that was used for the demonstrators was either pine or douglas fir, both of which are commonly found in construction projects. Bothe are softwoods that offer strength and durability, making them suitable for structural applications. Previous study already pointed out the structural capacity of reused lumber from deconstruction or salvaged from demoltions sites.

During our selection process the lumber pieces were visually inspected and graded based on their condition. The salvaged lumber showed signs of previous use, including nail holes and cuts, but its structural integrity was still intact.

During the construction of the demonstrators, compression testing was performed on the salvaged and reclaimed lumber to assess their strength. The tests encompassed both pine and Douglas fir species, using 10" long pieces obtained by cutting conventional dimensional lumber (2 by 4s). Four sets of test specimens were defined: reclaimed lumber sourced from a demolition site and deconstruction training, as well as salvaged wood from the renovation of the Pearl, in addition to construction waste and new lumber purchased from a retailer.

Since reclaimed lumber often comes with imperfections such as nail holes and cuts due to its previous use, it is crucial to consider these factors when assessing its structural performance. Consequently, before conducting the compression tests on both reclaimed construction waste and new lumber groups, extra categories for testing were created wherein defects or hearts present in each group were carefully inspected. A total of ten specimens were tested for each category to obtain comprehensive data. The Humboldt Compression Machine (250,000lbs) was used to apply a compressive force to the specimens until failure occurred. During the testing the relative humidty was varying between 38 - 41% and the temperature was kept constant around 87°F. The measurements included the pound per square inch (PSI) and the total pound

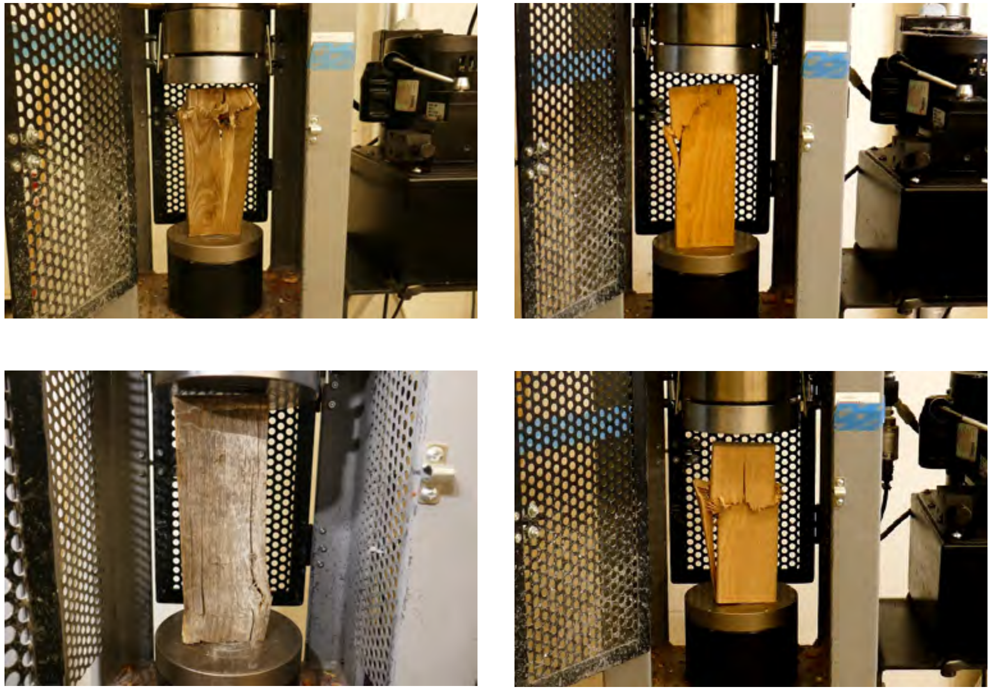

Figure 48 Various specimen after failure inside of the compression machine

force applied to the specimens at the point of failure. Additionally, the moister content of the specimens was captured using a infrared thermal imaging moisture meter. All specimens were photograft before and after the testing to gain an undertsanding of the causes of failure.

Results

The compressive strength of dimensional lumber can vary significantly depending on the species of wood, its moisture content, and the direction of the grain relative to the load. However, as a general guideline, the compressive strength (parallel to the grain) of many common types of softwood lumber, such as pine and douglas fir is often in the range of 5,000 to 7,500 psi. The compression test for the lumber specimen in this study were in the range of 4,000 to 7,300 for the new lumber, between 3,700 to 7,300 psi for the reclaimed construction waste and between 3,500 to 11,500 psi for the reclaimed lumber from old structures. In the three sets from reclaimed and salvaged lumber the spread of the load-bearing capacities can vary a lot. While the pieces reclaimed from deconstruction training showed relatively

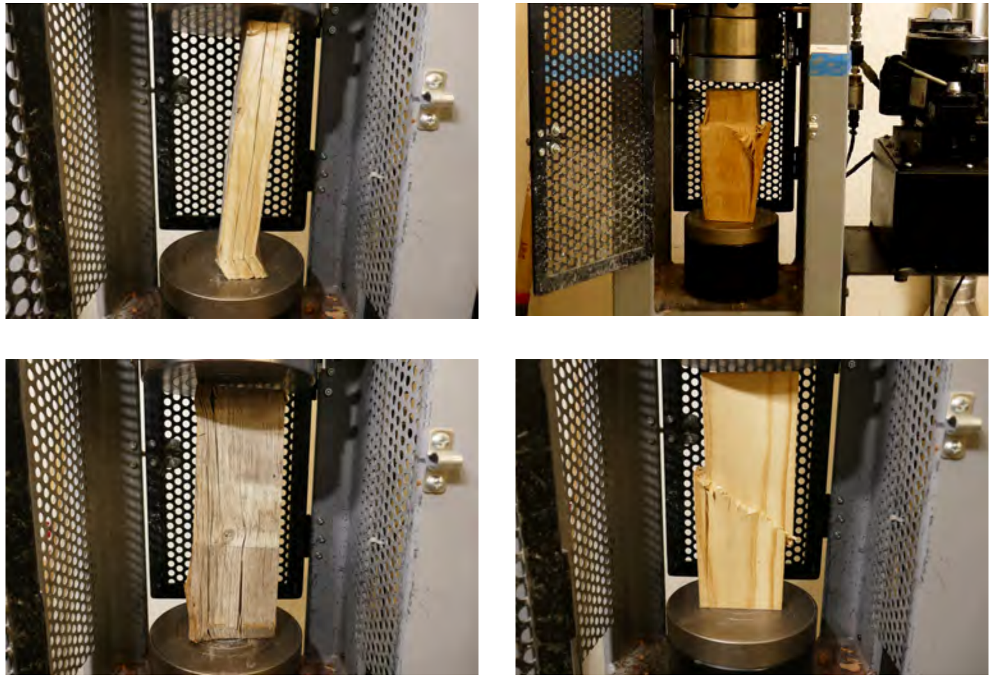

Figure 49 Various specimen after failure inside of the compression machine

consistent compressive strength values, ranging from 4,800 to 5,800 psi, the reclaimed lumber from another old structure, The Pearl in San Antonio, exhibited a wider range of compressive strength, ranging from 4,500 to 11,500 psi.

Overall, the compression tests revealed that the reclaimed lumber exhibited slightly lower strengths compared to the new lumber. When analyzing the testing reults it becomes clear that the defects have an impact on the performance of the lumber. For instance set G, the new lumber with defects, preforms similarly to the reclaimed lumber. Even the reclaimed construction waste with defects is comparable. Only the new lumber without defects outperformed the other groups in terms of strength. The highest compression strength was found in the old lumber salvaged from the renovation of the pearl (set E). Half of the specimen presented a rather high compression resistance before cracking

However, it is important to acknowledge that the variability in compression strength can be significant. For instance, the test results of set E echibited a wider range of compression strengths compared to other sets analyzed. This observation indicates

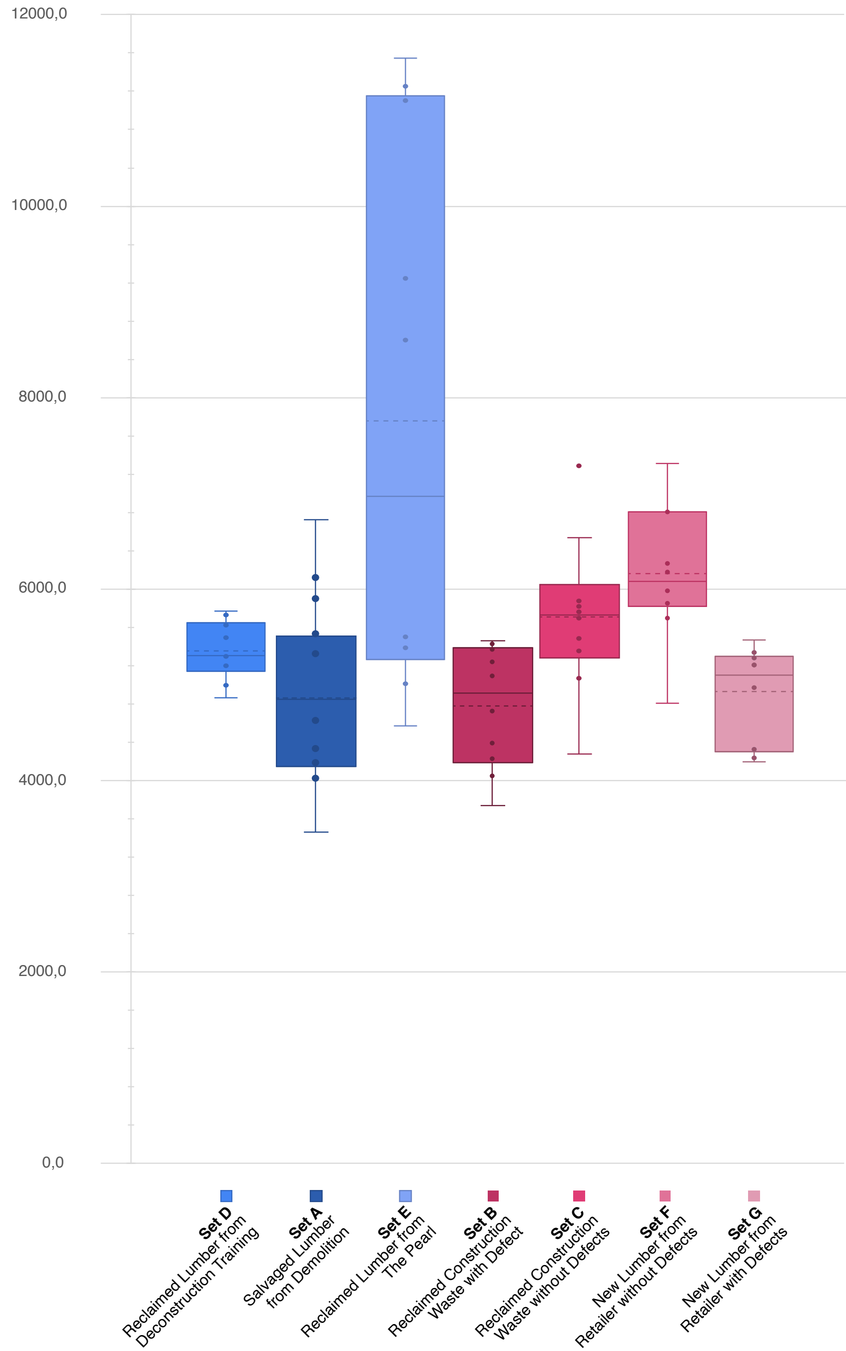

Figure 50 Candle chart showing the pounds per square inch (PSI) values for the lumber sets

that the quality and strength of reclaimed lumber are influenced by various factors including its origin and prior utilization.

The variation in compression strength among different sources of reclaimed lumber highlights the need for thorough assessment and selection procedures when considering its use in construction projects or structural applications. It is essential to account for these differences during material sourcing and site planning stages to ensure optimal performance and structural integrity.

The results of the compression tests conducted for this study align with previous research, demonstrating that salvaged and reclaimed lumber has the potential to meet the structural requirements necessary for construction. This finding implies that reclaimed lumber could be a viable alternative in construction projects where sustainability and resource conservation are valued. Moreover, it highlights the importance of considering reclaimed lumber as a valuable resource in terms of its suitability for various load-bearing applications.

Despite the limited sample sizes used in this study, it is evident that salvaged lumber exhibits sufficient strength to be considered suitable for structural applications in building construction. The findings support its viability as a reliable material option similar to a previous study on reclaimed materials for housing projects (Chini & Acquaye, 2017). However, further research efforts are necessary to gain deeper insights into whether the found variations are similar accros recycled lumber from different sources. These additional investigations would enable a comprehensive assessment of the potential differences lumber from deconstructions and inform more precise recommendations regarding their appropriate usage.

In conclusion, the evaluation of salvaged and reclaimed materials is crucial for maximizing their use in construction projects. It is worth noting that there are variations in strength properties between new lumber and reclaimed lumber. Although this study suggests that reclaimed lumber can be comparable to new lumber when it comes to compression strength, some adjustment or modification must be incorporated into design codes and use provisions to account for any reduction in strength compared to new timber counterparts. By implementing appropriate grading standards specific to recovered materials like “reclaimed,” engineers and architects could ensure suitable utilization while abiding by established quality assurance procedures defined by industry regulations.

Set D
Reclaimed Lumber from Deconstruction Training

Figure 51 Specimen 2 of set D before (left) and after (right) the compression test

Set A
Reclaimed Lumber from Demolition

23220 lbs	4425 psi	24240 lbs	4617 psi
28720 lbs	5471 psi	18180 lbs	3463 psi
29500 lbs	5610 psi	22730 lbs	4330 psi
27430 lbs	5225 psi	18840 lbs	3589 psi
26700 lbs	5085 psi	35310 lbs	6726 psi

Figure 52 Specimen 1 of set A after the compression test

Set E
Reclaimed Lumber from The Pearl

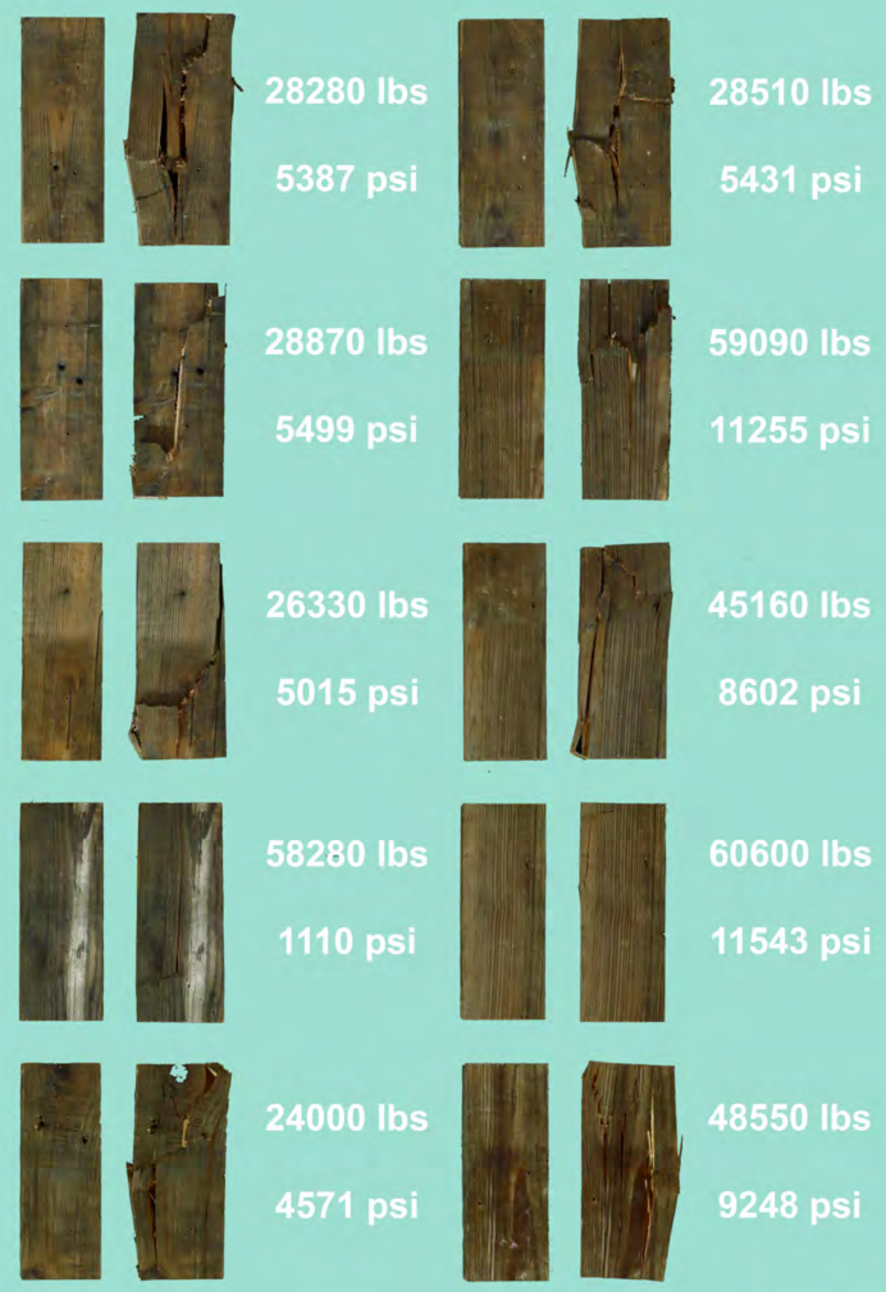

Figure 53 Specimen 9 of set E before (left) and after (right) the compression test

Set B
Reclaimed Construction Waste with Defect

19620 lbs

3737 psi

21250 lbs

4048 psi

28660 lbs

5459 psi

27500 lbs

5238 psi

28490 lbs

5427 psi

23050 lbs

4391 psi

22220 lbs

4232 psi

28190 lbs

5370 psi

26760 lbs

5097 psi

24820 lbs

4728 psi

Figure 54 A piece of set B inside the compression machine

Set C
Reclaimed Construction Waste without Defects

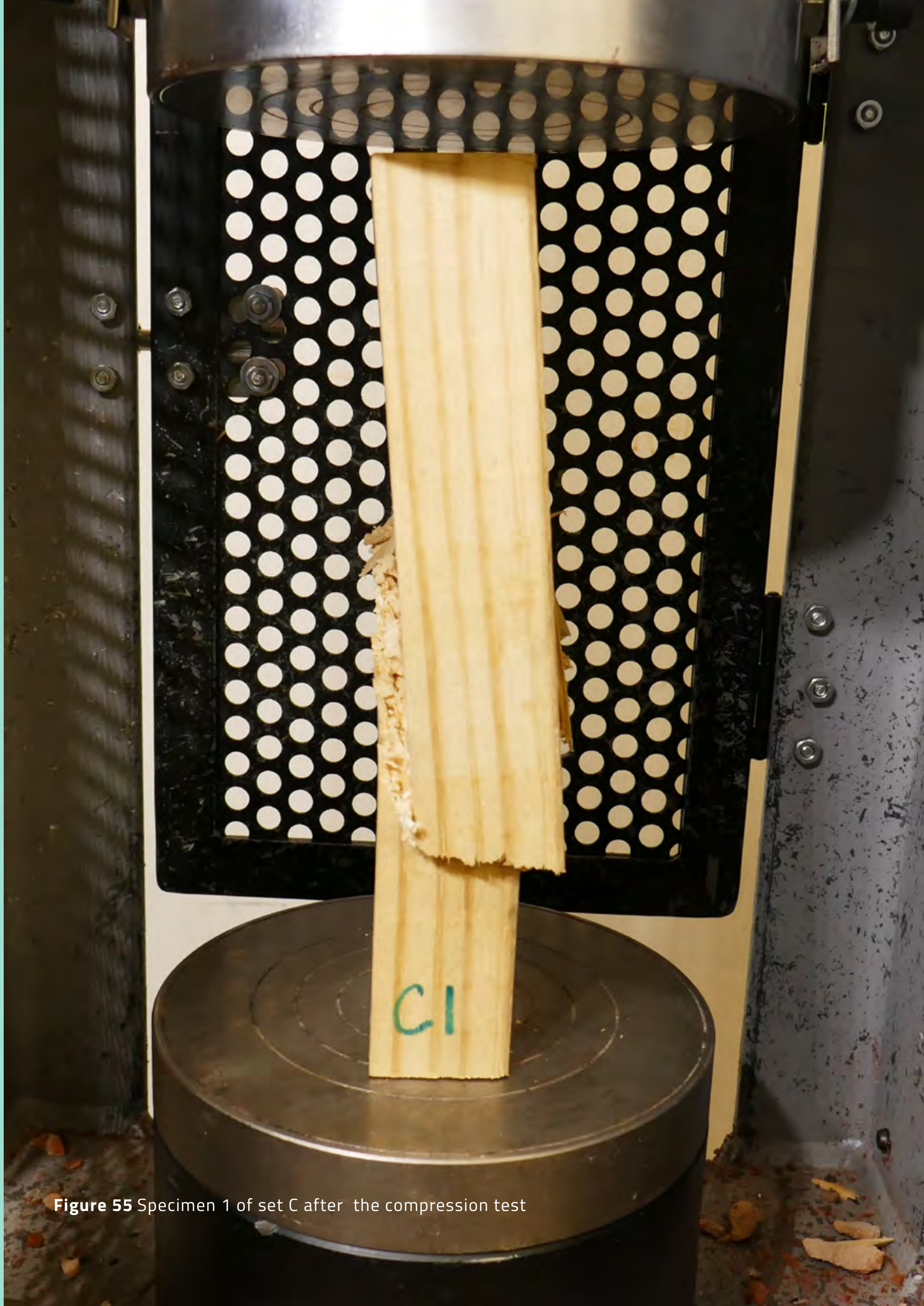

Figure 55 Specimen 1 of set C after the compression test

Set F
New Lumber from Retailer without Defects

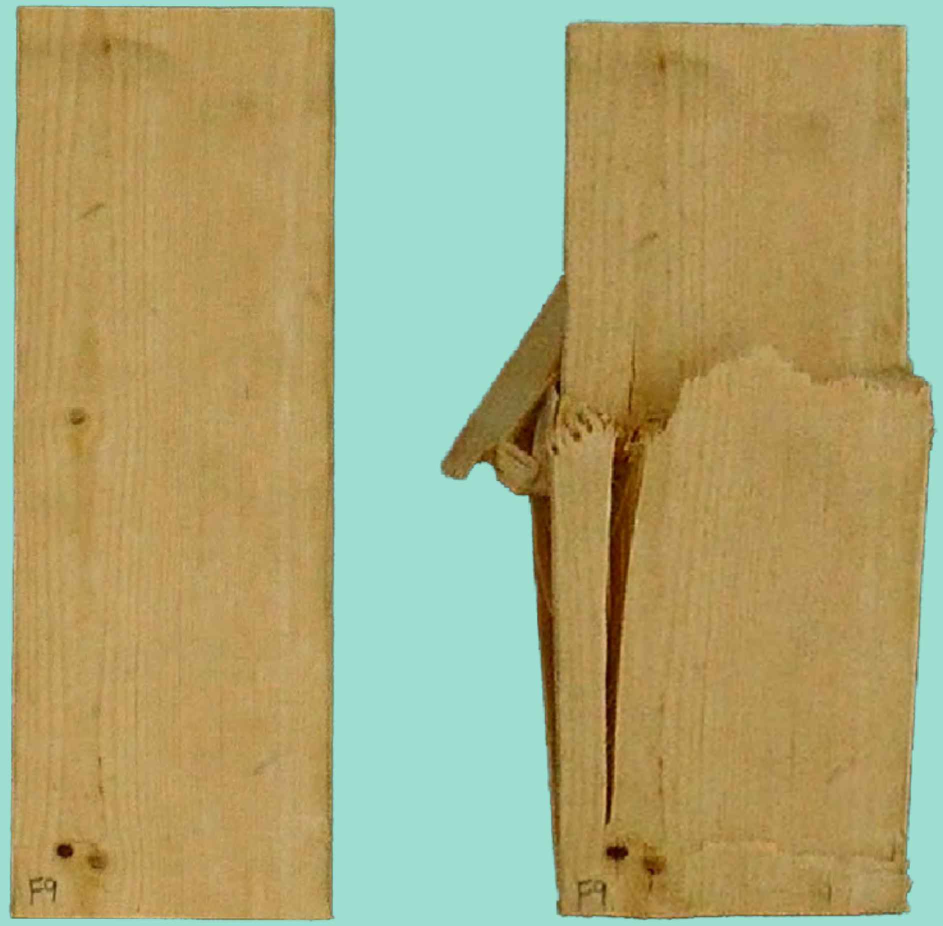

Figure 56 Specimen 8 of set F before (left) and after (right) the compression test

Set G
New Lumber from Retailer with Defects

Figure 57 A closeup of a lumber piece after failure

CASE STUDY: ACCESSORY DWELLING UNITS FROM REUSED LUMBER

Figure 58 The framing prototype made from reclaimed lumber

FRAMING WITH RECLAIMED MATERIALS

Stick framing is one of the most common construction techniques for single family houses in San Antonio. It became widely adopted as a construction method for residential and commercial buildings during the 1830s and 1840s. Stick framing involves constructing the structural frame of a building using individual wooden members, such as studs, joists, and rafters, which are assembled on-site. This method replaced earlier techniques like timber framing, which utilized larger, handcrafted beams and joints. Stick framing offered several advantages, including faster construction, lower costs, and greater flexibility in design. It revolutionized the construction industry and continues to be the predominant framing method used in the United States today.

From an engineering perspective, ensuring the performance of reclaimed lumber in service is crucial, which requires the establishment of suitable design values (Falk et al. 2012). Given that reclaimed lumber has been found to have lower strength than new lumber, adjustments in lumber use provisions and design codes are necessary.

To address this difference in building with reclaimed lumber the easiest way is to increase the cross section of the used pieces. In our case we constructed the conventional stick framing, that usually would have been made from 2 by 4s, but instead used reclaimed lumber with larger dimensions, such as 2 by 6s or even 2 by 8s. Moreover, one can easily reduce the

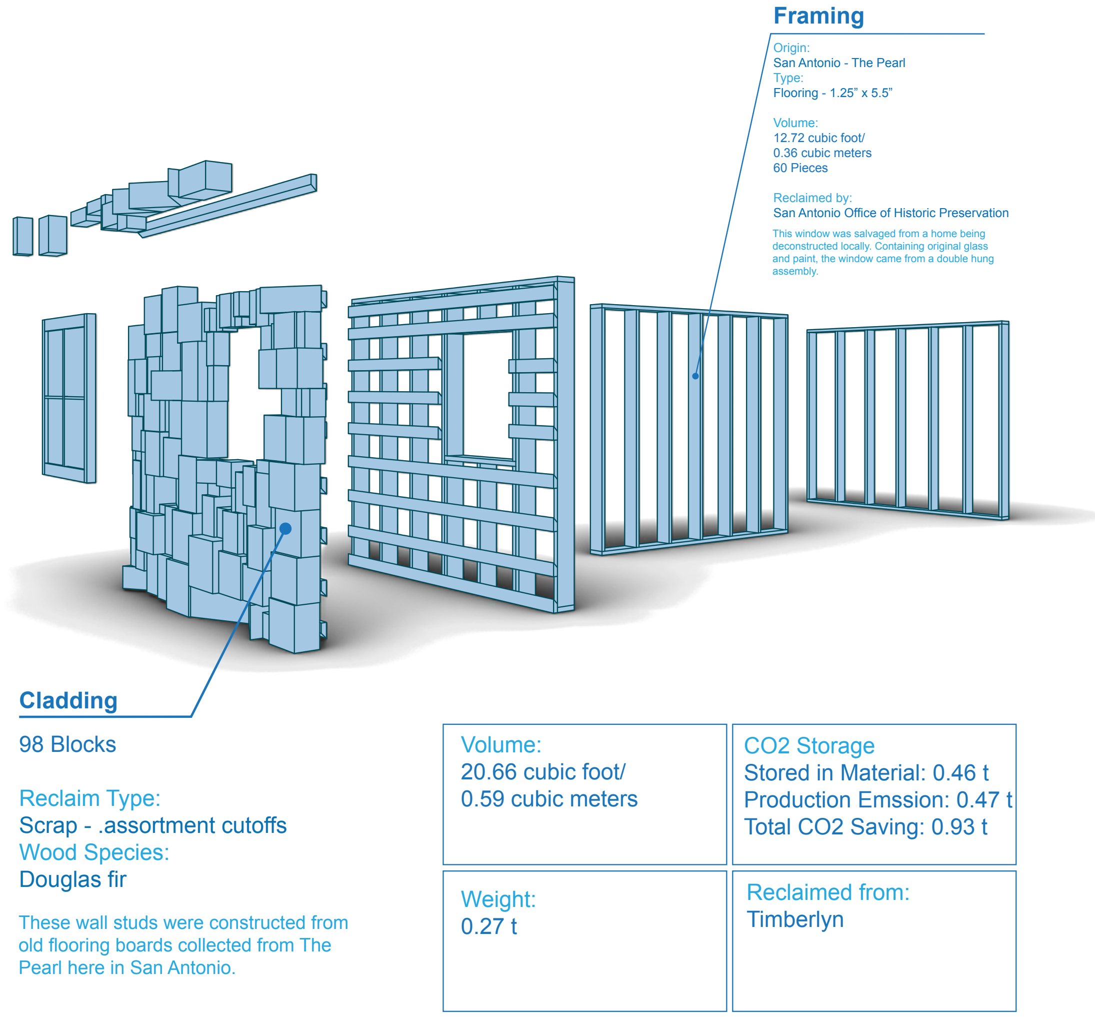

Figure 60 Assembly diagram of the prototype

Figure 61 Defect in the connection of the framing stud

Figure 62 Defect in the framing stud

distance between the sticks. This modification ensured that the structural integrity and load-bearing capacity of the framing system were maintained.

The use of reclaimed materials in construction poses challenges compared to conventional framing. One primary concern is the condition of the wood, as it may have defects such as warping or being non-straight. Additionally, reclaimed lumber tends to be harder than new lumber due to its age and previous use. These characteristics can make working with salvaged timber more difficult and require special attention during design and construction processes.

To explore these challanges a prototype was build from salvaged wood. The design consist of three walls, one of which includes a reclaimed window and partial cladding. The purpose of this prototype was to assess the feasibility and performance of using salvaged lumber in a real construction scenario. The walls were assembled and put together at the site of the Material Innovation Center.

By addressing these technical barriers through rigorous quality control measures and innovative building techniques, there is an opportunity to enhance the acceptance and trade of recovered dimensional lumber in the construction industry.

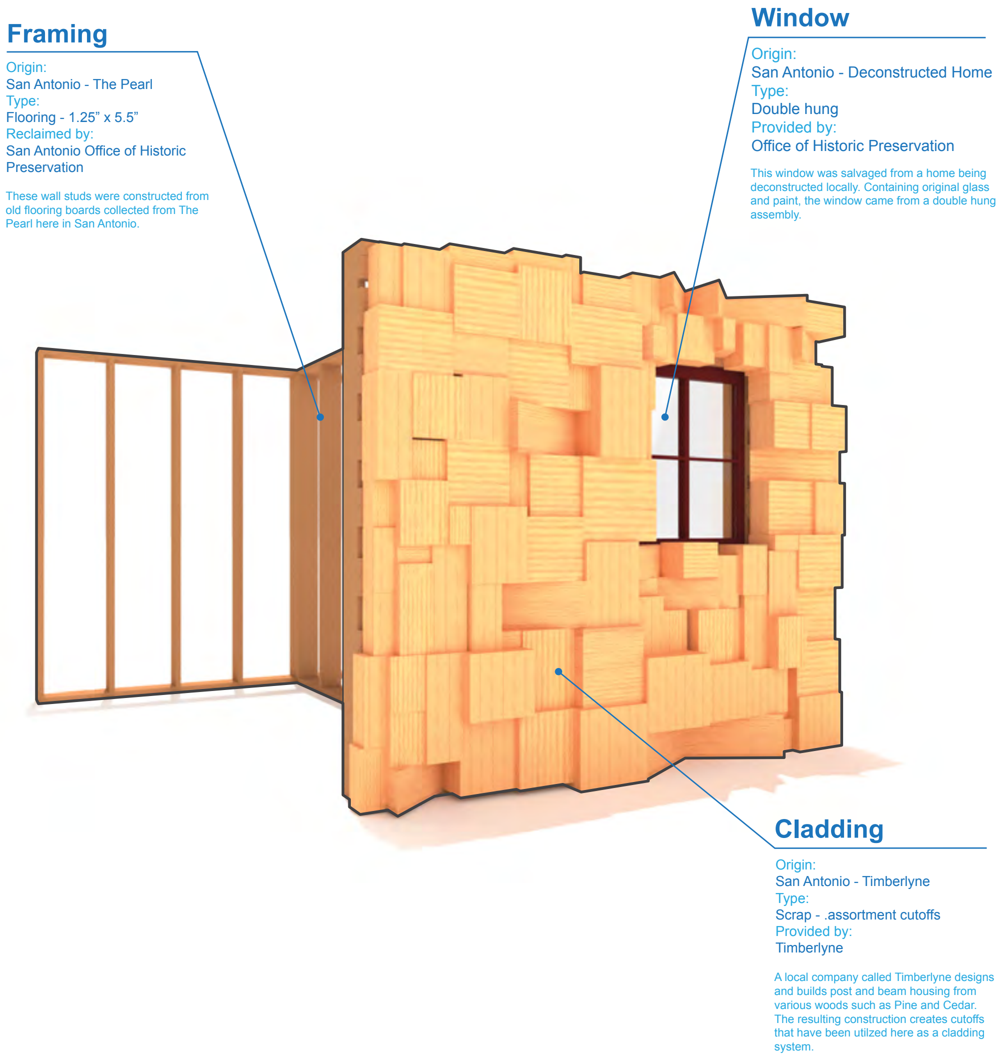

Figure 63 Digital model for the prototype

Figure 64 Front view of the prototype at the Material Innovation Center

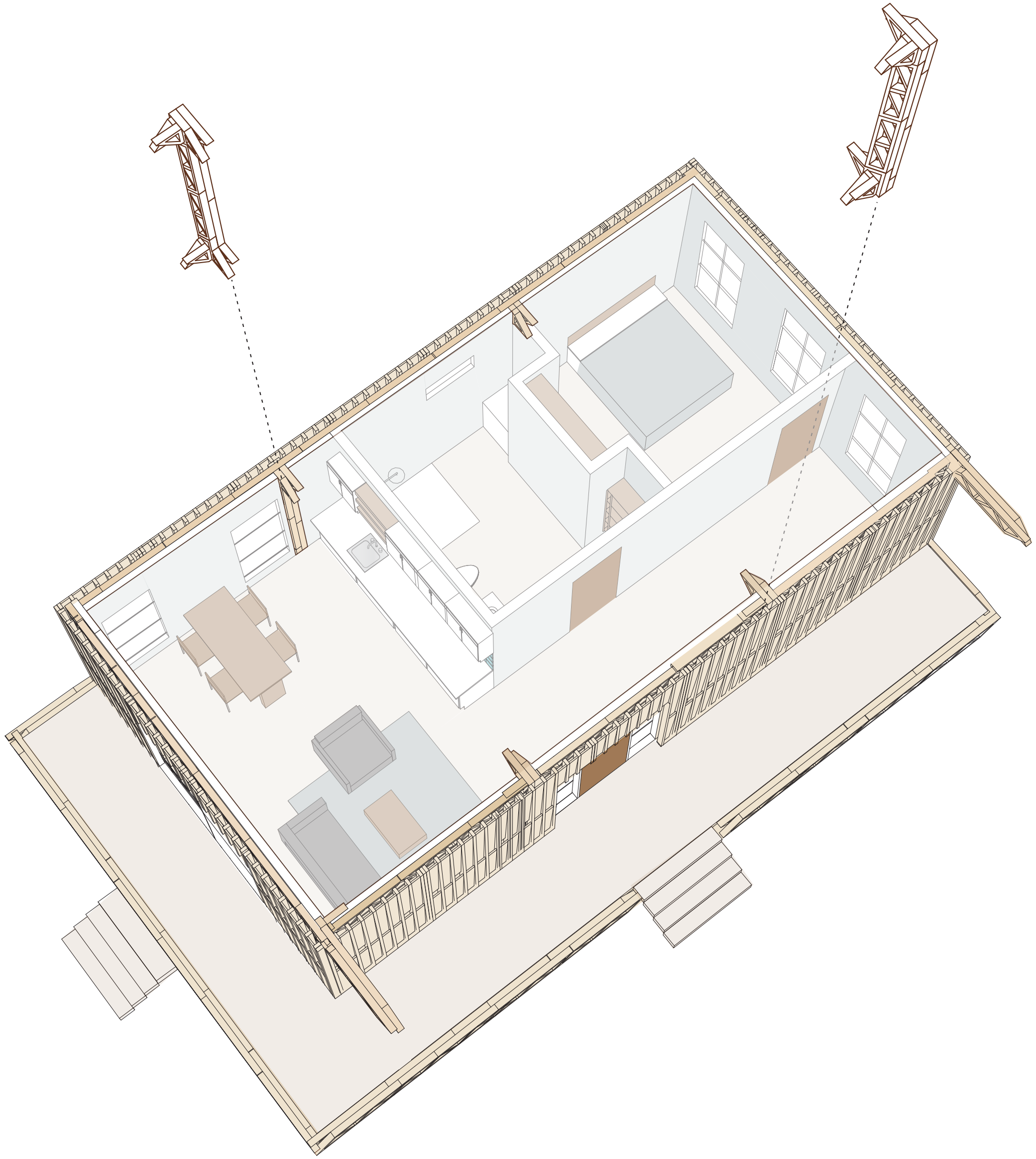

Figure 65 Topview of an ADU layout made from the proposed modules

MODULAR TRUSS FROM RECLAIMED LUMBER

Another demonstration project that was undertaken as part of this case study involved the construction of a modular truss system using reclaimed lumber. This modular truss system was designed to be easily assembled and disassembled, making it ideal for temporary structures or buildings that may need to be relocated in the future. The modular truss system was constructed by carefully selecting and preparing salvaged lumber to ensure its structural integrity. The designed truss system primarily addresses the issue of varing dimension commonly found in reclaimed lumber. Therefore, the truss elements are designed as discrete modular pieces with a hight of 14" (35.5cm) and a maximum length of 48" (121.9cm). It was important to design the modular system so that each module can be carried by maximum two persons to enable easy on site assembly. The elements are intended to be prefabricated at a factory or the Material Innovation Center and then transported to the construction site for assembly.

The use of modular construction not only offers the advantage of easy assembly and disassembly, but also provides flexibility in design and future repurposing. Besides the assembly the modules offer also various configurations, making them feasible for future repurposing into new structures. By offering a reversible connection between the truss pieces using mechanical fasteners, such as screws or bolts, the modular truss system allows for easy disassembly and reassembly without causing damage to the reclaimed lumber. Especially, for ADUs that might only be temporary structure the easy disassembly and potential reselling of the parts may

Figure 66 Connection detail

offer benefits. One can imagine that such building systems provided for affordable housing throughout a city. Once an ADU or any structure build from thee modules can serve as donor for a new structure.

The modular system is constructed using a double truss structure that is interconnected by cross braces. This configuration serves the purpose of enhancing both stability and strength across the entirety of the system. While such an approach may seemingly be perceived as less material-efficient due to its additional layer, it can also be considered as an adaptation aimed at addressing the inherent unpredictability associated with reclaimed lumber. Given that material defects or weaknesses might not always be readily apparent, this layered structure plays a pivotal role in accommodating such uncertainties while ensuring optimal performance of the overall system. Moreover, the presence of these layered truss elements offers another advantage: self-alignment during assembly. Consequently, fitting between modules becomes considerably easier and more straightforward.

The prototype was constructed by utilizing a limited set of modules, specifically consisting of straight truss pieces, corner pieces, and truss-to-corner connectors. A total of 24 such modules were employed in the assembly process, which could conveniently fit within two pickup trucks. This modular approach to construction exhibits several benefits including simplified logistics and ease of transportation due to the compact nature of these standardized components.

An entire ADU could potentially be constructed using this modular truss system made from reclaimed lumber. Depending on the size and design of the ADU, a larger quantity of modules would be required. Illustrated on the next page is an ADU with a pent roof. The pent roof ADU design showcases the versatility and adaptability of the modular truss system. The design still utilizes the straight truss and corner pieces, additionaly it requires two different types of modules for the roof structure: ridge truss pieces and gable-end truss pieces. These additional modules allow for the creation of a sloping roof that is commonly seen in residential structures. By changing these additional pieces the modular system can be costumized easily to meet different roof slope criteria.

The use of reclaimed lumber in the construction of this modular truss system not only showcases the potential for structural reuse but also highlights the importance of innovative design

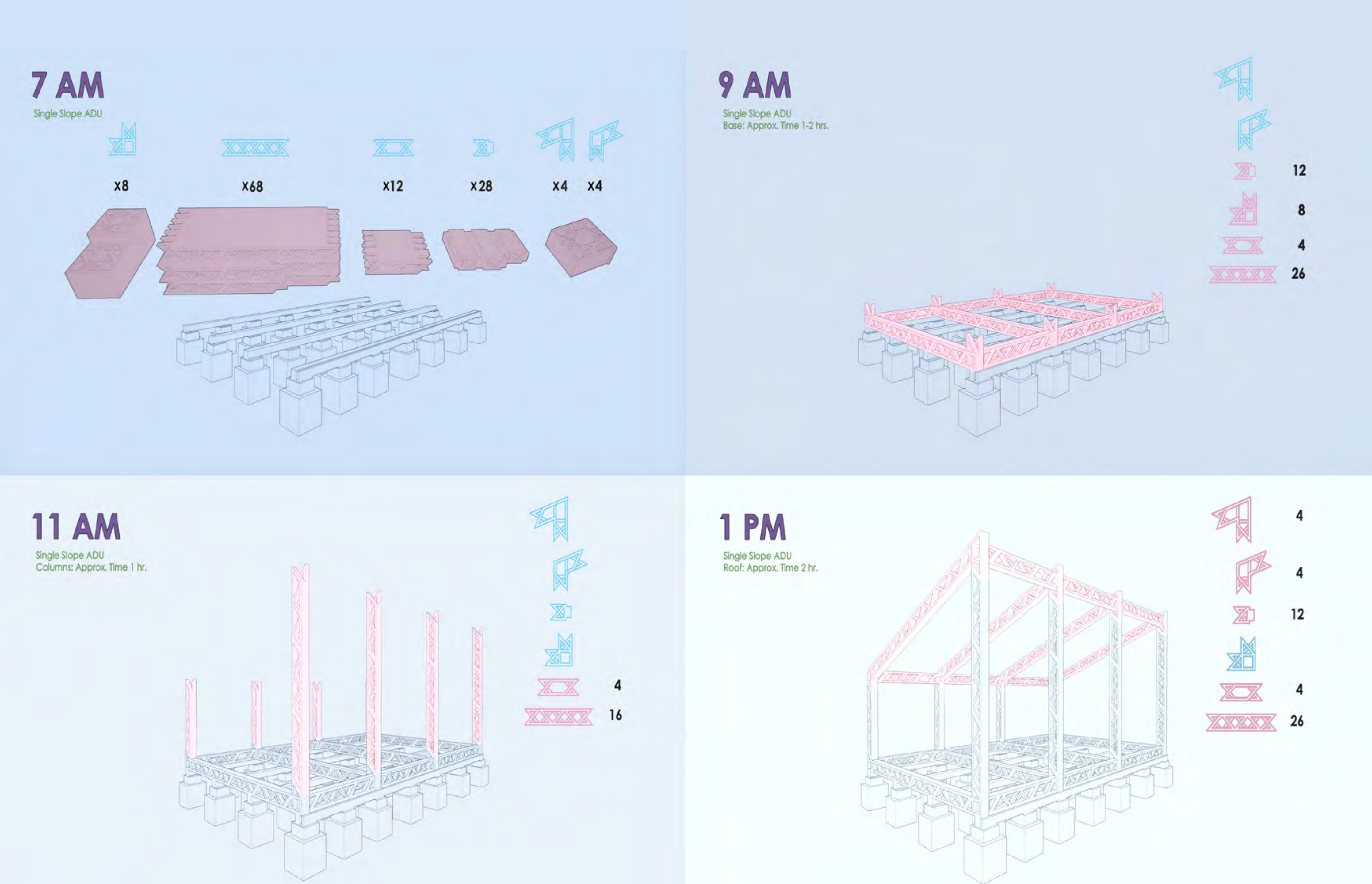

Figure 67 Assembly sequence of the structural components for an ADU

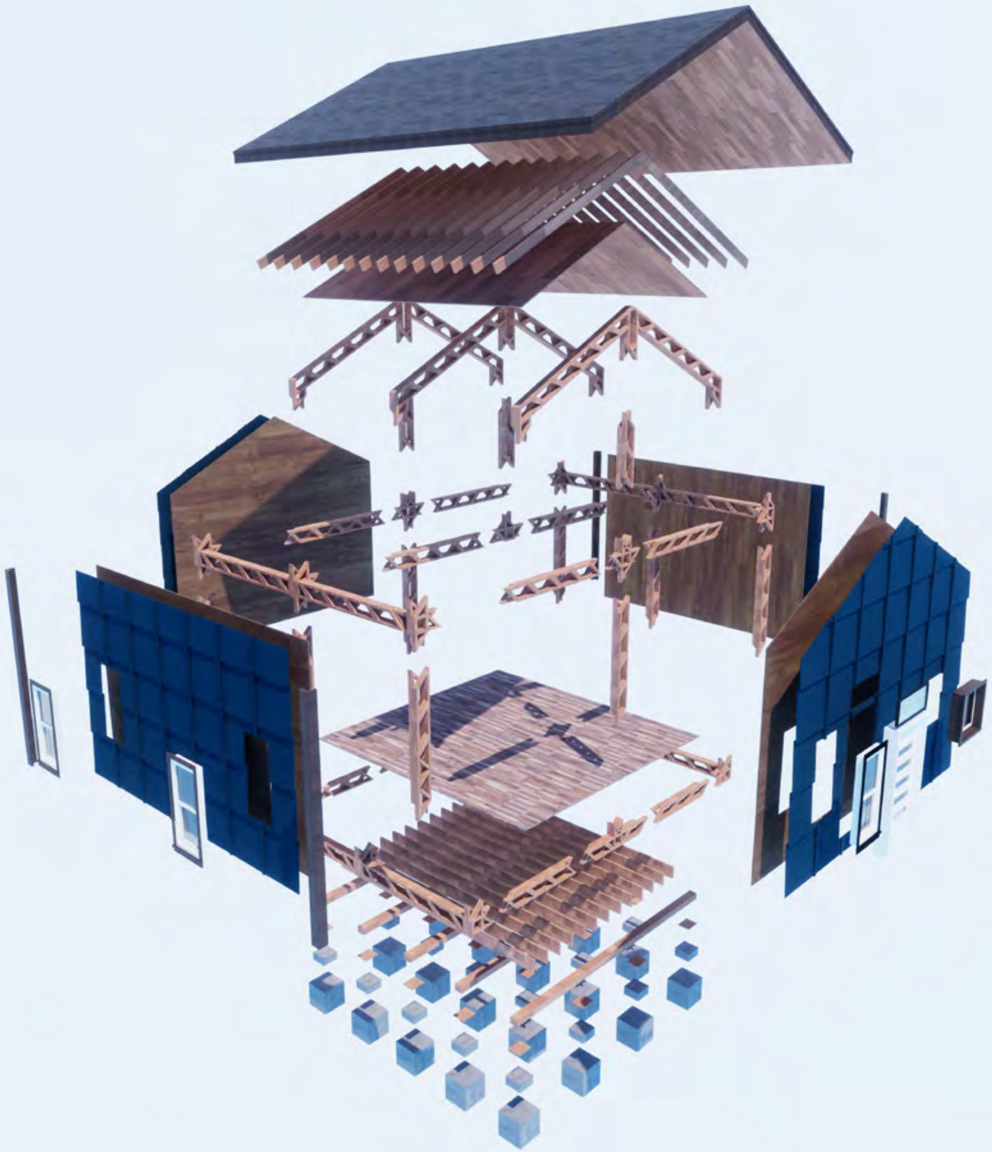

Figure 68 Explosion drawing showing all components for an ADU

Figure 69 Envisioned construction setup before assembly

Figure 70 Envisioned construction process

Figure 71 Finished ADU

Figure 72 Rendering of a finisched ADU

Figure 73 Imaginery storage of prefabricated blocks made from reclaimed lumber

Figure 74 Unloading of truss blocks

Figure 75 Half assembled prototype with truss blocks

Figure 76 Connection bolt detail

Figure 77 Part label with QR code

DIGITAL INVENTORY SYSTEM

Establishing an inventory system constitutes a crucial first step towards managing reclaimed lumber more efficiently. This database archives crucial information about each piece of reclaimed lumber, from species and dimensions to grade. In order to streamline the tracking and management process, each piece of lumber is tagged with a unique identification number, such as A001. This facilitates tracking from the moment of receipt to the point of sale or utilization.

To initiate the process of setting up an inventory management system, a database is constructed using an online platform - Google Sheets being an accessible and versatile option. This database acts as a central repository that holds crucial data about the reclaimed lumber, such as species, dimensions, and grade.

Beyond cataloguing the lumber's basic characteristics, it's of paramount importance to log the condition of the lumber. Any defects or signs of damage that may compromise its usability should be thoroughly documented. This level of detail enables a comprehensive quality assessment before the materials reach the customer, ensuring they meet the necessary quality benchmarks.

Along with these specifics, the database should also capture details about the lumber's storage locations. Whether the materials are stored at construction sites, warehouses, or yards, the exact rack or pallet locations should be included in the record. This greatly aids in organized storage and prompt retrieval processes.

With an aim to streamline operations within

		Geometry			Material		Tracking						
Index	Block Name	X in mm	Y in mm	Z in mm	Weight (in kg)	Wood Species	Storage Location	Source	Date received	Date sold/ used	Customer/ Project	QR Code
1	A-001	189	194	137	3.5	Douglas fir	UTSA Wood Shop	Timberlyne	10/21/2022	12/01/2023	UTSA Fabrication Seminar	
2	A-002	186	87	479	5.4	Douglas fir	UTSA Wood Shop	Timberlyne	10/21/2022	12/01/2023	UTSA Fabrication Seminar	
3	A-003	289	238	306	14.8	Douglas fir	UTSA Wood Shop	Timberlyne	10/21/2022	12/01/2023	UTSA Fabrication Seminar	
4	A-004	241	241	483	19.7	Douglas fir	UTSA Wood Shop	Timberlyne	10/21/2022	12/01/2023	UTSA Fabrication Seminar	
5	A-005	238	191	500	15.9	Douglas fir	UTSA Wood Shop	Timberlyne	10/21/2022	12/01/2023	UTSA Fabrication Seminar	
6	A-006	321	189	378	16.0	Douglas fir	UTSA Wood Shop	Timberlyne	10/21/2022	12/01/2023	UTSA Fabrication Seminar	
7	A-007	238	191	360	11.4	Douglas fir	UTSA Wood Shop	Timberlyne	10/21/2022	12/01/2023	UTSA Fabrication Seminar	
8	A-008	238	240	244	9.8	Douglas fir	UTSA Wood Shop	Timberlyne	10/21/2022	12/01/2023	UTSA Fabrication Seminar	

Figure 78 Screenshot of the online repository

an organization, the inventory management system was designed with the capacity to integrate with other operational systems, in our case the design CAD environment. The aspiration is for the inventory system to provide real-time updates across these domains, thereby enhancing operational efficiency and client satisfaction.

In conclusion, the implementation of a specialized inventory management system can significantly enhance the oversight and efficiency of managing reclaimed and salvaged lumber. By enabling meticulous tracking and accountability, all stakeholders within the supply chain remain informed about the provenance of the materials. This ensures that only the highest quality materials make it to the marketplace, boosting customer satisfaction and reinforcing a commitment to sustainable practices. Moreover, such an inventory system also facilitates a more accurate forecast of supply and demand, helping businesses to better plan their procurement and sales strategies. It also contributes to reducing waste and inefficiencies, further underlining the sustainability benefits of using reclaimed and salvaged lumber in construction.

Figure 79 The label with index and QR code

Figure 80 The finished prototype


Figure 82 Detail of stacked blocks

STACK FOR REUSE

The rise in costs and the limited availability of construction labor in recent times have placed significant strain on the housing market, causing a decrease in affordability when it comes to building houses. In order to address this issue, one potential solution is to explore the use of recycled materials and modular construction. This approach not only helps reduce material expenses but also lessens the burden on transportation infrastructure within local communities. Additionally, it becomes crucial to reassess current construction methods and strategies with an aim to enhance overall efficiency.

One method of achieving such efficiency is the adoption of prefabricated, modular systems. This case study focuses on the efficient and rapid assembly of prefabricated structural components. By manufacturing the modules offsite and transporting them to the construction site, construction timelines can be significantly shortened and labor costs reduced. This approach represents a paradigm shift in construction, where the bulk of the work shifts from the site to the manufacturing facility, leading to increased productivity and less disruption to the local environment.

The proposed building blocks for walls and the slab construction system are designed to be stackable, bearing similarity to Lego blocks. This discrete logic simplifies the construction process and renders complex assembly instructions unnecessary. The self-supporting blocks require no falsework, further simplifying the construction process.

Moreover, these building blocks serve a dual purpose, acting as construction scaffolding during the assembly of the roof slab. Skilled construction workers were able to utilize the horizontal lumber beams of these blocks as practical steps, facilitating their access to and from the roof area and enabling them to execute their assigned tasks with precision.

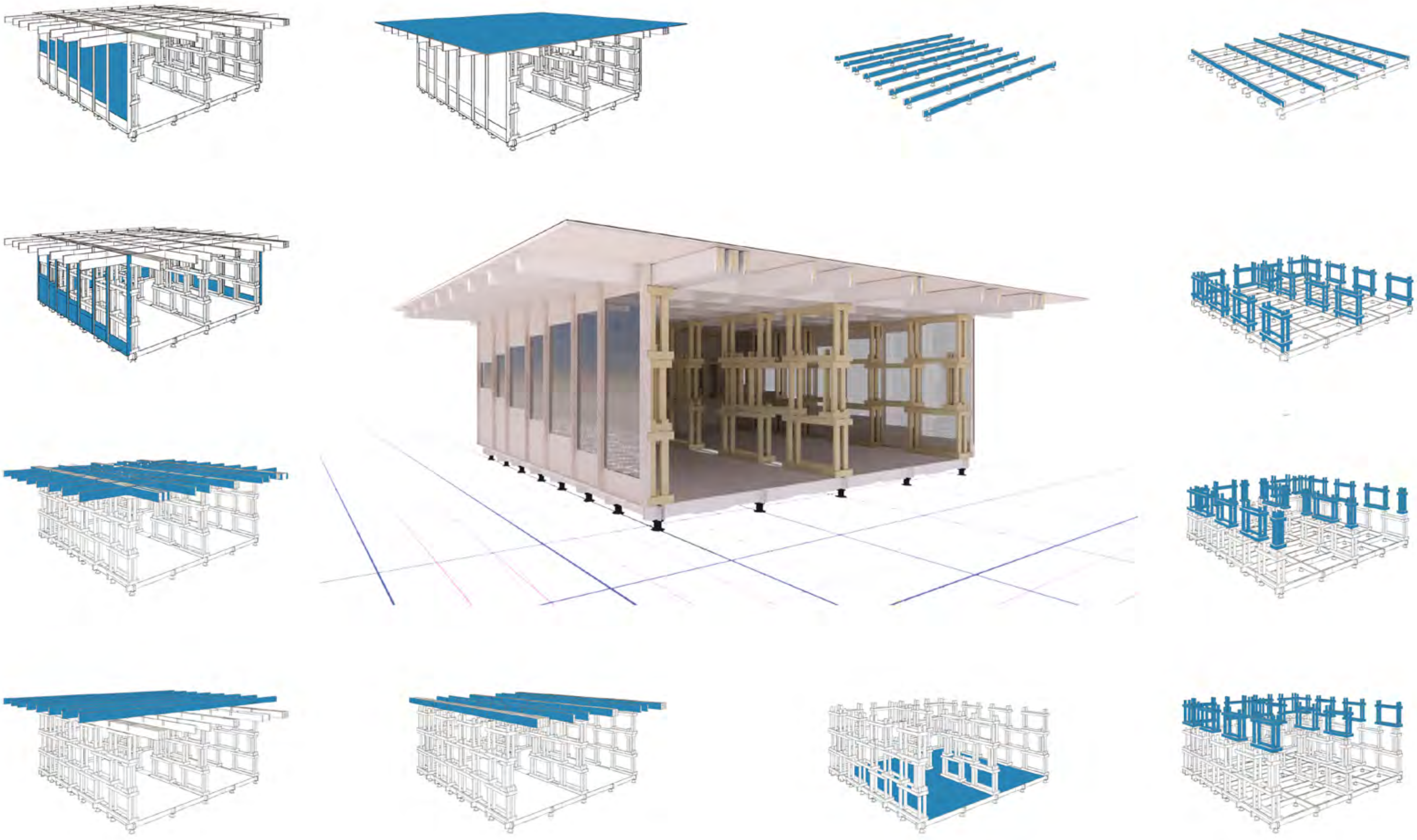

Figure 83 Assembly sequence of an ADU, starting from top right

Figure 84 Assembly process for the blocks

Figure 85 A student is using the blocks as a ladder during the construction.

Although the block design results in a thicker wall layout, the space between the studs offers multifunctional possibilities. It can be utilized for insulation, plumbing, storage, among other purposes, transforming what might be seen as a design limitation into a functional advantage.

The use of prefabricated wall systems and modular construction methods not only streamlines the construction process but also allows for greater flexibility in design. By decoupling the design and construction processes, architects and engineers can explore innovative design possibilities without being constrained by traditional construction limitations. The used blocks offer vast possibilities of combinatorics to creat an ADU as long as the design copes with the block dimensions. Consequently, the final building product can be a harmonious blend of aesthetics, functionality, and sustainability.

Prefabricated wall systems and modular construction methods have gained significant popularity in the construction industry due to their ability to streamline the building process while also allowing for greater design flexibility. By separating the design and construction phases, architects and engineers are able to explore innovative possibilities without being limited by traditional constraints. This approach offers a wide range of combinatorial options when utilizing blocks, such as creating an Accessory Dwelling Unit, as long as the designs adhere to block dimensions.

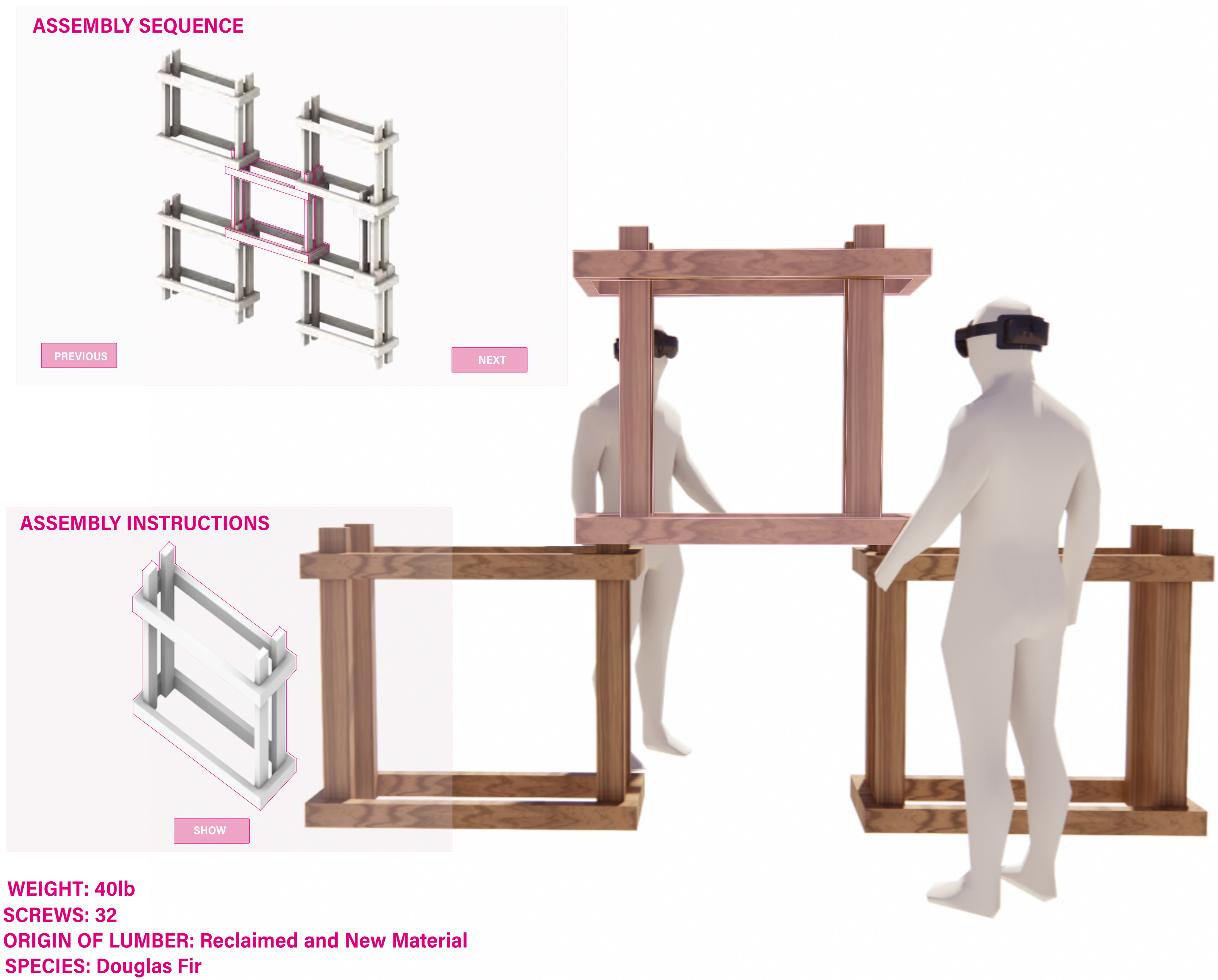

Figure 86 Concept drawing for the augmented reality instructions

The result is a final building product that harmoniously combines aesthetics, functionality, and sustainability. The use of prefabrication techniques not only saves time but also reduces waste generated during construction activities. According to research , noise levels and disruptions caused by nearby buildings are significantly reduced by approximately 30-50% with prefabricated modular constructions compared to traditional methods (Yao et al., 2020).In order to successfully implement the use of prefabricated modular construction methods, it is crucial to provide adequate training and education to the workforce involved (Zhang & Tsai, 2021). Better workforce training in the construction industry, especially in the realm of Accessory Dwelling Units (ADUs), has numerous benefits. Skilled workers are essential for any construction project, but more so for ADUs, which require workers to quickly adapt to a new construction plans due to the small size of the projects. Training helps workers to better understand the intricacies of ADU construction and equips them with the skills to efficiently and accurately complete their work. One method that can enhance workforce training in the construction industry is through the use of augmented reality technology (Nasseddine et al., 2022).

Quality training enhances workers' efficiency and productivity by helping them understand the best practices for constructing ADUs. This can reduce the time it takes to complete a project and can also minimize mistakes that could lead to costly rework. This is particularly important for ADUs, which are often

Figure 87 Illustration of the AR assembly instructions

Figure 88 The overlay of the digital model with the assembled blocks

built in tight spaces or in residential neighborhoods where delays or mistakes can have significant impacts.

Training can also improve worker safety. Construction is a dangerous profession, and ADUs often involve working in close quarters or in residential areas with unique safety considerations. By teaching workers how to safely handle equipment and materials, and how to anticipate and mitigate risks, training can reduce the occurrence of accidents and injuries on the job.

As for the use of augmented reality (AR) in workforce training and during ADU construction, it offers transformative potential (Tan et al. 2022). AR can provide a visual and interactive method of training, allowing workers to learn in a more engaging and effective manner. For instance, trainees can use AR to visualize the steps of a process, practice skills in a safe and controlled environment, or explore a 3D model of an ADU before they start building it.

During construction, AR can be used as a tool to assist workers. For instance, AR

can overlay digital images onto the real world, showing workers exactly where components should go or how they should be assembled. This can reduce the likelihood of mistakes, speed up the construction process, and ensure that the final product aligns with the design specifications.

AR can also facilitate better communication and collaboration among project stakeholders. For example, architects, engineers, and construction workers can use AR to visualize and discuss aspects of the ADU design, helping to ensure everyone has a clear understanding of the project and their roles in it. This can help avoid misunderstandings or miscommunications that could lead to delays or design discrepancies. In this study AR was used to effectivly communicate construction steps. A 3D model of the ADU to be constructed is projected onto the site, which potentially could also be used during design decisions by the property owner to chose placement and orientation of the ADU. During assembly of the prefabricated blocks, the AR system displayed step-by-step instructions and visual cues, helping the workers to accurately position each

Figure 89 Fully assembled structural parts of the ADU

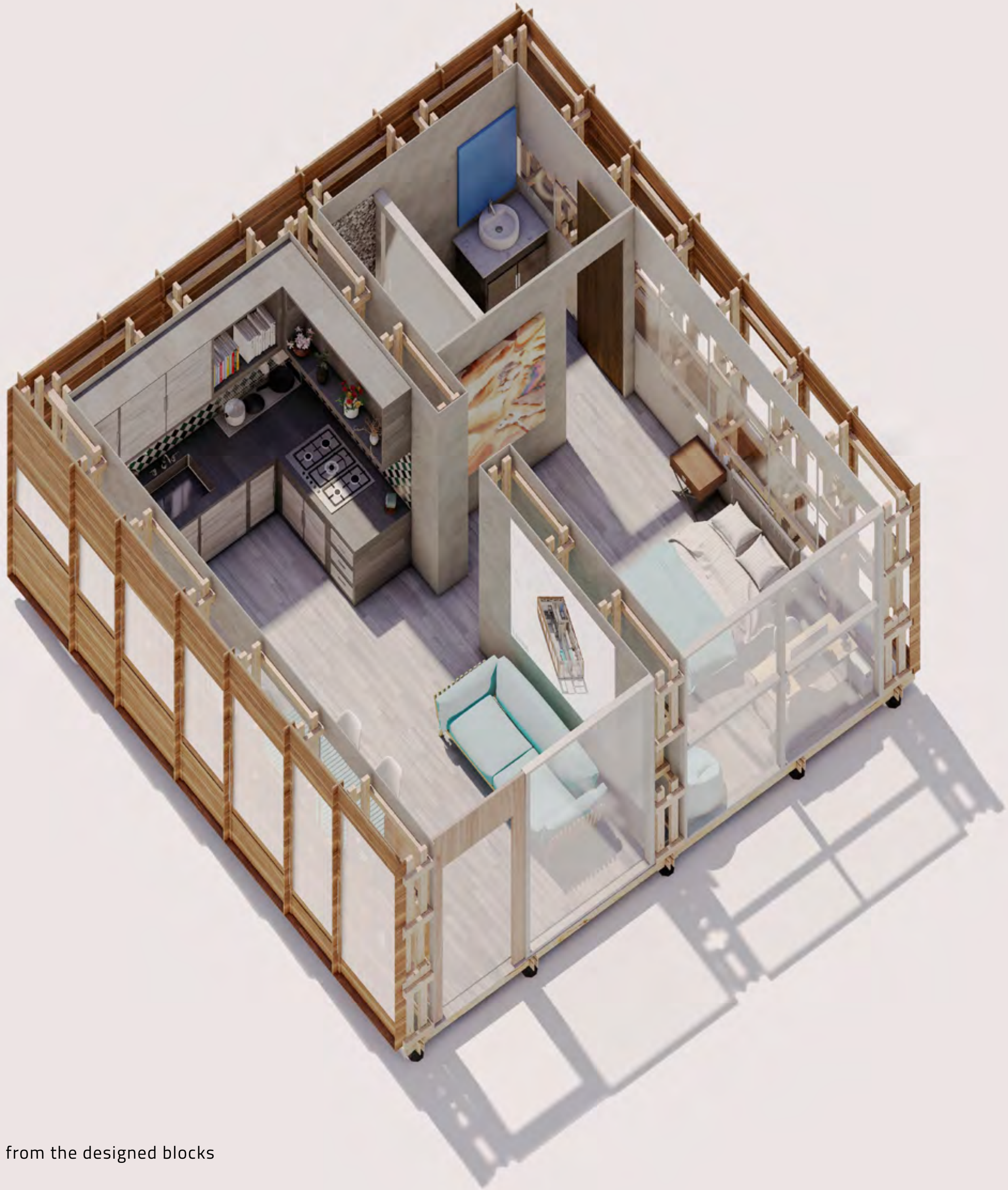

Figure 90 Topview of an ADU layout made from the designed blocks

INNOVATIVE ADU DESIGNS FROM RECLAIMED MATERIALS

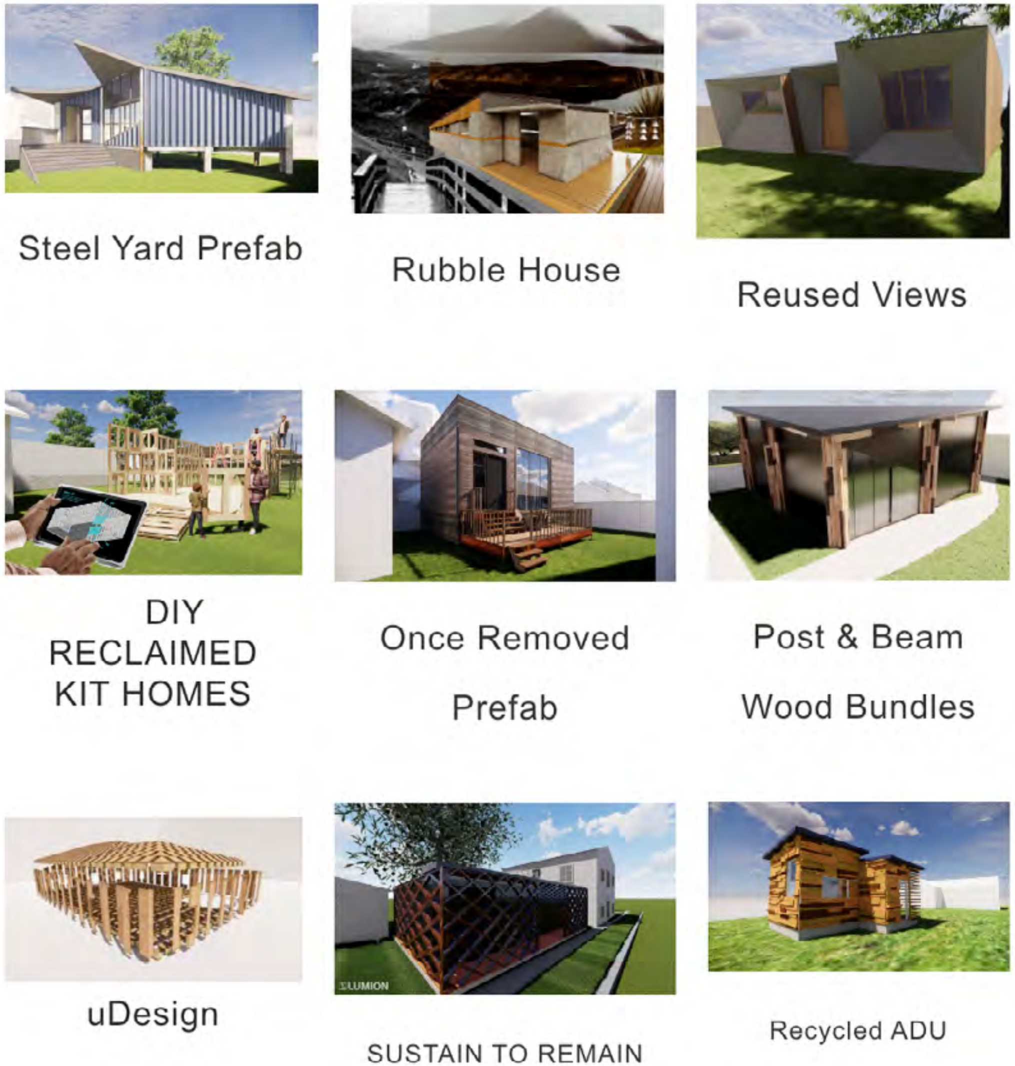

Figure 91 Nine student ADU designs

A STUDENT'S PERSPECTIVE

In the evolving landscape of sustainable design, architects and designers are increasingly turning to repurposed and reclaimed materials. Among the many housing solutions that have gained popularity, Accessory Dwelling Units (ADUs) stand out, especially in urban settings where space is a premium. This chapter delves into an intriguing project where students embarked on the journey of designing ADUs using reclaimed materials. Their challenge was not just to develop designs but also to strategize a method for non-architects to adapt these designs through an online configurator. This multifaceted challenge birthed a range of diverse and innovative solutions.

Design Objectives and Challenges

The primary objective of this project was to intertwine the principles of sustainable design with user flexibility. Students were encouraged to harness reclaimed materials to craft ADUs that not only emphasized sustainability and waste reduction but also catered to the diverse needs of potential end-users. The inherent challenges were manifold. Reclaimed materials come with their own set of constraints, be it in terms of quantity, quality, or dimensions. Marrying these with the demands of an intuitive online configurator that could accommodate such material diversity was indeed a complex task.

Diverse Material Choices

´The students' creativity shone brightly in their eclectic choice of reclaimed materials. They ventured beyond the conventional, embracing everything from the rustic charm of reclaimed lumber to the contemporary allure of old windows. These materials not only underscored the sustainability ethos but also introduced design elements that set these ADUs apart from their conventional counterparts.

Selected Designs

Of the 17 designs that were birthed from this project, certain ones stood out for their innovative material use and configurator adaptability. The project "Post & Beam Wood Bundles" is a testament to the warmth and coziness of reclaimed

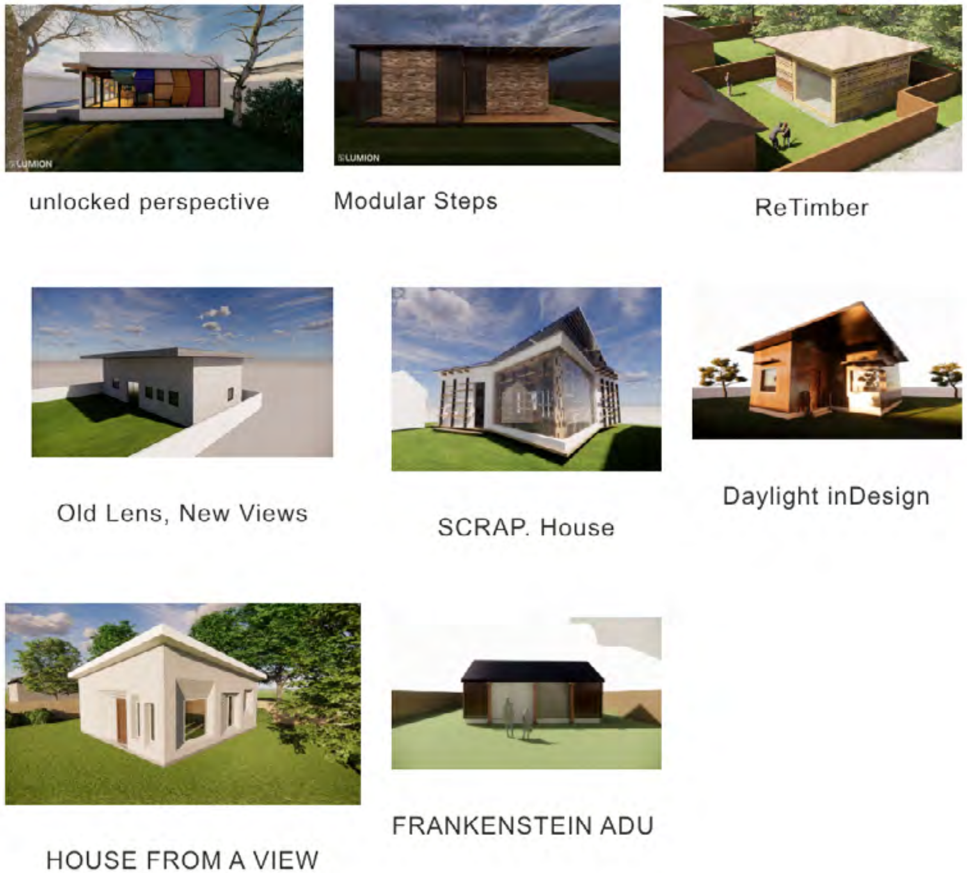

Figure 92 Eight student ADU designs

lumber, with its cabin-like ambiance. Users, through the configurator, can seamlessly adjust the layouts and even choose between different reclaimed wood finishes. On the other end of the spectrum is the "Reused Views", a design that champions old windows. It's a celebration of natural light, offering a modern, airy aesthetic. The configurator's genius lies in its ability to let users rearrange window placements, striking a balance between privacy and light.

Prototyping and Material Testing

Beyond the designs, students ventured into the realm of prototyping. These small-scale models were instrumental in testing the designs' feasibility, especially in terms of the structural and aesthetic viability of the reclaimed materials. It was this tangible, hands-on approach that truly bridged the theoretical with the practical.

The Online Configurator

Emerging as a cornerstone of this project was the online configurator. This digital tool transformed the design experience, enabling potential end-users to visualize and tweak designs to their specific requirements. Its user-centric interface ensured that even those unfamiliar with architectural crafts could design an ADU that was both functional and aesthetically sound.

Conclusion

This student-driven endeavor showcases the potential when sustainability meets innovation. The blend of creative designs with the digital configurator's capabilities paints a future where ADUs are more than just additional spaces; they're sustainable, bespoke habitats reflecting their occupants' unique visions.

For an in-depth exploration of all student designs and the online configurator, one can visit:

https://adu-configurator.weebly.com/

Figure 93 Outdoor rendering

WHEN ONE DOOR CLOSES ANOTHER ONE OPENS

Kristina Bodden

Figure 94 Topview of the ADU site

Figure 95 Prototype made from a reclaimed door

Figure 96 The shading devices made from reclaimed doors are half open, half closed.

Figure 97 Rendered floorplan

"When one door closes, another one opens." This philosophy is embodied in our ADU design, ensuring comfort for both homeowners and renters. Central to this design is the use of reclaimed doors as a shading façade, addressing the dual challenges of construction waste and privacy concerns inherent to ADUs. The abundance and standardized sizes of doors, coupled with their historical significance, inspired their repurposing into prefab wall panels. Recognizing privacy as a primary concern for both ADU builders and occupants, these reclaimed doors were innovatively used as a shading system. This design effectively balances natural light with privacy, offering a unique and sustainable solution.

Figure 98 Outdoor rendering

POST & BEAM BUNDLED WOOD

Lauren Gronnevik

Did you know that all used lumber under 8 feet typically ends up in landfills? At our company, we've taken a stand against this wasteful practice. We exclusively use wooden studs under 8 feet, repurposing what would otherwise be discarded, giving landfill-bound lumber a new lease on life. When you choose our products, you're not just getting a standard ADU; you're investing in a unique piece of art. Each of our post and beam constructions is a mosaic of different studs, each with its own history. This results in a harmonious blend of various wood species, culminating in stunning, extravagant posts and beams. Our installation process is straightforward, with each post and beam individually bonded, forming a modular construction system. Remarkably, our assembly requires no nails, glue, bolts, or any other fixtures—just pure, reclaimed lumber.

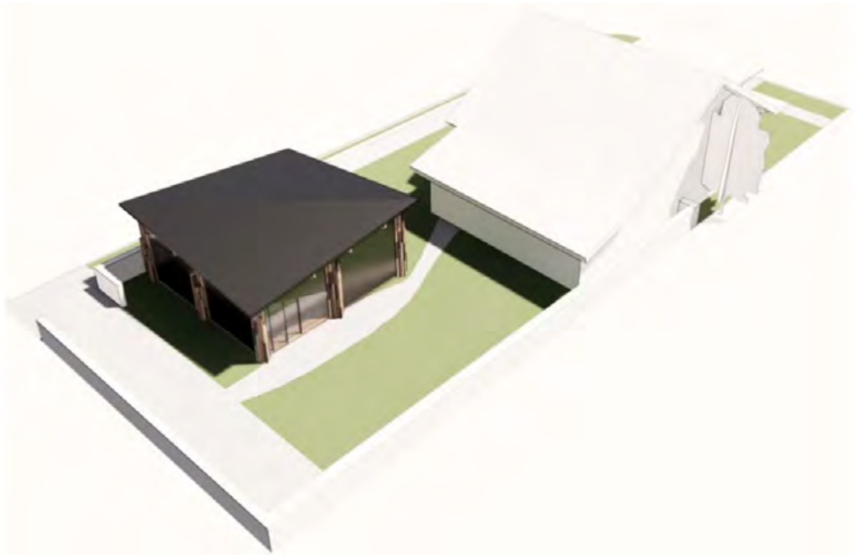

Figure 99 Topview of the ADU site

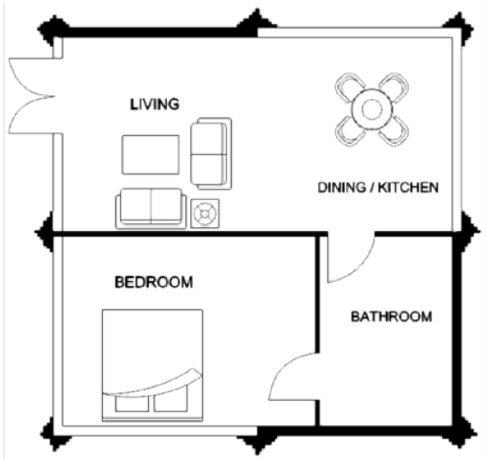

Figure 100 Floorplan

Figure 101 Rendered floorplan

Figure 102 Prototype from dimensional lumber

Figure 103 Assembly process of the post and beam structure

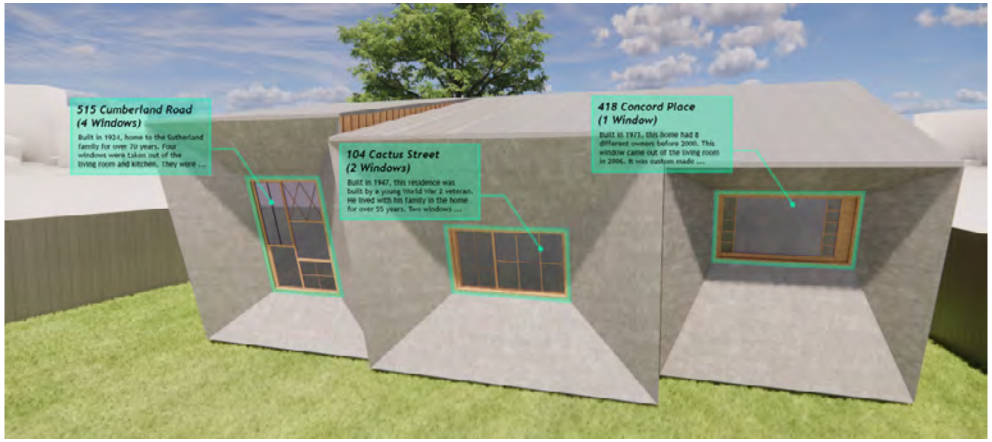

Figure 104 Outdoor rendering with infromation about the origin of the windows

REUSED VIEWS

Elizabeth Wostarek

Windows from old buildings, rich with history, can be repurposed as central design elements for new accessory dwelling units (ADUs). In this design journey, we explored various window arrangements, finalizing three adaptable designs through our interactive configurator. One notable window originated from a house built in 1918, which was deconstructed in 2022. Despite its age, the window remained in remarkable condition. Such timeless pieces can be sourced from deconstruction sites, salvage stores, or online platforms, infusing modern ADUs with a touch of heritage.

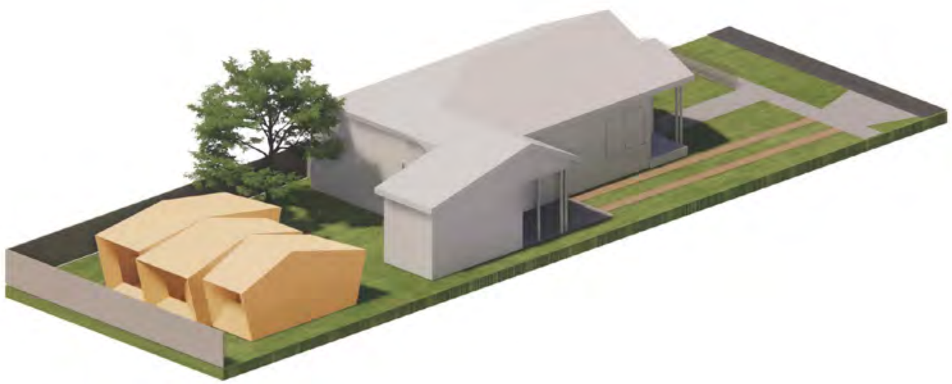

Figure 105 Topview of the ADU site

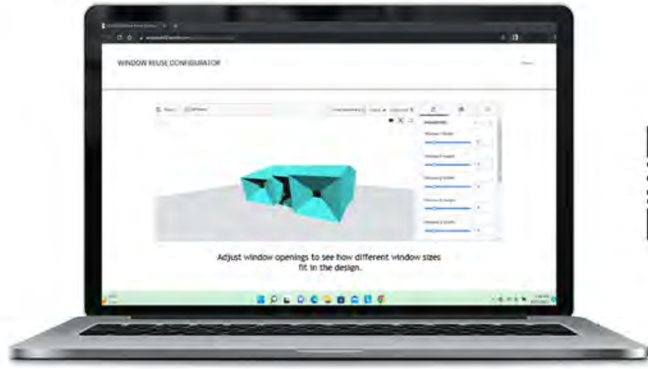

Figure 106 Online configurator

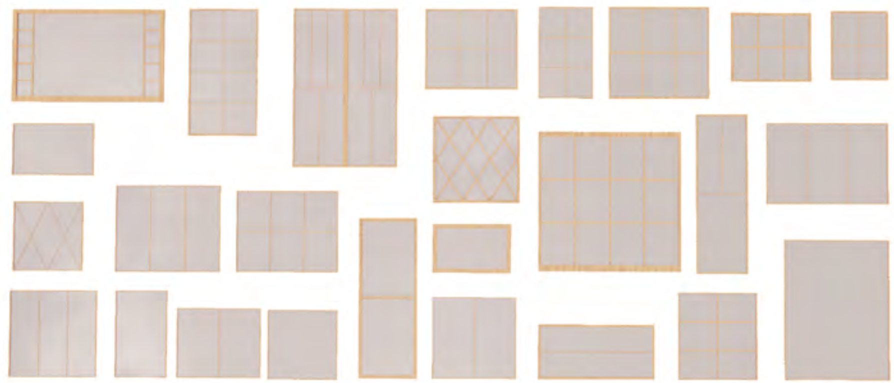

Figure 107 Size variations of reclaimed windows

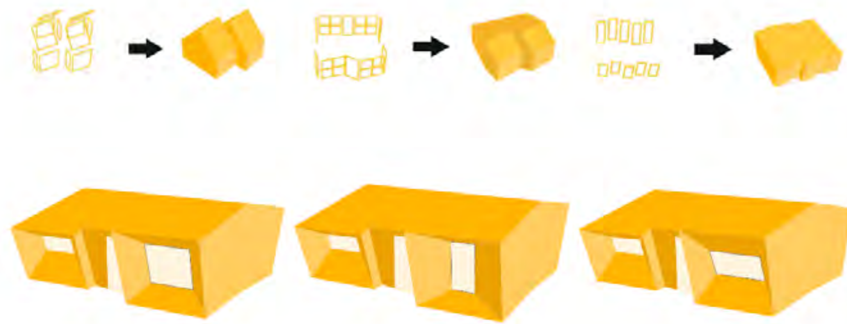

Figure 108 Arrangement options for the reclaimed windows

Figure 109 Outdoor rendering

STEEL YARD PREFAB

Matthew Maldonado

Figure 110 Topview of the ADU site

Figure 111 Prototype

ReTimber ADU advocates the idea of repurposing the past for tomorrow's construction. We salvage old dimension lumber, transforming it into the foundation for future Accessory Dwelling Units (ADU). Each piece, sourced from deconstruction sites, undergoes rigorous evaluation for its structural integrity and potential value. These reclaimed woods are then crafted into three-layered panels, designed for straightforward assembly. Leveraging our unique techniques and software, we offer a customizable ADU experience, allowing users to adjust size and layout to fit their specific space. With ReTimber, you're not just building; you're crafting a dream space from reclaimed memories.

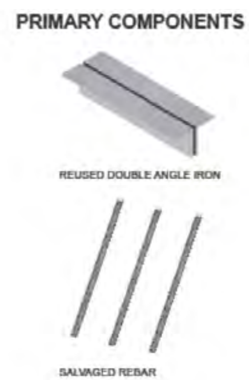

Figure 112 Salvaged metal pieces

Figure 113 Prefabrication process

Figure 114 Outdoor rendering

RE-TIMBER

Luis Flores

ReTimber ADU advocates the idea of repurposing the past for tomorrow's construction. We salvage old dimension lumber, transforming it into the foundation for future Accessory Dwelling Units (ADU). Each piece, sourced from deconstruction sites, undergoes rigorous evaluation for its structural integrity and potential value. These reclaimed woods are then crafted into three-layered panels, designed for straightforward assembly. Leveraging our unique techniques and software, we offer a customizable ADU experience, allowing users to adjust size and layout to fit their specific space. With ReTimber, you're not just building; you're crafting a dream space from reclaimed memories.

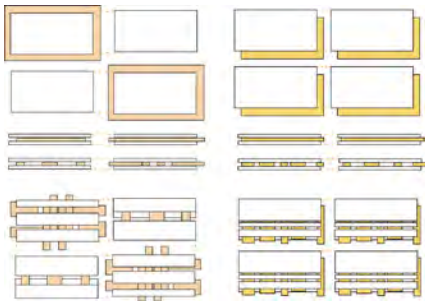

Figure 116 Arrangement options for the panels

Figure 115 Prototype

Figure 117 Closeup rendering of two panels

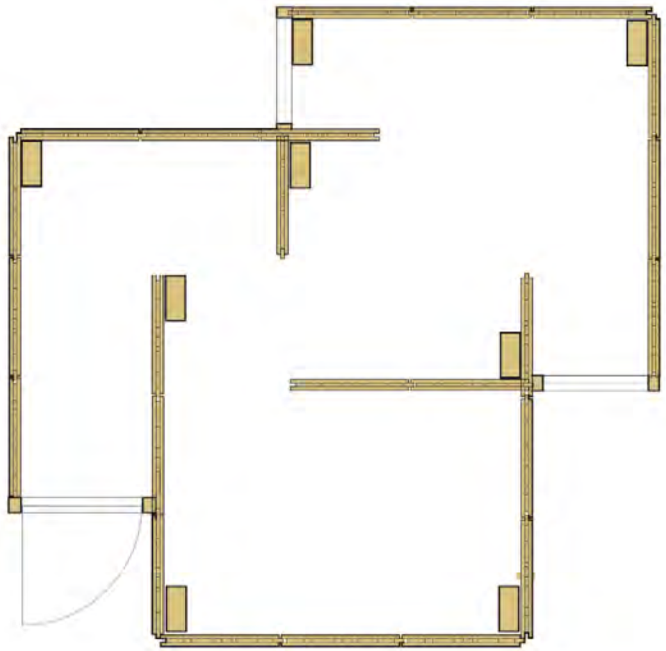

Figure 118 Floorplan

Figure 119 Outdoor rendering

DIY RECLAIMED KIT HOMES

Emy Jauer

Figure 120 Topview of the ADU site

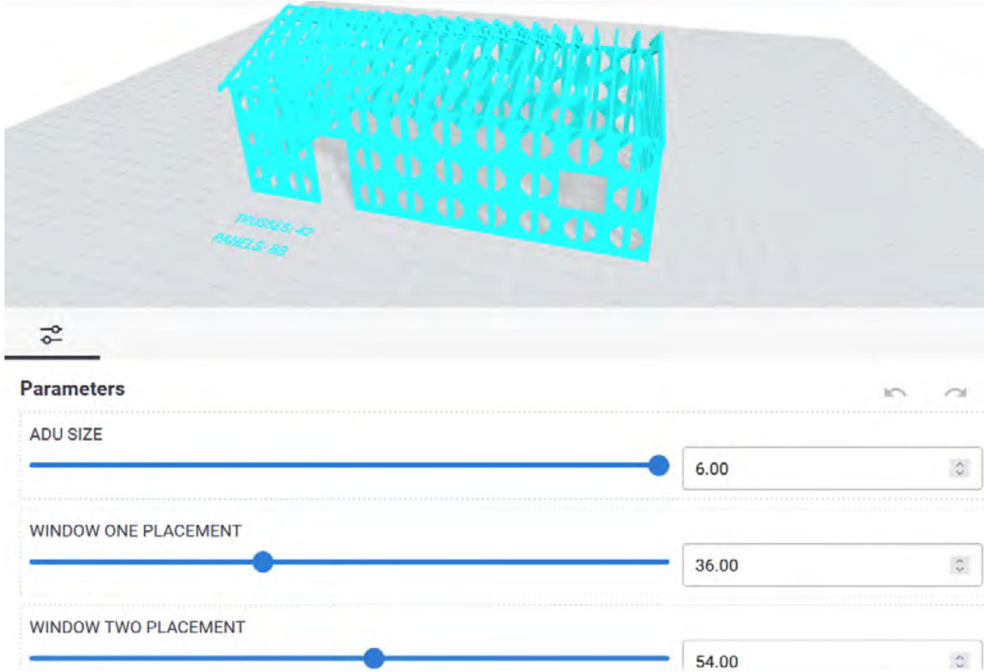

Figure 121 Online configurator

Figure 122 Prefabrication training

Figure 123 Fully assembled structure of the ADU

Timber scraps, often discarded due to non-modular dimensions, pose an environmental and resource challenge. DIY Reclaimed Kit Homes offers a sustainable solution, turning these overlooked pieces into valuable assets for addressing the low-income housing shortage. Many construction sites deem short or damaged lumber pieces as waste, but we see their potential. By repurposing these scraps, specifically 2x4s, 2x6s, and 2x8s, we've developed a modular system of sandwiched frames and trusses. This innovative approach not only conserves materials but also creates adaptable structural frames that can be reused in various building configurations, maximizing utility and minimizing waste.

Figure 124 Assembly instructions

Figure 125 Roof trusses

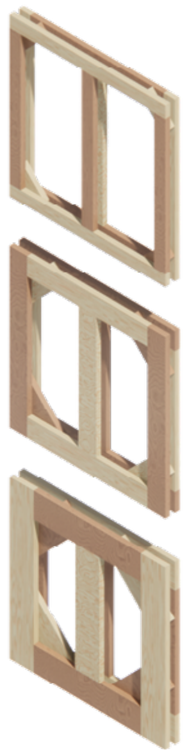

Figure 126 Panels

Figure 127 Prototypes of the panels

Figure 130 Floorplan

ONCE REMOVED PREFAB

Samuel Trevino

Utilizing a chassis foundation, our design bypasses the need for a permanent slab, promoting flexibility and sustainability. We champion repurposed construction by using reclaimed timber for structural elements like floor trusses, flooring, and exterior cladding. Beyond the structure, our ADUs are equipped with modern smart home components, including a Lithium-Ion Battery Unit and an Air Filtration ERV System, optimizing efficiency and cost-effectiveness. A notable example of our sustainable ethos is our floor truss, crafted entirely from salvaged wood waste, underscoring that even smaller discarded materials can be innovatively repurposed in construction.

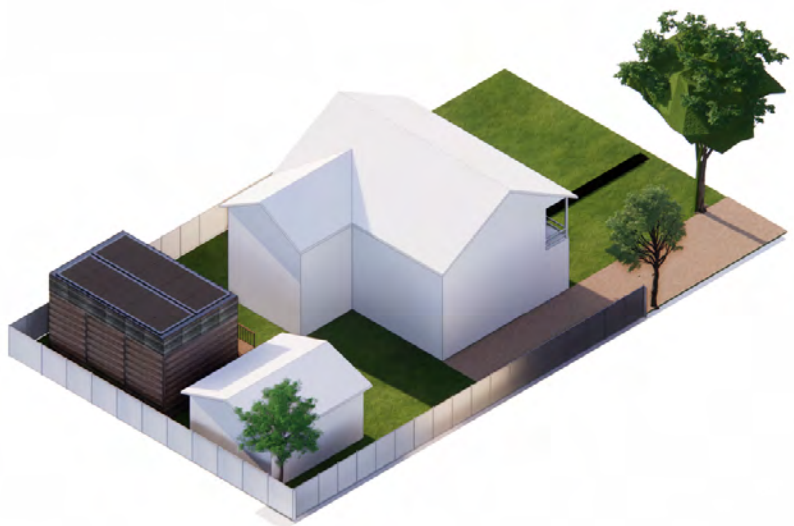

Figure 129 Topview of the ADU site

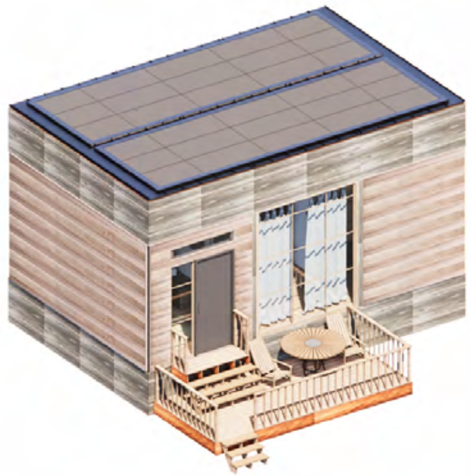

Figure 131 Isometric view

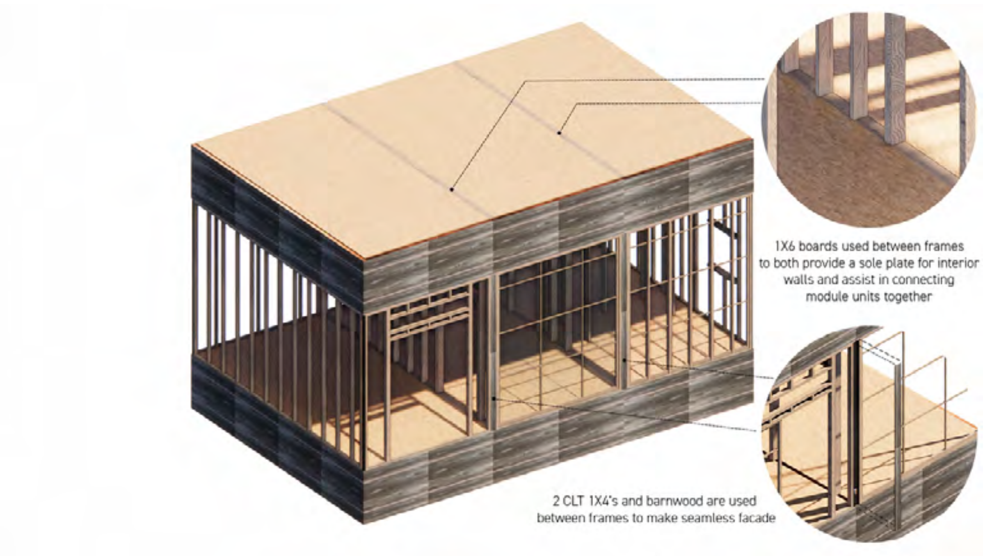

Figure 132 Wood types

Figure 133 Assembly process

Figure 134 Chassi design

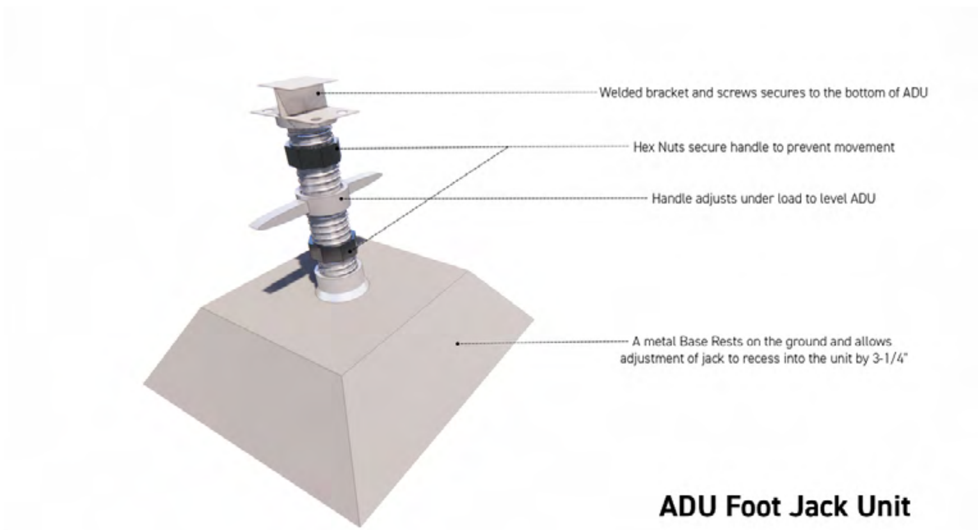

Figure 135 ADU foundation system

Figure 136 Outdoor rendering

SCRAP. HOUSE

Jacob Reyes

Figure 137 Topview of the ADU site

Figure 138 Structure

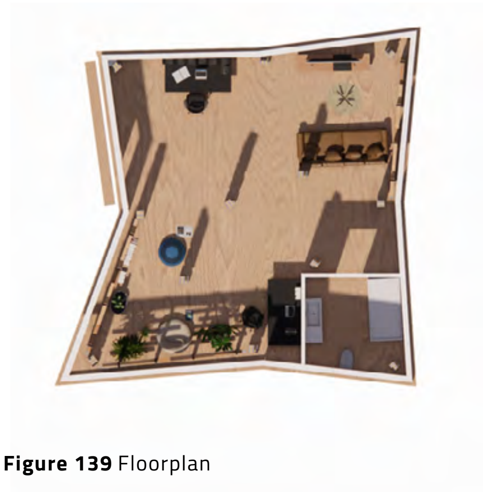

Figure 139 Floorplan

Utilizing salvaged lumber is our commitment to sustainability. Sadly, most lumber under 8 feet is discarded, deemed too short for traditional construction. We see potential in these pieces. By combining them with nails and glue, we create robust timber posts suitable for various ADU applications. One such design is "The Traditional" ADU, which follows a set floorplan and uses conventional stud framing. To simplify the process for our clients, we pre-construct these posts at our facility. Once ordered, they're transported and assembled on-site within a day. Each wood piece undergoes thorough evaluation and cleaning before being cataloged in our digital system. This database, paired with our software, optimizes wood arrangement for each post.

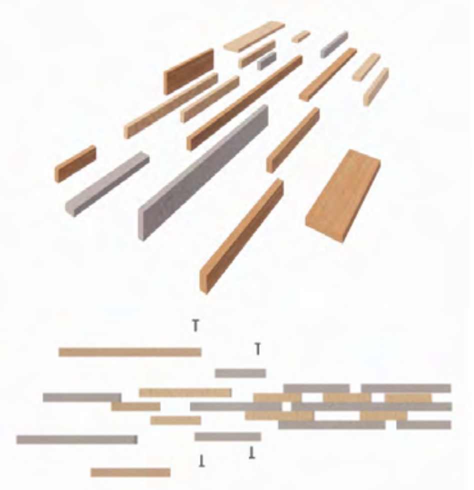

Figure 140 Assembly of prototype

Figure 141 Prototype

Figure 142 Interior rendering

RECOMMENDATIONS AND CONCLUSION

Figure 143 Potential ADU design based on a truss system

RECOMMENDATIONS

This report presents a comprehensive investigation of how the Material Innovation Center (MIC) could support the establishment of a Salvage-to-Accessory Dwelling Unit (ADU) pipeline and the formulation of suitable housing development policies. It delves into case studies exploring the use of salvaged and reclaimed lumber for ADU construction, highlighting the advantages of such an approach, while also acknowledging the challenges associated with sourcing and using these materials.

Despite these challenges, the report underscores that ADUs, owing to their smaller scale and lesser structural demands, serve as excellent platforms to experiment with the application of reused materials. To further substantiate these initial findings, it is advisable to undertake additional research exploring the viability and potential advantages of employing salvaged materials in a well-established prefabrication center. This should include the provision of adequate training for manufacturing and on-site construction at the MIC.

The Material Innovation Center's exploration into the Salvage-to-Accessory Dwelling Unit (ADU) pipeline represents a significant advancement in this discourse surrounding sustainable housing development methodologies. This research, both comprehensive and detailed, highlights the multifaceted advantages of salvaged and reclaimed lumber, encompassing environmental, economic, and socio-cultural dimensions. By examining the intricacies of sourcing and utilizing these materials, broader implications for sustainable construction practices and potential impacts on urban development and community resilience were illuminated.

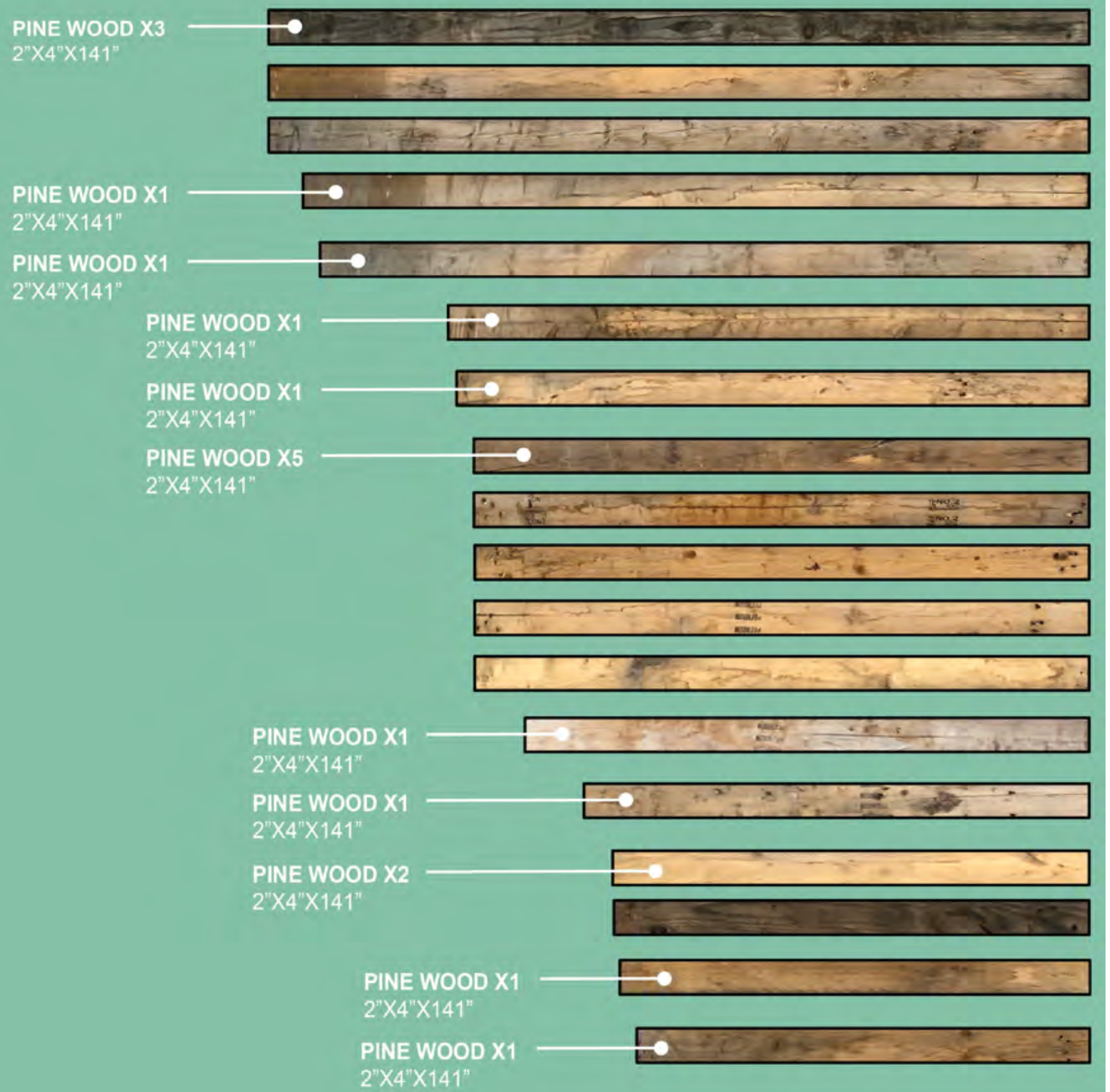

Figure 144 Reclaimed lumber pieces

Material Acquisition and Digital Inventory

The Material Innovation Center provide most of the materials utilized in this research. However, compared to the ease of browsing a conventional retailer for available material there is still a lack of infrastructure.

A notable initiative in this direction is the implementation of a digital inventory tool. The proposed tool, developed during this research, serves as an initial step to comprehensively track and categorize inventory at the Material Innovation Center. Ideally, future availabilities of structures that will be dismantled should be seamlessly integrated into local storage units' offerings. In this study, materials were sourced from two different streams: long-term storage places managed by the Office of Historic Preservation and restricted availability materials from a construction site experiencing storage challenges. Making such an inventory accessible to a network of local partners involved in affordable housing repair and production promotes collaboration within an ecosystem focused on sustainable construction practices while potentially expediting adoption.

In addition to organizing the materials in an inventory, it is crucial to develop a grading and testing system specifically for reclaimed materials intended for structural usage. Existing grading systems like ASTM D245 and National Design Specification for Wood Construction can serve as a starting point but need adaptation to accommodate reclaimed lumber. This adaptation will help address safety concerns and reduce uncertainties for designers, engineers, and construction companies involved in using these materials.

Furthermore, by promoting the integration of locally sourced reclaimed building materials, there is not only an endorsement of sustainable practices but also a compelling economic rationale for their utilization.

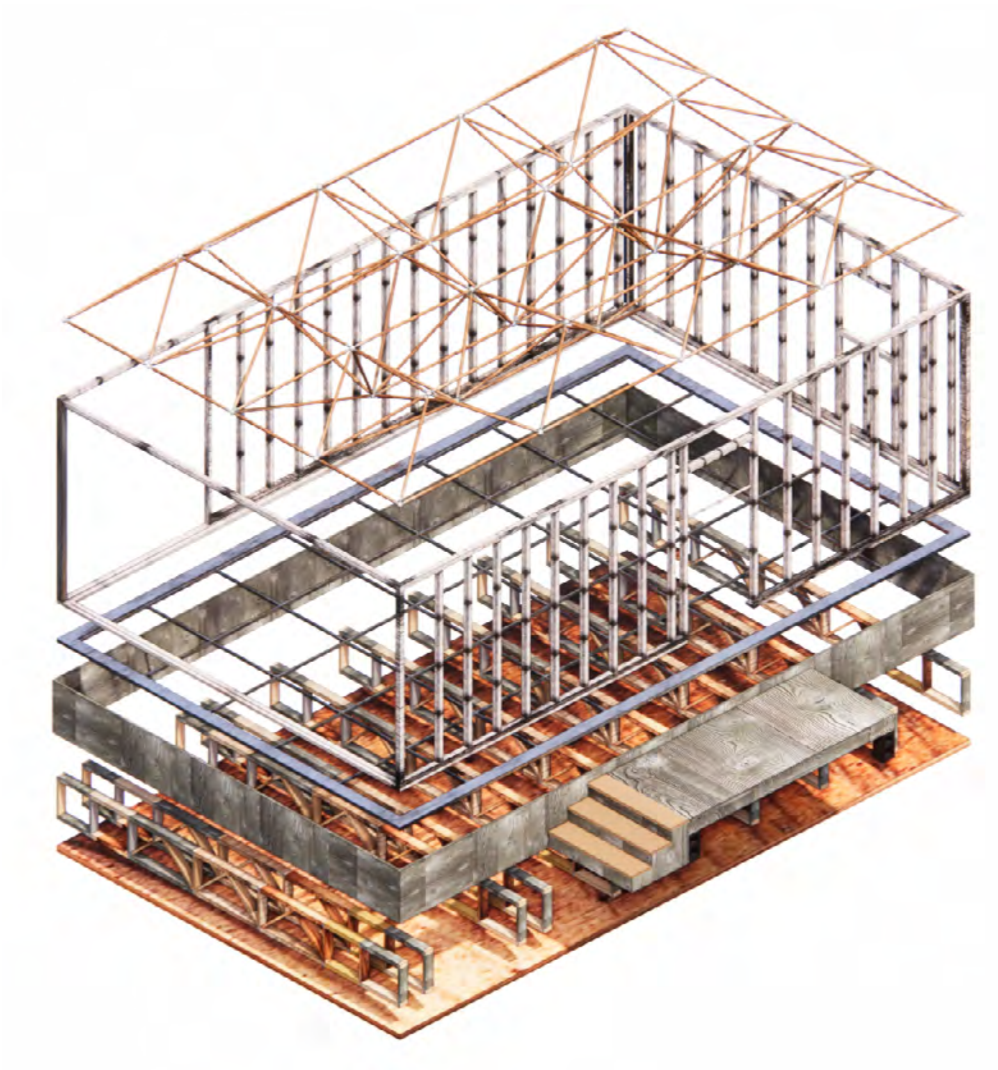

Figure 145 Various components made from reclaimed materials

Design Innovations and Incentive Structures

The study also emphasizes the need for integrating considerations for utilizing salvaged and reclaimed materials in the design process. Instead of simply reusing them in conventional ways, it is important to address potential structural limitations. Additionally, understanding the challenges associated with deconstruction and reclaiming lumber can provide valuable knowledge to designers, highlighting the importance of Design for Disassembly (DfD) as an emerging paradigm in sustainable architecture and construction. One possible approach to facilitate ease of disassembly could be through modular building systems, which would allow for effortless assembly and disassembly, ultimately extending the lifespan of materials.

Furthermore, incorporating Design for Disassembly principles in construction designs can bring about numerous benefits from a logistical standpoint including simplified construction processes, improved inventory management efficiency, and feasible transportation. To maximize the availability of secondary timber for construction purposes, it is essential to establish design standards that take into account the unique characteristics of salvaged and reclaimed timber.

A notable example of a commendable effort to integrate salvaged materials into mainstream construction is demonstrated through the development of pre-permitted Accessory Dwelling Unit designs that utilize reclaimed materials sourced from outlets such as the Material Innovation Center and other local suppliers. This initiative showcases a commitment towards promoting sustainable practices

Figure 146 Facade designs for an ADU made from reclaimed materials

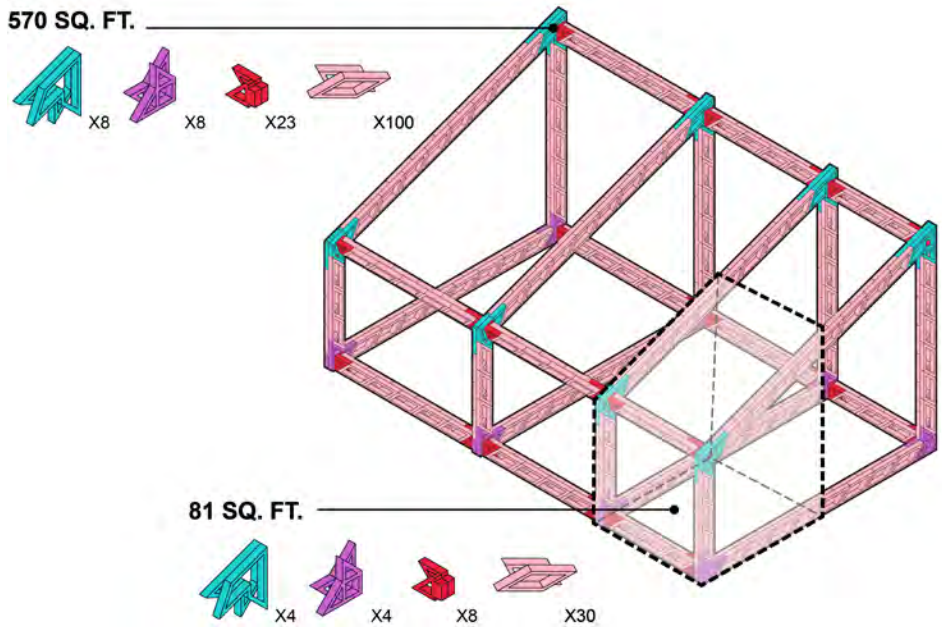

Figure 147 Components for structural assembly of an ADU

by incorporating salvaged materials in building projects.

However, it becomes apparent that the challenges for incorporating reclaimed materials are not as much in the spatial arrangement and floorplan layouts, but more so in the construction system. Two proposed prefabricated building systems present numerous possibilities within a prefab building system. The Material Innovation Center can play a crucial role in managing the manufacturing of modular components, thereby providing more certainty regarding material availability. Additionally, having a testing facility where prefabricated building blocks can undergo rigorous tests before being utilized as accessory dwelling units is highly advantageous. Prefab construction also simplifies on-site assembly, leading to cost reductions and enabling property owners to actively participate in the construction process. This becomes especially beneficial during periods when there is a shortage of workers for small-scale construction projects. Furthermore, disassembling modular components at the end-of-life stage is much easier compared to conventional framing systems. These parts can then be recirculated for new ADU constructions or sent back to the MIC for recycling purposes.

Figure 148 UTSA students duringthe deconstruction training

Research Endeavors and Educational Platforms

Throughout the duration of this research study, over 30 architecture students were exposed to the concepts and ideas surrounding the reuse of building materials. The proposal to allocate funding for additional studios and studies that validate ADU structural systems using reclaimed materials is praiseworthy. By implementing prototype projects in older residential neighborhoods, we can effectively demonstrate the feasibility and advantages of this approach. Furthermore, establishing a satellite workshop and program for UTSA students at the Material Innovation Center could serve as an incubator for innovation, fostering a new generation of professionals who are skilled in Salvage-to-ADU, Design for Disassembly, and disaster recovery research. The report also emphasizes that further research is necessary to assess the long-term durability and performance of structures constructed with salvaged and reclaimed materials. This would ensure adherence to essential building standards and regulations while confirming their structural integrity.

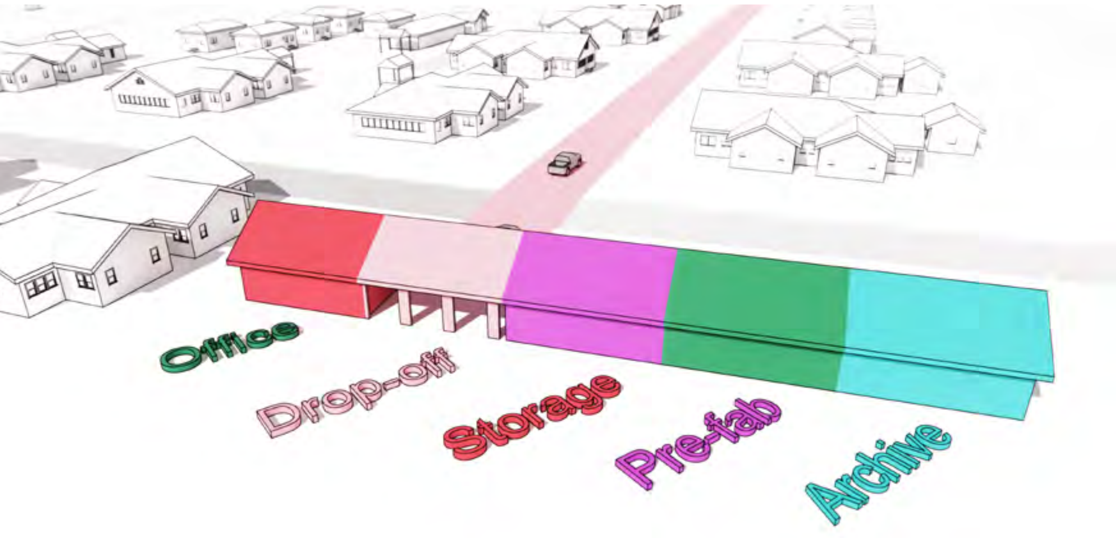

Figure 149 Concept sketch for the Material Innovation Center

Circular Economy Initiatives

The implementation of reclaimed materials necessitates a paradigm shift among various stakeholders in the construction industry, as well as the generation of novel business concepts. A circular economy accelerator program inspired by the COIL Zero Waste Economic Transformation Lab model could serve as an exemplar of MIC's progressive approach. By providing local startups and businesses with resources, workspace, and event facilities, the Material Innovation Center can establish itself as a focal point for sustainable innovation. Moreover, forging new partnerships with key players such as general contractors, material outlets, micro-research projects, innovation studios, and design workshops will further bolster the centre's position as a central hub for sustainable construction.

In order to promote sustainable construction practices, it is imperative to conduct a comprehensive analysis of current design guidelines and building codes. This will help identify any barriers that may impede the reuse of building materials, thus allowing for more progressive regulations to be implemented. Additionally, an effective community engagement campaign should be developed to generate interest in sustainable housing solutions. By educating the public about the diverse uses of salvaged and reclaimed materials - such as ADU construction or repairing homes - one can foster grassroots support for sustainable construction initiatives.

The study compared three different garage doors made from new, salvaged, and reclaimed lumber to showcase the significant potential of incorporating reused materials in construction projects. It was discovered that using on-site salvaged materials proved to be both time and cost-effective, which highlights the importance of increasing the reuse of locally sourced materials. The study also suggests that resellers who deal with reclaimed materials should improve their inventory systems for better stock management. This research aligns with Denhart's findings on deconstruction programs post-Hurricane Katrina, which emphasize the value of repurposing materials that would otherwise go to waste.

Figure 150 Prefabrication of structural components for an ADU

Figure 151 Material storage at the Material Innovation Center

Figure 152 Transport of ADU component with a pickup truck

Conclusion

In synthesizing these findings and initiatives, it becomes evident that the Material Innovation Center is a crucial and active influencer in the trajectory of sustainable construction. The design and construction tasks of ADUs are promising tasks to address an important aspect of a community-oriented sustainable built environment. Championing the use of locally salvaged and reclaimed materials, fostering collaboration, and driving community engagement positions the centre as a benchmark for sustainable construction practices. Overcoming prevailing challenges like insufficient demand and supply for recycled materials, inadequate design guidelines, and stringent building regulations could pave the way for wider implementation of salvaged and reclaimed materials. This research, therefore, serves as both an academic contribution and a directive, urging stakeholders across the spectrum to recognize the unparalleled potential of salvaged and reclaimed materials and to collaboratively advance toward a more sustainable and ecologically harmonious future in construction.

In conclusion, to foster the wider use of salvaged and reclaimed lumber in construction, the establishment of standardized design guidelines and building codes is essential. This report marks a significant step towards understanding the necessary steps towards a sustainable future in construction, emphasizing the potential and the need for efficient use of salvaged and reclaimed materials.

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IMPRESSUM

DESIGN FOLLOWS AVAILABILITY: DESIGN OF AFFORDABLE DWELLING UNITS BASED ON RECLAIMED MATERIALS IN SAN ANTONIO

Editor

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