Suburban Forestry

An Investigation into the Reuse of Native Timber in Aotearoa

by

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An Investigation into the Reuse of Native Timber in Aotearoa

How can design solutions facilitate the reuse of native timber in the built environment?

Abstract

Cities in Aotearoa are undergoing a rapid increase in density as a response to the national housing crisis. As a result, the production of building materials and large-scale demolition create mass carbon emissions and vast quantities of waste, exacerbating the ongoing global environmental crisis

As density and demolition have increased, the country's older housing stock has declined. Notably, the large quantity of state houses built throughout the 1930s-50s has seen a steady decrease. Rapid clearance of these houses to provide space for new government builds has sent much of the native timber with which these houses are constructed to landfills. As logging of native trees has essentially disappeared in Aotearoa, due to the historical depletion of forests, any native timber that ends up as demolition waste is unlikely to be replaced.

This thesis examines how architectural solutions can facilitate the preservation and reuse of this native timber. Through an iterative design exploration, this research examines how heritage and sustainability can be explored through material reuse. Physical and speculative investigations have informed an understanding of the qualities of reused native timber and how these influence the design process.

Acknowledgements

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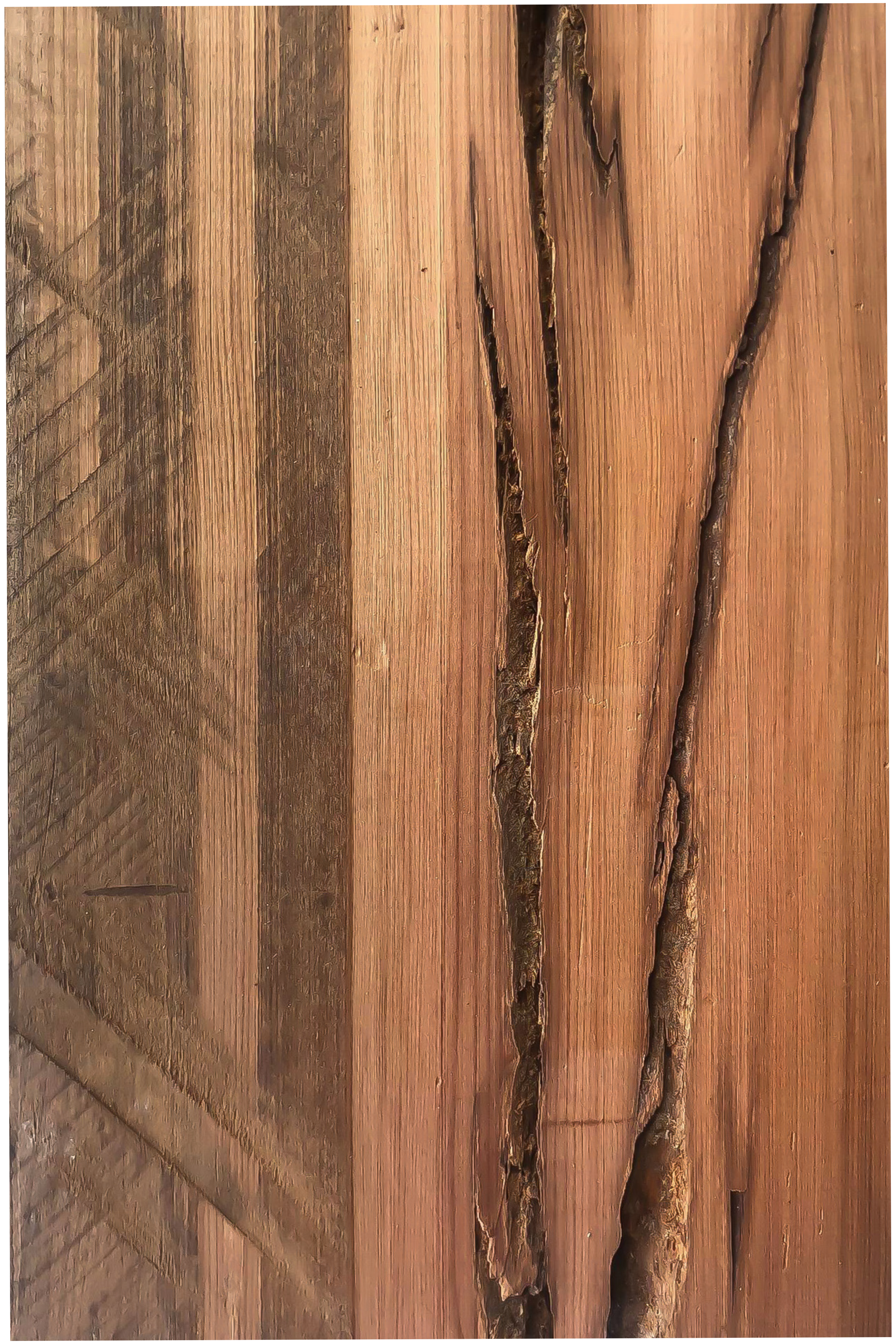
1. Introduction



1.1 Research Context

In Aotearoa, we currently face both a housing and environmental crisis. The country is currently undergoing a steady increase in urban expansion (Fig 1.01). As we rapidly attempt to build enough housing to meet the demand of those in need, concern for the environmental impact of our buildings often takes a back seat. To address both of these problems, we must consider one without allowing the other to fall by the wayside. The increasing density of our cities creates two major environmental issues. The first of these is the production of demolition waste. Single-unit dwellings are often demolished to provide land for high-density builds with the resulting waste often finding its way into landfill.

The second issue is the increased need for new materials. While steps are being taken towards using sustainable, low-carbon building materials, the consistent production of materials maintains consistent carbon emissions for each new building. Material reuse offers an alternative to the current systems that are currently escalating these issues. By applying materials taken from demolished or deconstructed buildings to new builds, the loop of material production and use can be closed. A focus on deconstruction rather than demolition will facilitate more complete reuse.

The justification for reuse, however, goes beyond sustainability. Aotearoa has an extensive history of timber architecture and craft, dating back to its earliest human inhabitation. This architectural tradition was facilitated by an extensive range of native timbers, many of which are of extremely high quality and durability. However, mass forestry and exporting of native timbers ranging from the colonial period to the late 20th century have caused a depletion of Aotearoa's forests (McGlone et al, p. 10, 2022). The slow-growing nature of many of these trees has meant that forestry of native timbers has essentially disappeared.

Disappearing also at an increasing rate is the presence of these timbers in our built environment. Ageing homes are reaching the end of their lifespan, no longer fitting the needs of Aotearoa's cities. Leaky and poorly insulated homes are commonplace in Aotearoa as the result of material deterioration and construction faults (Cooney, p. 42, 2010). The removal of deteriorated homes and the clearing of land for increased density over the past few decades has removed much of the native timber from our built environment Some of this now composes a portion of the large volumes of timber contributed to landfills each year (Fig 1.00). The use of native timber floors, cladding, windows,

Material Type

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Weight in Tonnes

Fig 1.00 Composition of Waste Disposed of to Landfills in New Zealand 2020 - Ministry for the Environment

and doors has diminished greatly as aluminium, plasterboard, and MDF takes their place. Native timbers are already seeing some reuse in our built environment, but this tends to take the form of bespoke elements such as furniture or bench surfaces often created by individuals for their own homes.

The development of architectural systems designed around the facilitation of reuse, if implemented, could encourage the preservation of native timber on a much larger scale. Structural reuse of materials poses risks to building integrity, particularly in materials as often imperfect as timber. A focus on cladding, rather than structure, could bring valuable material from being hidden in the framing of a house to being a visual asset. This would increase not only the presence of heritage materials in the built environment but act as a prompt for the reconsideration of material reuse.

These issues converge in the large-scale removal of low-density state houses that is currently occurring in Aotearoa. These houses were constructed across the country during the 1930s-50s. While portions of the stock of these houses have been sold by the government periodically, many are still state-owned. The clearance of these government-owned state houses often provides land for higher-density builds, leading to large-scale demolition (Kelly, 2021). The reintroduction of the native timber from these houses into the built environment would offer an encompassing solution to the issues of demolition waste, material reuse, and heritage preservation all presented by Aotearoa's increasing density.

This thesis will propose a method of reusing this timber through a circular cladding system. The research will seek to understand the material, its inherent qualities, and how it can be repurposed. This will influence several cladding explorations designed around the qualities, availability, and limitations of the material. The iterative design of a cladding system will provide a means of exploring reuse-based design and the processes that facilitate it.

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Fig 1.01 New Homes Consented, Selected Regions, Rolling Annual, March 1991-November 2019 - Statistics New Zealand

1.2 Methodology

The process of design in this research was informed by investigations of the context surrounding native timber use in Aotearoa and the wider practice of material reuse. Case studies and analysis of relevant literature informed a more refined understanding of the principles and goals of material reuse in the built environment. These established a material source as a basis for design. This context was used to provide an initial set of design constraints under which to begin an iterative design investigation through digital drawing and small-scale modelling.

Early iterations were informed by contextual research, with design-led outcomes used to generate conclusions for more refined parameters. This informed a more specific iterative process based on design outcomes and speculative applications. 1:1 modelling contributed to both design refinement and to the understanding of reused native timber's physical properties through making. These findings then informed the creation of a prototype and an investigation of potential application. This method of design operates within the processes outlined in Bruce Archer's operational design model, in which design iterations are initially informed by an array of data (Rowe, p. 49, 1987). These iterations in turn contribute findings to this data, resulting in a refined set of parameters and narrowing of scope for further design. The concluding design outcome of this research has been used to form a series of theoretical applications, limitations, and potential avenues for research continuation.

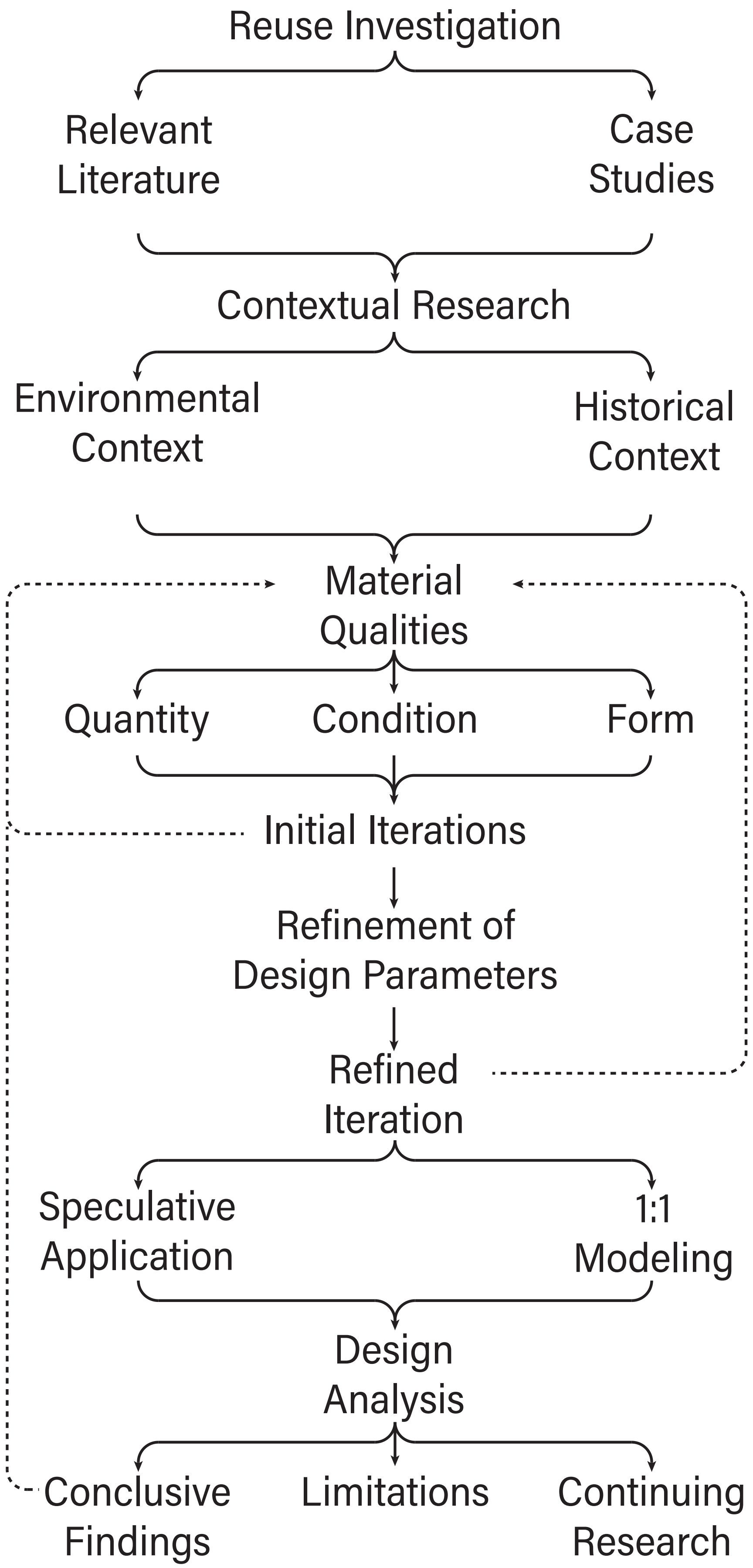

Fig 1.03 Research Methodology Diagram

1.2.1 Scope

This research aims to investigate how design solutions can be developed to enable the continuing reuse of native timber. Design solutions will be informed by explorations of wider circular reuse in the built environment and an investigation into the context of native timber in state housing, both historically and in the present day. For the purpose of this thesis "state house" or "state housing" will be used to refer specifically to those built during the 1930s-50s.

Investigations of the physical qualities and potential limitations of reused native timber will be undertaken. This will be used to develop an iterative series of cladding system design outcomes. Designs will be developed specifically around circularity and will respond to the qualities of reused native timber.

The development of a cladding system in this research is a means of investigating how reused material influences the design process. This research is concerned with the use of materials post-demolition and deconstruction through the process of iterative design, rather than performance testing or an exploration of economic viability.

1.2.2 Aims

This research aims to better understand how reuse-based architecture can preserve disappearing materials in the built environment. It also aims to offer alternatives to construction systems that contribute to climate degradation and produce large volumes of waste. The objectives of this research are:

To understand the use of native timber in state housing and the forms, conditions, and quantities in which it appears.

To undertake an iterative design process that produces a potential architectural application for reused native timber.

To understand the process and the limitations of reuse-based design.

To explore alternative architectural systems that operate within a circular built environment, rather than a linear one.

2. Material Reuse in the Built Environment

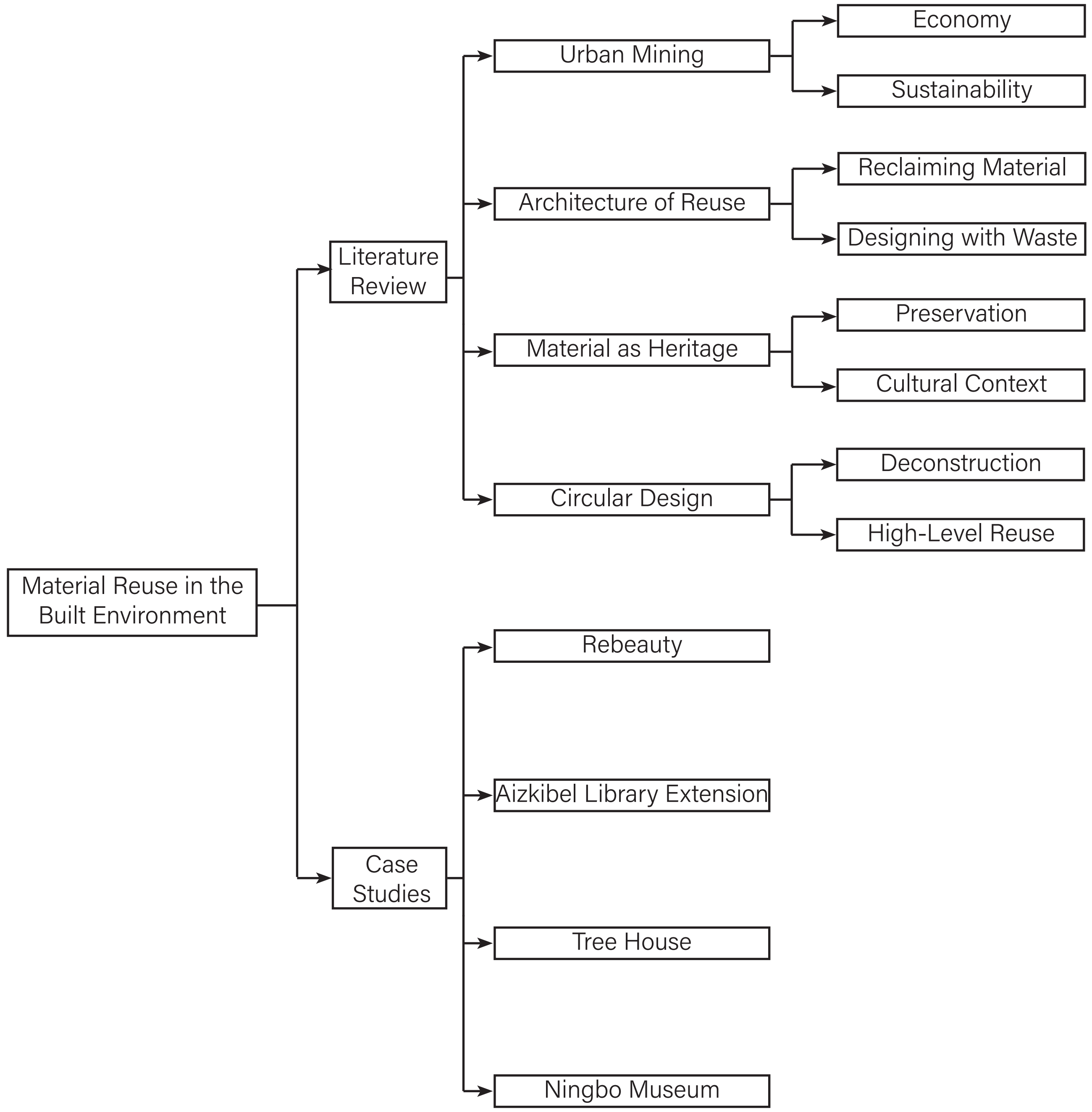

Fig 2.00 - Material Reuse Investigation

2.1 Literature Review

Ideas of architectural reuse and a circular built environment have been suggested since Jane Jacob's concept of "Urban Mining" in the 1960s. It is only by understanding the larger context of material reuse that the application of this within Aotearoa can be made possible. This literature review takes place in four parts, each aimed at understanding different economic, environmental, and cultural areas in which material reuse operates. The first of these is an investigation into the concept of urban mining, an environmental and economic approach to cities and buildings as a wealth of material. The second is a review of the guides that have already been laid out for those wishing to reuse materials within the context of architecture, as well as relevant theses relating to the issue specifically in Aotearoa. The third focuses on work that has been carried out tying material reuse to architectural heritage. The fourth section aims to understand research that has been conducted around circular architectural systems.

2.1.1 Urban Mining

Incorporating systems of reuse into our built environment is not a new concept. An early piece of literature addressing this is Jane Jacobs' *The Economy of Cities*, which introduces the concept of "Urban Mining". In *The Economy of Cities*, Jacobs proposes that cities should create systems for the circular use of not only materials but for chemical and water wastage as well. Although many of the proposed solutions in this writing have become redundant with changing perspectives on sustainability, the theory remains a strong blueprint for understanding the complete lifespan of production and the total reuse of all elements of a city. Jacobs' work pioneered the concept of a circular economy and outlines the potential in cities to both consume and produce through how we use waste. She theorises that "cities will become huge, rich and diverse mines of raw materials" and that the continued exploitation of the resource contained in our built environment would expand our capacity to reuse and further the economic viability of a circular economy (Jacobs, p. 110, 1969). Michael Braungart and William McDonough's *Cradle to Cradle* is another important piece of literature relating to circular systems of resource consumption. The theory posed in their writing is that our current system of consumption is linear, i.e., "cradle to grave". Several approaches are suggested for creating a circular system or "cradle to cradle" system. This reconsiders contemporary understandings of sustainability, such as a focus on biodegradability, to prioritise reuse and upcycling as a means of extracting more value from the materials and resources in our products. The concept of reuse is outlined through various economic lenses, such as the consideration that "the energy, effort, and materials that were put into manufacturing… are lost to the manufacturer once the customer purchases" (Braungart, McDonough, p. 112, 2009). Mark Gorgolewski's *Resource Salvation* lays out a series of strategies to be incorporated into reuse-based systems. Gorgoleski suggests that a fundamental reconsideration of ownership is the key to true circularity and would encompass an increased focus on service, performance, and transformation as a means of creating an increased value of material (p. 26, 2017). The central thread that links theories of urban mining or a circular economy is that the process must consider much more than simply materials and their qualities. There is a heavy emphasis on economic efficiency and the interests of stakeholders and producers.

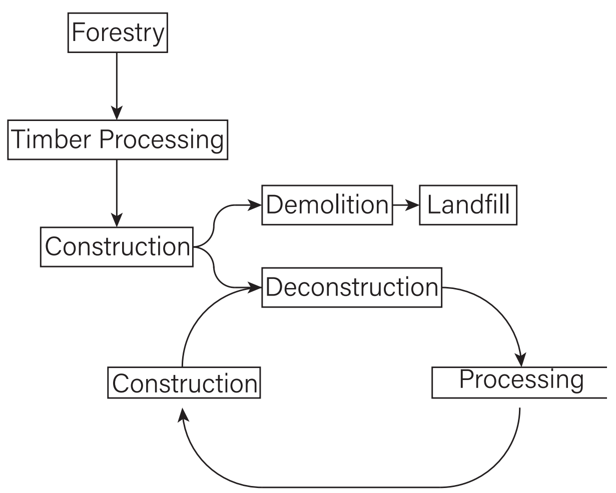

Fig 2.01 - Urban mining applied to timber in the built environment

The processes of reuse that are suggested in Jacob's work are expanded in contemporary works based on the circular economy. These systems suggest the introduction of new roles and procedures within the businesses that supply materials. As additional lifespans for products are introduced, so must additional appraisals and quality checks. This may, under the systems outlined by the theorists discussed prior, reshape the role of the supplier. As businesses make the effort to ensure that their products may be efficiently reused, so too will they create potential economic benefits of reclamation of products that have reached the end of their current lifespan. This research will investigate a second role that must occur during the process of material reuse: that of the designer. Design experiments carried out with reused materials will help expand the pool of knowledge when the applicability of material is considered within the framework of a circular economy.

2.1.2 Architecture of Reuse

Material reuse specific to architecture has two main areas of relevancy. The first is the consideration of existing buildings. This includes the complete or partial preservation of a building and the reuse of individual components from a building that is being demolished or deconstructed. The second is how reused components can be incorporated through design. This encompasses both architectural and non-architectural components and their incorporation into architectural design.

Bill Addis' *Building with Reclaimed Components and Materials* is an encompassing guide to the reuse of construction and demolition waste. Understanding materials as they appear within existing buildings allows the design of systems based on materials other than those currently in possession. Through methodical categorization and testing of standard materials that are utilised across several architectural typologies, Addis creates a framework for viewing a building as the sum of its total material wealth as "when designing buildings to incorporate reclaimed products and materials it becomes virtually essential for the project team to identify the source of suitable materials and products before detailed design can commence, and before specification and tendering is undertaken" (Addis p. 1, 2006).

Whole House Reuse is an Aotearoa-based project that examines the process of design stemming from material claimed from a condemned Christchurch home and the decisions one is pushed to make when committing to total reuse of all the materials in a building. Project director Julie Arnott describes the process as "an opportunity for examination, transformation, and reuse of the often-overlooked resources that make up one home. This project presents those resources to the creative industry and offers the challenge to design and produce viable solutions to the waste occurring" (p. 9, 2014). *Whole House Reuse* sets itself a dogmatic approach where everything must be used. This forces an adaptable design approach. Often when materials are reclaimed from demolition, there is still a division between what is considered "usable" (e.g., timber, bricks, furnishings) and what is considered "waste" (e.g., insulation, nails, wallpaper). When we can shift our perception away from disregarding these materials then we can begin to develop design strategies that keep them in use.

On the more hands-on side of reuse-based architecture is Dan Philips, founder of phoenix commotion, who built houses out of 70-80% recycled materials. The design of these houses is fluid and changes throughout the construction process depending on the availability of materials. This grassroots approach to reuse serves to provide test examples for reuse across a range of materials and provides an example of a more symbiotic relationship between design and material. The original intention of the material is no longer important in favour of efficiency and wastage avoidance. Phillips questions the preconceptions we have around architecture and how ideals of perfection often cloud our vision, stating "If something isn't perfect, if it doesn't line up with that premeditated model? Dumpster" (2010) This creates a focus on the inherent quality of the materials used. For example, a broken sink loses its association with this original intention and becomes simply a piece of porcelain, usable in a wider variety of applications. While Philips' work offers interesting precedent for the re-imagination of material use, the case-by-case basis under which each house is constructed provides systems that are difficult to replicate. What can be applied to this research is the underlying conventions, such as repetition, to extract use from as wide a range of material as possible. A similar reimagination of material can be seen in examples of the work of Superuse Studio. The studio outlines several strategies with which to approach material reuse. One strategy is the employment of "Material Driven Design". This results in a "Dynamic Final Design", which can vary until the entire project is complete, as "when the design is fixed and the search is on for specific suitable used materials, the chance of success is smaller" (Superuse). Reducing the perception of a material to its qualities (size, shape, colour, durability etc.), rather than its original use, can open up the potential design outcomes and allow the relationship between material and outcome to become more informed.

2.1.3 Material as Heritage

The nature of reuse, as opposed to recycling, is that the material retains some degree of association with its previous use. Specifically, when we see a material that is worn, damaged, or marked in some way, we associate these imperfections with a past existence. One of the most common ways this association appears in architecture is through work in heritage preservation. This can be framed as the reuse of a building in its entirety or segments (e.g., a façade) within its original context. *Rescue and Reuse* focuses on the holistic nature of heritage revitalisation and preservation and its benefits on a social, economic, and environmental level. A key focus in the preservation of heritage architecture is that it provides an incentive to keep vernacular craft skills alive as these skills are required to work most effectively with older materials and building techniques (Morrison, Waterson, 2019).

However, in the rapidly increasing density of cities across Aotearoa, complete preservation is not always a viable option. This is where the ideals of heritage and the retention of vernacular craft begin to filter through into material reuse. A notable example of this is the work of Wang Shu. Shu employs traditional folk craftsmanship that has generally been lost in China (Chau, p. 361, 2015). By working closely with craftspeople to reinvent these traditional techniques for a modern context, Shu is able to reuse bricks and tiles that have been salvaged from local villages that have been demolished (p. 359, 2015). The work of Gordon Matta-Clarke also investigates the use of reframed material to gesture to its original context. Matta-Clark's *Bronx Floors*, which took small rectangular sections of a floor, exposing the entirety of its composition. This created an object that was "threaded with the seams of their former architectural life" (Lee, p. 77, 2000). While this work considered buildings as sources for art rather than architecture, there was still a focus on the material qualities and Matta-Clark took a preservationist sensibility towards New York's condemned buildings (Lee, p. 73, 2000).

Between these approaches to heritage, three levels of reuse are made apparent. The first is preservation within an original architectural context, concerning the immediate historical context of a building. The second is reuse within a new architectural system, concerning vernacular building techniques and materials. The third is reuse outside of architecture, concerning ideas of the recontextualization of an object outside of its original intent. Understanding the role heritage plays in reuse introduces several approaches to utilise in this research. The use of vernacular craft is a valuable tool for understanding how best to work with materials that have been created for use in more traditional systems. Buildings that utilise architectural heritage as a visual tool allow themselves the use of a majority of materials

regardless of condition or age. This means that a system that can successfully function around imperfection and avoid excessively altering materials is an ideal outcome.

2.1.4 Circular Design

As well as reusing material from demolition, an essential means to waste reduction is the creation of a continuous circular system. *The Architecture of Waste* outlines the introduction of a "New Deconstruction", repurposing the use of the term that traditionally addresses an established architectural style to refer to "a literal deconstruction in which a large proportion of the materials used are designed to be demountable and reused in the future" (O'Donnell, Pranger, p. 192, 2020). One specific precedent discussed in *The Architecture of Waste* is the UMAR unit on the Swiss Empa campus. This building is designed to be completely disassembled at the end of its lifespan, with connections between architectural elements free from adhesives that could limit deconstruction (p. 198). Circular design also features in Superuse Studio's design strategies, termed "Demountable" or "Detachable" construction and "ensure[s] that materials and building elements can be released without damage during maintenance or at the end of their lifespan". *Defab* addresses mounting construction waste by investigating how "light timber framed buildings might be redesigned to be more readily deconstructed into individual material components for reuse at the end of their useful life" (Finch, 2019). Finch's project challenges conventional construction techniques that lack concern for wastage designing not only around circularity but around efficiency and accessibility through the design of a set of computer numerical control (CNC)-routed parts that combine to form a modular structural frame. Vandkunsten architects, in their *Rebeauty* project, term their approach to circular design "high-level reuse" (p. 10). This is the process of reinterpreting demolition waste as materials to be used for circular architectural systems. By designing systems with reused materials that encourage reuse themselves, a longer-term solution is offered for the prevention of waste. Where recycling offers a series of diminishing loops of reuse, circular design offers a consistent cycle.

2.2 Case Studies

2.2.1 Rebeauty

Stemming from a renovation that resulted in the removal of vast amounts of wood flooring, Rebeauty is Vandkunsten architects' investigation into the aesthetics, feasibility, and performance of interior and exterior claddings designed around the use of reused materials (Vandkunsten Architects, p. 3, 2017). This involved a series of prototypes designed around the concept of "high level reuse", i.e., not only reusing materials but facilitating their continued reuse using demountable systems (p. 10). There are a few guiding design techniques that are evident across each design featured in the Rebeauty project.

The first of these is an adherence to the current form of the material. Systems are dictated by the current form of the material. This means that leniency around heights, thicknesses, and widths becomes an essential part of each design. Battens are a primary element (Fig 2.02, 2.04), with uneven grids created according to the available resource to which panels can be mounted. This is aided by the second guiding design principle, which is the use of perforation-free mounting systems. Steel brackets and wedges allow full removal free from damage alongside tolerance of profile variations (Fig 2.06).

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Fig 2.02 - Steel prototype

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Fig 2.04 - Folded metal shingle

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Fig 2.03 - Pantile facade prototype

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Fig 2.05 - New Nordic wall

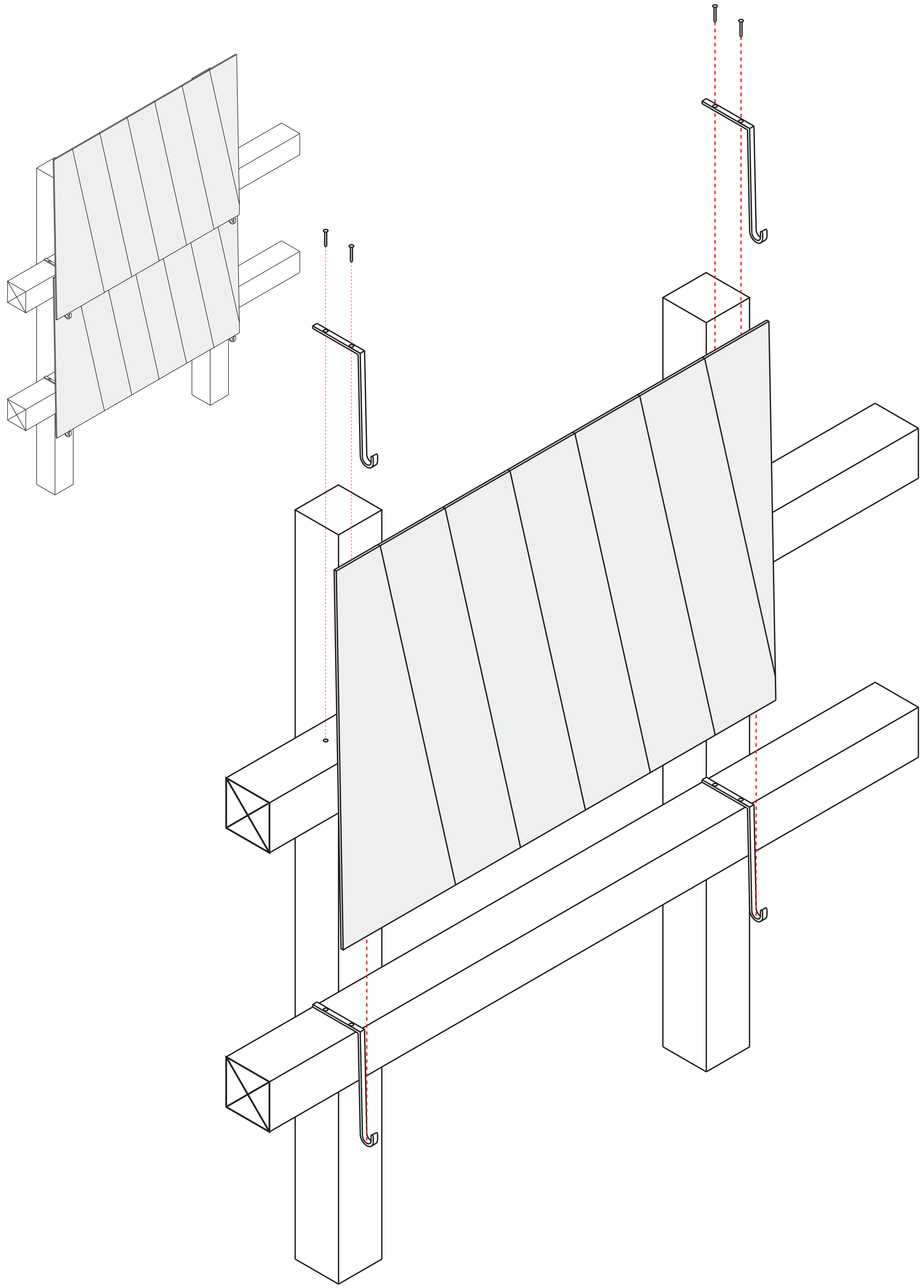

Fig 2.06 - Steel prototype

2.2.2 Aizkibel Library Extension

This is a key example of the reimagination of material in a new context in which it takes a visual priority. Estudio Belderrain have used pre-existing site materials in this project, cladding the building in timber railway sleepers pulled from the tracks that previously ran through the site (Estudio Belderrain, 2006). Stacking timber sleepers like bricks within steel frames creates a building that blends traditional and modern construction techniques to maximise the use of material (Fig 2.08). The incorporation of vernacular techniques in this project makes reference across multiple material typologies. When constructing with bricks, the use of mortar as a connection allows a consistent surface to be created from imperfect individual elements. In the Aizkibel Library Extension, supporting steel frames create voids between each sleeper, a gap that plays the role of mortar in this facade. The uneven surfaces of the timber require little workshopping as they rarely come into contact with one another.

The major drawback to this extension is a large amount of extra engineering that is incorporated into facilitating material reuse. The large sleepers, combined with the elements used to hold them and additional insulation and secondary cladding, use up far more resource to enable the timber rain screen than a more conventional cladding system (Fig 2.09). If excessive amounts of new materials are needed to allow reuse, the environmental benefits begin to reduce.

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Fig 2.07 - Aizkibel library

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Fig 2.08 - Aizkibel library facade

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Fig 2.09 - Aizkibel library section

2.2.3 Tree House

The Phoenix Commotion's Tree House, built with a majority of reused materials, incorporates an extremely diverse range of materials and reuse techniques which vary in terms of relevancy to this research. There are two major examples of material-led design in this building. The first is the ceiling created using picture framing off cuts (Fig 2.12). This adheres to the philosophy of the company's founder, Dan Philips, who employs repetition to utilise materials often considered too small or irregular to be useful (Phillips, 2010). Irregular materials make up the house's foundation and take the form of a dead Bois d'arc tree (Fig 2.10). Philips discusses that despite the quality of timber from the Bois d'arc tree, it is not used in an architectural context due to its undisciplined limbs (Dirksen, 2017). To facilitate its use in architecture, any design must be adjusted to the specific form of the tree, on a case-by-case basis.

While the case-by-case use of materials pushes architectural reinterpretation, it is also where the limitations of the Tree House lie, along with many of Phoenix Commotion's other projects. Much of the material reuse is based on the fact that it is solely applicable to one house. Not only does this mean many of the systems used would be impractical outside of their immediate context, but much of the design does not lend itself to deconstruction. This may be linked to the perception of much of the materials as "trash". By fixing together large volumes of offcuts or broken material, Phillips aims to remove this perception. However, the unique nature of the designs also increases their risk of becoming defunct or impractical and the use of grout or adhesives to fix materials in place risks large-scale wastage at the end of their lifespans.

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Fig 2.10 Tree House exterior

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Fig 2.11 Tree House exterior

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Fig 2.12 Tree House interior

2.2.4 Ningbo Museum

Amateur Architects' Ningbo Museum utilises material reuse to preserve heritage and vernacular craft on a huge scale. This building combines efficient, modern construction techniques such as reinforced concrete walls with traditional crafts such as the stacking of discarded bricks and tiles (Fig 2.13, 2.16). While the large volumes of new concrete reduce the positive environmental impact of this building, the concrete walls cast an interesting light on vernacular craft when paired with the tile and brick cladding. Traditional methods of craft are often perceived as bespoke or boutique in the face of the industrialised production of architecture we have today. However, by pairing the two techniques of building across elements of the same scale, Amateur Architects demonstrate the viability of vernacular crafts at a commercial scale. As craftspeople were brought into the project with the specific responsibility of creating the reused areas of the façade, a development of the skill has occurred, therefore making it a viable option outside of this project (Wöhler, p. 61, 2010).

The potential fluidity of reuse is also emphasised by the scale of this project (Fig 2.15). Although there is frequent repetition of the particular material typologies, there is great variation across each façade in the way that these materials are combined (Fig 2.14). Initially, architect Wang Shu individually drew each façade with a detailed layout of tile and brick. However, the final product varied greatly, under Shu's instruction to "let nature take its course" (p. 61). The elevations for this design can be seen simply as proof of concept. A general idea of the quantity of material needed is important to the completion of the project, but exact replication of a predetermined design requires complete categorisation of every individual reused element, which hinders progress.

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Fig 2.13 Ningbo Museum facade

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Fig 2.14 Ningbo Museum circulation

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Fig 2.15 Ningbo Museum

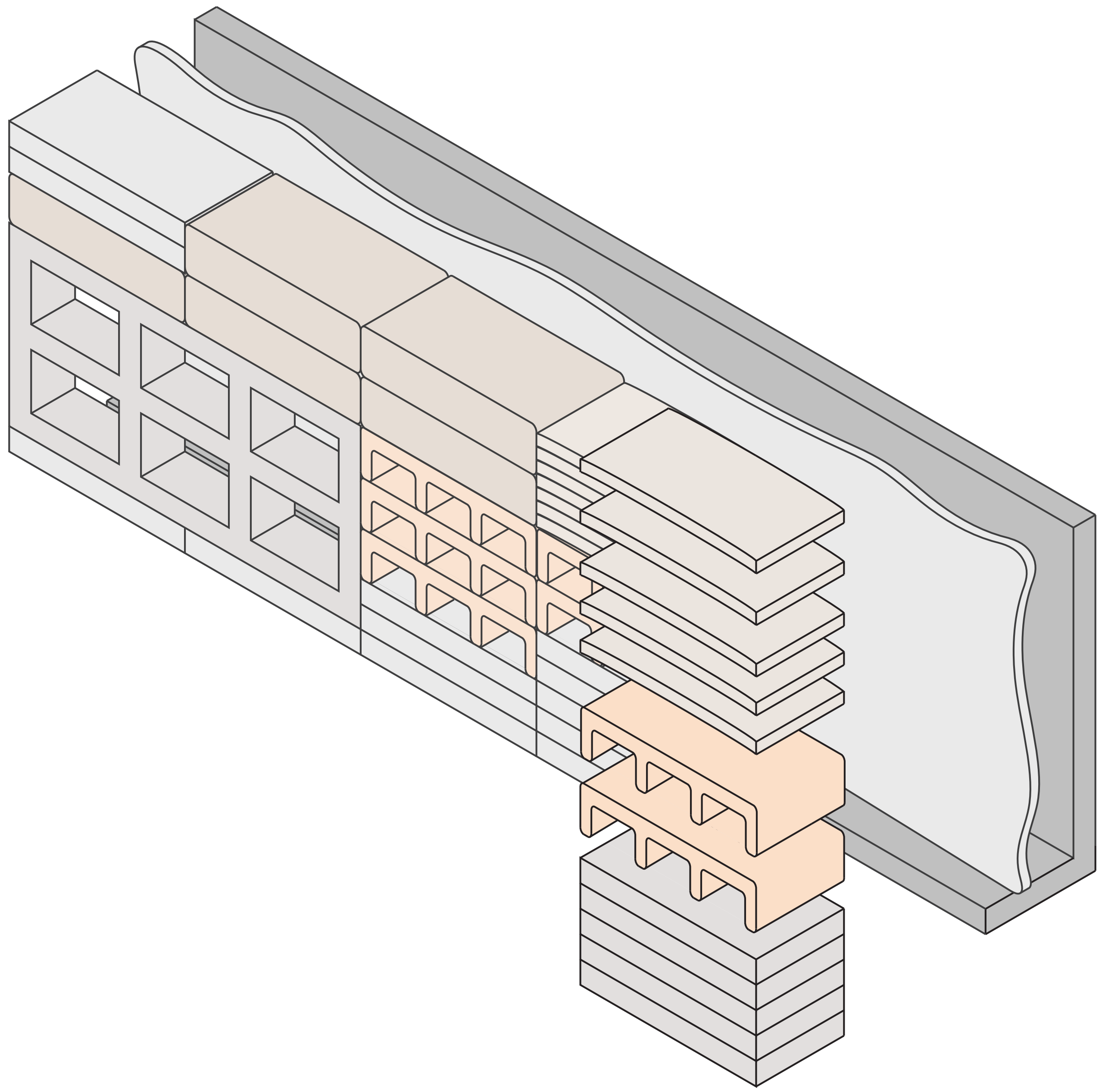

Fig 2.16 Ningbo Museum facade composition

3. Material Context

Native timber has been examined in two parts. The first is an investigation into the architectural use alongside changes in forestry to understand the prevalence of native timber in the built environment. The second part is an investigation into the state of this timber at present day and the conditions, sizes, and quantities that it is likely to be available in. This will inform a base understanding of potential reusable native timber to inform design iterations.

Opposite page Fig 3.00 Rot in rimu sarking

3.1 Native Timber use in Aotearoa

Row one: Forestry of Native Timber in Aotearoa

Information sourced: (Swarbrick, 2007)

Row two: Domestic Architecture in Aotearoa

Information sourced: (Gatel, 2014)

Maori timber use pre Europan arrival:
Timber was used often in combination with other materials, such as raupo, making up columns and ridge beams. This tended to be made up of unaltered straight lengths from branches or trunks. Around 15 the introduction of ponamu tools facilitated more intricate carving and therefore more complex profiles of timber began to appear in buildings (rown, 9).

Prior to 1 4 :
auri and a few other natives were used for European boat building with a small amount of exports to Australia taking place.
1 4 :
Formal European settlement begins, Totara and Rata are used for sleepers and fence posts while ahikatea and auri are used for houses.

1 5 :
Sawmills begin to appear near forests and coastal towns.

1 :
d rushes cause a large increase in logging.

1 9 :
Forestry control is introduced among dwindling timber supplies.

As inland timber becomes accessible with railroads Rimu begins to be more fre uently logged.

19 5:
auri logging peaks as trees become more scarce.

191 :
Felling of 7 mile bush between Wairarapa and Hawkes ay completed.

19 :
The planting of Pinus Radiata increases.

9 :
ome forests are managed under regenerative forestry systems.

19 :
Exotic timber forests begin to mature for use.

195 :
Waipoua auri forest is made a sanctuary.

19 :
Forest Service completes the creation of six forest parks and six sanctuaries. Initially ignored eech forests in the south island are felled for timber and land use.

1977:
Maruia Declaration is presented to parliament, demanding government protection of native forests.

199 :
Forests Act essentially brings native logging to a close.

Post :
The currently available forms of native timber are small private forests on private property, swamp auri, naturally fallen trees, and reused timber.

Prior to 1 4 :
Early colonial architecture was comprised mostly of timber eorgian houses, many of which were built outside of the country and imported. Additionally, Raupo was used to construct small scale housing by both Maori and Pakeha.

1 4 -9 :
Maintaining influence from England, many of the houses built during these years were large scale timber houses in the othic revivalist style. The Victorian style also pervaded many of these buildings. The introduction of christianity produced large, intricately carved Maori churches.

1 9 -19 :
A great increase in timber demand occurs during this period, largely due to the Arts and Crafts movement in which hand carved elements could often be found throughout homes in Aotearoa. These buildings tended to be built in the Edwardian style.

19 -5 :
Michael Joseph Savage's Labour government built extensive state housing during this period. Around , single dwellings were built. These were largely native timber construction, with some brick and plaster being used for exterior cladding. This era also saw Aotearoa developing its own version of modernism which used timber, brick, and stone to provide large floor plans at a low price.

195 -7 :
Late modernist houses built during this period tended to utilize timber for structural use only and leaned away from native timber as exotic timbers began to mature. Large scale flats replaced single unit dwellings and replaced weatherboards with plaster and concrete.

197 -9 :
Post Modernism and a uni ue approach to brutalism were the dominant style of this period and often mixed wood with masonry or concrete construction. Flats continued to be constructed, often using wood or fibrolite cladding.

199 - 1 :
This era saw some homes built with a return to external timber cladding as well as the increase in steel and aluminum use.

1 - :
The current climate of housing in Aotearoa is greatly influenced by the need for increased density. Townhouses, medium density flats, and apartments are replacing many single dwellings with ainga Ora attempting to meet the huge demand for housing with fast, medium-high density construction.

3.1.1 Native Timber Forestry Today

By the 1960s the forestry of native timber was beginning to quickly diminish (Fig 3.01). A maturing stock of exotic timbers meant that the need for timber was beginning to be met without native forestry (Swarbrick, 2007). Alongside this, a growing conservationist movement resulted in protests against deforestation (Nathan, 2007)(Fig 3.02). This movement culminated in the delivery of the Maruia Declaration, a document that outlined demands for sweeping environmental protection measures and received hundreds of thousands of signatures (Swarbrick, 2007)(Fig 3.03). As a result of the Forests Amendment Act 1993, public forestry of native timber no longer exists in Aotearoa. Large-scale radiata pine plantations such as the Kaingaroa Forest have allowed Aotearoa to become almost completely dependent on exotic timber (Kaingaroa Timberlands).

Private forestry of native timbers remains a closely monitored process under the Forests Act 149, allowing landowners to harvest trees according to careful regeneration processes. According to Farm Forestry New Zealand, approximately 23,000m^3 of privately forested native timber is processed each year, as opposed to approximately 944,000m^3 during the peak of native timber forestry in 1909. Ecological issues aside, the simple lack of native timber available means that if its presence is to be retained in the built environment, reuse is the most viable option.

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Fig 3.01 Volumes of rough sawn timber extracted from indigenous forests in New Zealand, 1928-2000

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Fig 3.02 Protesters from the Ecology Action Group 1972

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Fig 3.03 Delivering the Maruia Declaration

3.2 State Housing as Resource

As a means of refining the design scope, a particular architectural period has been chosen to allow standards from that period to underline design iterations. State houses built between 1930-1950 have been chosen as the bank of material from which the cladding system iterated in this research will draw. There are a few motivating factors behind this. The first of these is the abundance of the houses in question. Between 1935 and 1949, the government constructed 30,000 rental properties (BRANZ). This was approximately 20% of the housing constructed during this period (based on census data 1936-1951). Additionally, the majority of state housing was constructed with both standardised materials and variations on a standardised plan (Schrader, p. 96, 2005). A government-operated building system meant regulated construction techniques were used, meaning timber elements used across all state houses from this era are consistent.

Another factor is the frequency with which these houses are being demolished (Fig 3.04). While it cannot be assumed that all state houses being demolished were constructed during this period, it is clear that these houses are both the oldest state housing stock and some of the lowest in density. This makes them a prime choice for demolition as a means of creating space for higher-density builds (Fig 3.05-3.08). Kainga Ora has, in recent years, demolished approximately 3,000 houses for the purpose of site redevelopment (Kelly, 2021) and many of the completed and outlined projects displayed by Kainga Ora are being constructed on the former sites of state houses (Kainga Ora, 2022). These factors allow the design of a system that is reliable in terms of both consistency and availability of material.

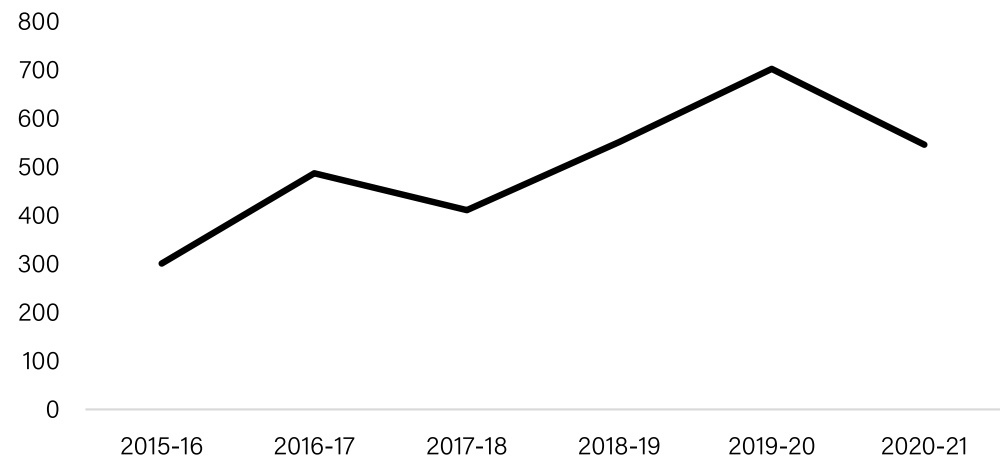

Fig 3.04 Number of State Houses Demolished 2015-2021

Canal Road, Avondale, Auckland.

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Fig 3.05 Demolished 1940s housing

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Fig 3.06 2021 Kainga Ora build

Segar Avenue, Mt Albert, Auckland.

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Fig 3.07 Demolished 1940s housing

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Fig 3.08 2019 Kainga Ora build

3.2.1 State-Based Reuse

Gorgolewski's suggestion of a service-based product can be used as a precedent for a state-operated system by which native timber can be reused. In *Resource Salvation*, two potential systems are outlined. The first is a closed cycle, where the reclamation and reuse of a material by a company is incorporated into the agreement of the initial purchase. The second is an open cycle, where the knowledge of reuse is shared publicly, allowing a greater variety of contexts in which a material may find itself in its second lifespan. Currently, native timber is reused in an open cycle, with demolition products sold on an open market at a variety of prices.

A closed cycle would mean that this cladding system is one constructed and utilised within the government's current construction projects, such as Kainga Ora housing. There are many potential economic advantages to this particular system. The first is low material costs. If the removal of state houses could be done through deconstruction rather than demolition, the materials produced would have no cost to the state other than labour for removal and processing. Additionally, the removal of material costs would justify the introduction of new government-funded jobs in both deconstruction and carpentry with opportunities of introducing skills relating to circular material use into the countries' workforce.

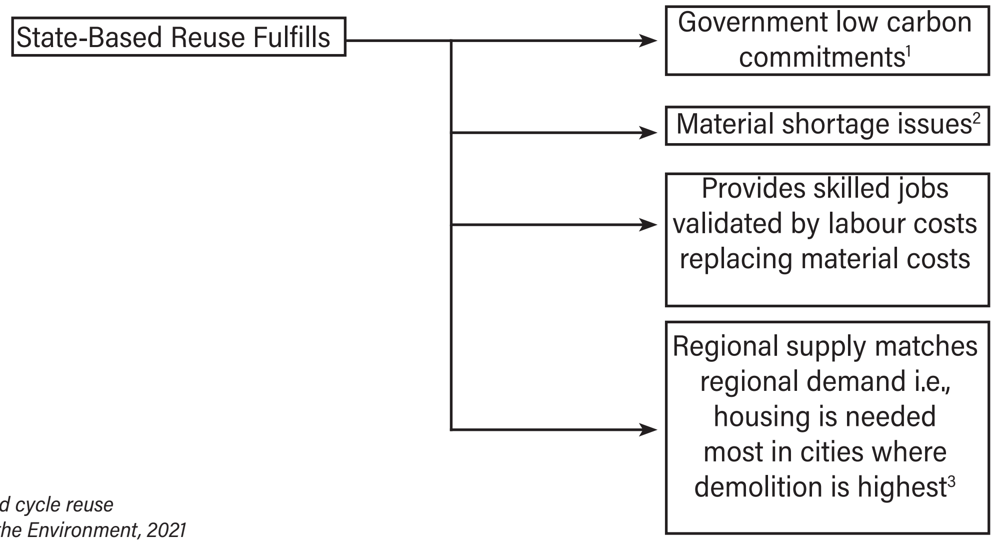

Fig 3.09 Closed cycle reuse
1. Ministry for the Environment, 2021
2. Olley, 2022
3.Ministry of Business, Innovation, and Employment, p. 10, 2021

3.2.2 State House Construction

The construction techniques used in state housing can be used to inform an effective design. The use of prefabrication was used to save time and increase efficiency with assembly on-site done mostly by hand (Schrader, p. 99, 2005) (Fig 3.10-3.13). This method can inform the reuse process. Time and machine intensive jobs such as removing nails and creating custom timber elements can be carried out offsite. In conjunction with this, the resulting system should be easy to assemble, either by hand or using tools standard to a construction site, so that specialist tasks are restricted to a singular offsite workspace.

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Fig 3.10 Assembly of prefabricated panels

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Fig 3.11 State house construction

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Fig 3.12 State house construction

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Fig 3.13 Assembly of prefabricated panels

3.2.3 Standard Timber Elements in State Houses

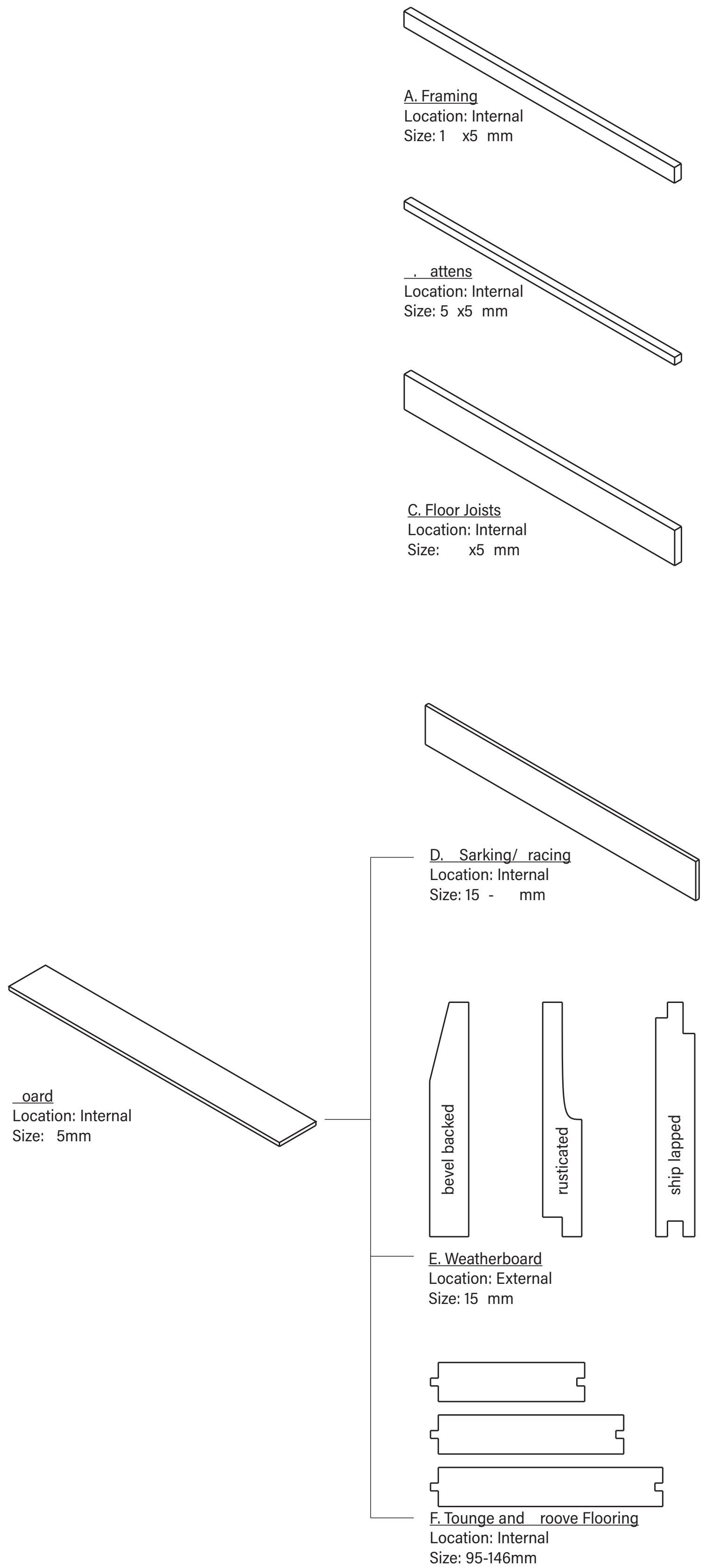
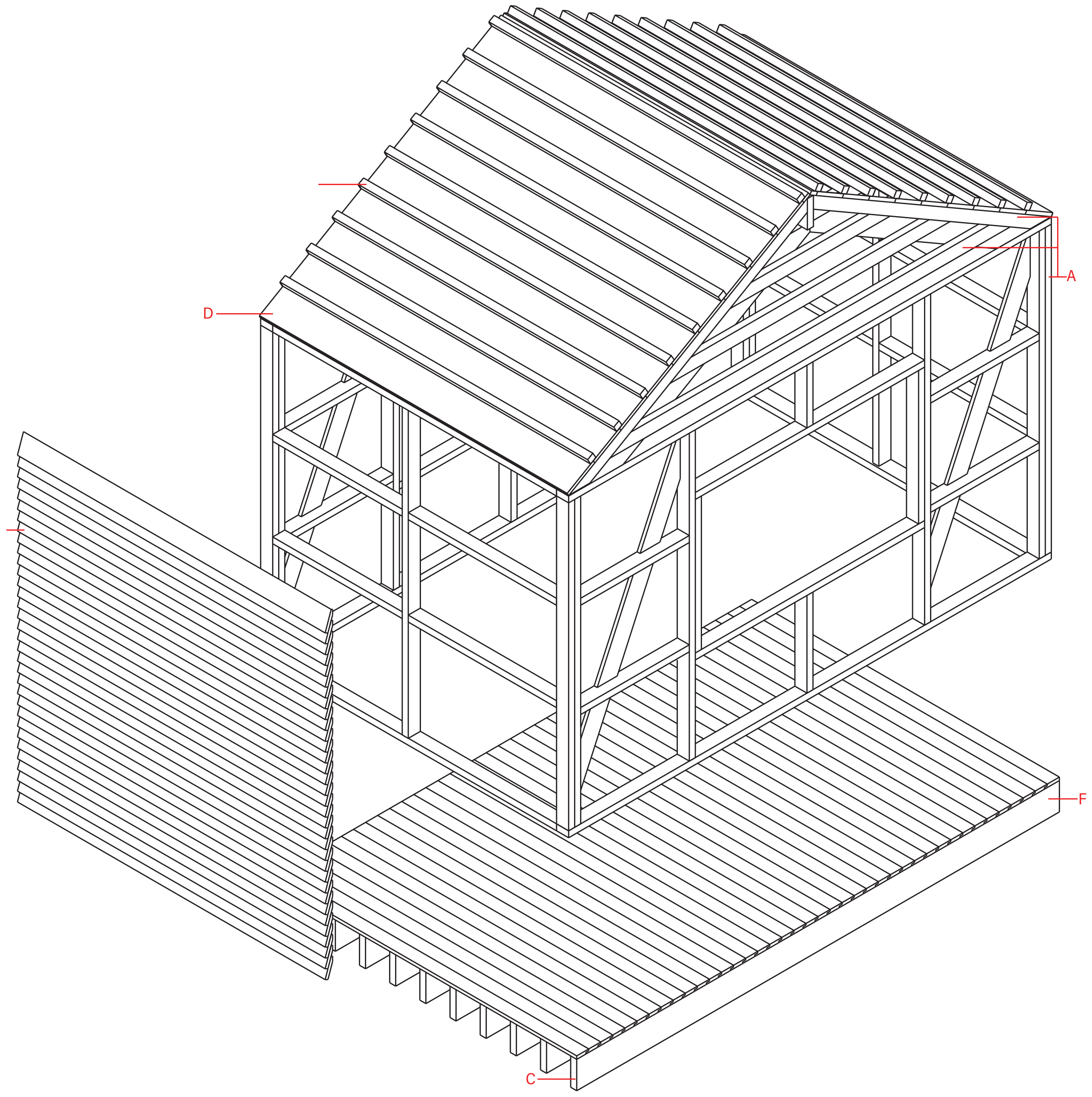
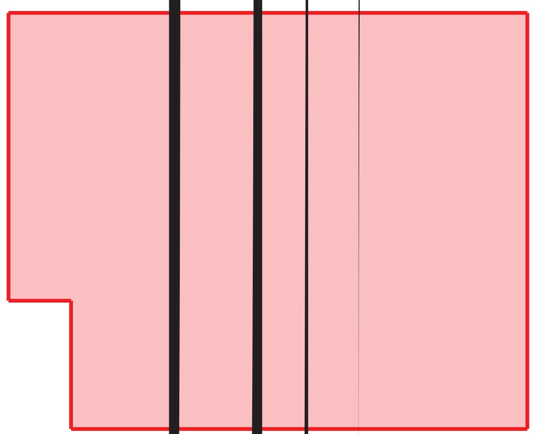


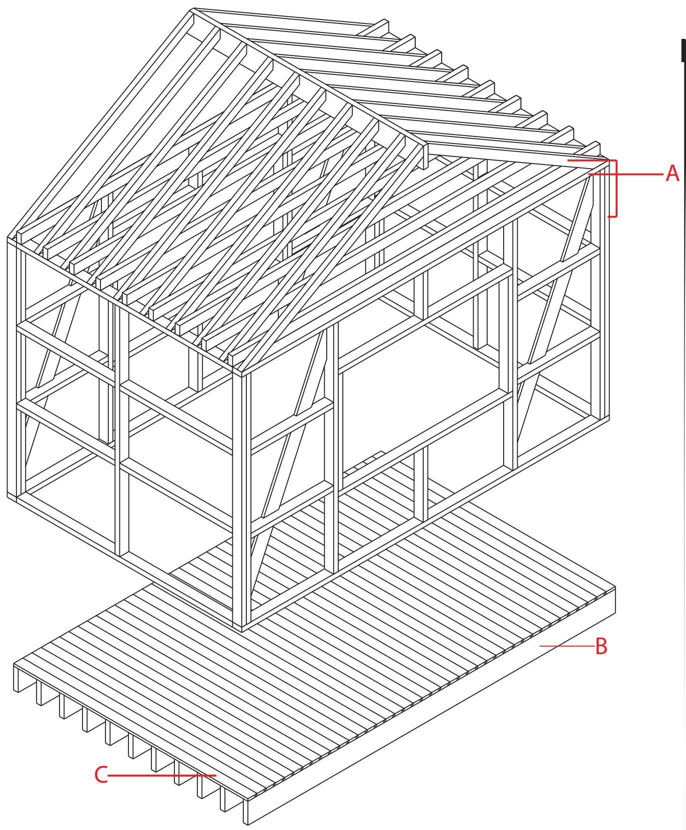
Fig 3.14 Timber profiles used in state housing

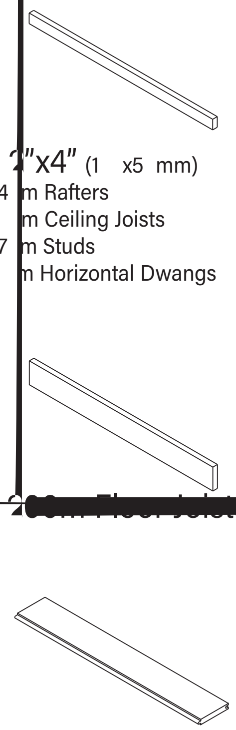


3.2.4 Quantities of State Housing Timbers from Demolition



9[illegible]-1[illegible]
Average floor area of [illegible] Z state house 194[illegible] (Elkink, 2[illegible])

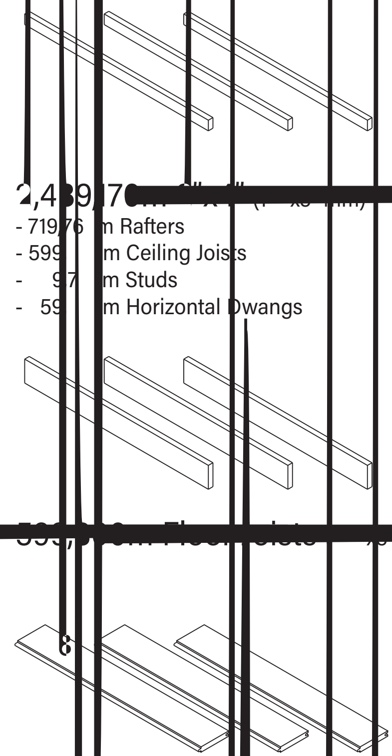




A. [illegible]"x4" (1[illegible] x5[illegible] mm)
- 4[illegible]m Rafters
- [illegible]m Ceiling Joists
- 7[illegible]m Studs
- 1[illegible]m Horizontal Dwangs

B. [illegible]

C. 65[illegible]



[illegible]4[illegible]9[illegible]7[illegible]
- 719[illegible]6[illegible] Rafters
- 599[illegible]m Ceiling Joists
- [illegible]97[illegible]m Studs
- 59[illegible]m Horizontal Dwangs

59[illegible]

[illegible]

Aproximate Lengths Per House of Consistent Elements
Based on "Light Timber Construction" from [illegible] ZSS 95. Based on an average floor plan of 97.5m[illegible] assuming aproximately 4[illegible] of external walls. Excludes internal wall structure and timber cladding, battens, and sarking.

[illegible],999 State Houses Demolished by [illegible]overnment [illegible]
Based on "State homes sales, leases expired and demolitions" from Kainga Ora

Fig 3.15 Potential timber quantities

3.2.4 Timber Elements of State Housing

State houses were constructed with several different cladding systems. These included timber weatherboards, stucco, and brick. While the exact quantities of each cladding type have not been found during this research, it is known that framing and flooring were consistently constructed with timber (Schrader, 2005). This helps to further limit the scope of this research. Weatherboards can be largely excluded from design considerations as they are more efficiently used as cladding in their current form, particularly if they retain the majority of their paint. Sarking and floorboards are a good starting point for cladding design due to their thin profile. However, where the cladding design must respond to the remaining timber elements is in the inclusion of framing and battens. These elements, consistently found in state houses, should be incorporated without the need for excessive alteration to create an efficient outcome.

As well as understanding standard profiles, an initial overview of common timbers used in state housing and their properties can inform design decisions. Understanding the technical properties of timber likely to be used in this cladding system can also inform potential treatments and applications to be applied to timber used in this cladding system. *Renovate: 1940-1960s* lists the most common native timbers used in state housing as rimu, matai, and miro.

3.2.5 Properties of State Housing Timbers

	RIMU	MATAI	MIRO	RADIATA PINE*
Density at 12% Moisture Content	595 Kg/m^3	610 Kg/m^3	625 Kg/m^3	500 Kg/m^3
Moisture Content When Green	130-140%	130%	130%	130-140%
Modulus of Rupture at 12% Moisture Content	88 MPa	76 MPa	94 MPa	90 MPa
Modulus of Elasticity	9.6 GPa	8.1 GPa	10.1 GPa	9.0 GPa
Kiln Drying Time for 25mm Board	4-18 Days	6-8 Days	N/A	2-4 Days
Use in State Housing 1930-50s	General framing, weatherboards, flooring, interior finishing, doors and windows	Flooring, sub-floor framing, weatherboards, exterior joinery, interior finishing	General framing, weatherboards, and flooring.	General framing, doors and windows, interior finishing
Appearance				
Notes	Splits tend to form whilst drying. Often nailed while green to avoid splits due to its brittle nature.	Most common in flooring due to its durability. Physical properties similar to hardwood.	Prone to distortion. Often sold as rimu or matai, hence its presence in state housing.	Availability rapidly increased in the mid-late 1950s, so not commonly found in housing from prior eras.

*Included for comparative qualities

Fig 3.16 Timber properties
Technical Properties - Clifton, N. C. (1990)
Use in State Houses - (Elkink, 2011)

3.3 Flaws in Reused Timber

While traditional demolition techniques pose the largest risk to the reusability of timber, other factors can affect the usability of even the most carefully deconstructed timber elements. The most commonly found issues with the timber sourced during this research were splitting, insect infestation, and rot. While these issues are not exclusive to native timber, they tend to be the product of untreated timber, which fell out of use after the introduction of chemical timber treatments in 1952 (BRANZ, 2013). While in most cases these issues do not rule out the use of the timber, certain precautions must be taken to ensure the integrity of design that may incorporate afflicted timber.

Fig 3.17 Splits

Fig 3.18 Borer

Fig 3.19 Rot

3.3.1 Splits

Splitting is an extremely prevalent source of damage in reused timber. Checks and splits are separations along the grain, with the latter extending between multiple surfaces (Fig 3.20). Shakes are a separation between growth rings, commonly forming at the end of a timber member, such as in Fig 3.21 (Buchanan, p. 35, 2007). These imperfections are caused by a variation in shrinkage whilst the timber is dried (p. 35) For this research, the term "split" will be used to encompass checks and shakes also, as these affect the integrity and workability of the timber in similar ways and require similar solutions. These flaws in timber are often exacerbated while in the built environment. As members are fixed in place, warping and external pressures put pressure on the timber and cause splits to lengthen and deepen (Clifton, p. 12, 1990). This, combined with brittleness from age and the force required to remove timber elements, can completely separate lengths of timber along grain lines.

Splits, while a risk in a structural context, are manageable in other uses (Buchanan, p. 35, 1999). The issue they pose in the context of a cladding system is their ability to collect moisture. The key to overcoming this will be to find a method of sealing these gaps, either through fixing the internal faces of the split together, or with some form of gap filler. Additionally, steps to avoid surface checking should be taken to avoid an excessive need for maintenance. Rimu, along with other native timbers, is susceptible to surface checking under alternating conditions i.e., continuous wetting and drying (Clifton, p. 67, 1990). This will mean that beyond taking steps to prevent moisture from entering existing splits, precautions such as eaves should be used in tandem with this system to ensure changing weather conditions and their effects on the timber are mediated.

Fig 3.20 Splits in rimu sarking

Fig 3.21 Splits in rimu 2x4

3.3.2 Borer

One major issue, for both reused and new timber products, is the risk of borer infestation. These are beetles that lay eggs on imperfections in timber surfaces, which then hatch into larvae. These larvae bore tunnels through the wood, consuming its nutrients and developing to adulthood (Fig 3.22). Once they have reached maturity, they form a small exit hole and fly away (Hosking, 1978). The presence of borer, other than creating cosmetic damage, risks the structural failure of a timber member if a major infestation has occurred (Hosking, 1978). Borer exit holes are also a potential issue for timber that is exposed to water, as the perforations may gather moisture.

The presence of borer in Aotearoa is widespread. The two most common types present are the common house borer and the two-toothed longhorn, which is indigenous to Aotearoa (Clifton, p. 24, 1990). Borer attacks are common across many varieties of timber, with rimu frequently becoming infested (p. 25). Due to a lack of chemical treatment in Aotearoa prior to 1955 (BRANZ, 2013), it is common to find borer in timber pulled from older houses. Several biocides can be used to treat or prevent borer, however many of these biocides contain chemicals that are extremely damaging to both the environment and human health (Jones, Brischke, 2017) and should be avoided in a residential context. In terms of extermination, heat treatment is a valuable tool, useful particularly in its relation to thermal modification. Temperatures above 52°C will eliminate most common insect infestations (Pinniger, p. 11, 2003), and thermally modified timber is resistant to borer (Abodo, p. 2, 2018), therefore creating a two-part benefit to this method of treatment that both assures any current infestation is removed and mitigates the risk of future damage.

Much of the wood that has been sourced for this research has been discovered to contain borer (fig 3.23). It is unknown if this is active or historical. However, the risk of taking large quantities of borer-affected timber into the woodworking space where much of the physical research has been conducted has been deemed too great. In continuation of this initial research, the reuse of affected timber is an ideal outcome. If thermal modification was utilised, it would be done prior to physical design experiments, as the effects on workability and changes in size would need to be known. Therefore, solutions could be employed to fill borer damage in a similar way to nail holes. A guarantee of removal along with a confidence that reinfestation will not occur would help to shift the perception of borer-damaged timber from a risk to the built environment to an asset.

Fig 3.22 Borer in rimu 2x4

Fig 3.23 Borer in rimu 2x4

3.3.3 Rot

Rot is the term used for a variety of timber fungal infections found in timber. This is a common problem in reused timbers, as the likelihood of moisture entering older buildings is high. Dry rot, affecting timbers even in relatively dry temperatures, is less common in Aotearoa, but far more difficult to remove as even timbers that have been left in dry conditions for extended periods may still contain the infection (Standard NZ, p. 8, 2012). Wet rots occur in higher moisture environments (Fig 3.24,3.25). While common throughout Aotearoa (p. 5), the remedy for wet rot is simpler and the risk of reuse lower than its dry counterpart. Removal of the damaged area of timber removes the permeable, damaged surface and if the timber is removed from damp conditions the fungal infection will lose its source of nutrients (Ridout, p. 98, 1999).

Ensuring that rot does not occur during the timbers reuse cycle is similarly a matter of ensuring that the environment for fungal infections to grow does not occur. Outside of chemical treatment, thermal modification lowers susceptibility to fungal infections (JSC Timber, 2020) as it lowers not only the overall moisture content of the timber but the permeation of the cell walls (Abodo, 2022). It is also important to consider design when reducing the risk of rot. When rain inevitably hits the timber, a reduction in the time this water is allowed to sit means reducing the creation of conditions in which fungal infections thrive (Standards NZ, p. 16, 2012). Careful attention to proper drainage, runoff cavities, and appropriately sloped surfaces will factor into the overall durability of reused timber systems.

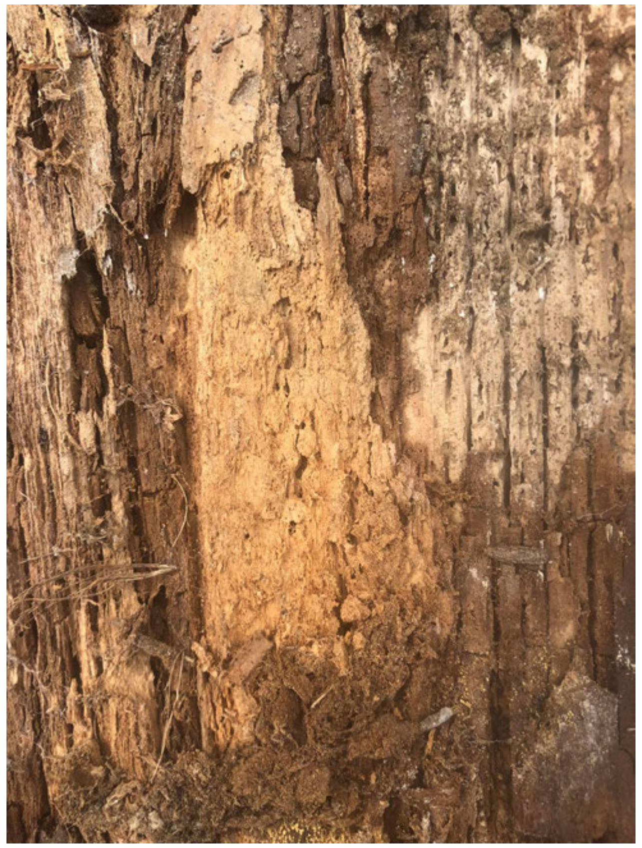


Fig 3.24 Rot in rimu sarking

Fig 3.25 Rot in rimu sarking

3.4 Timber Treatment

Unlike some native timbers, such as totara, the timbers commonly used in state housing, such as rimu or miro, are likely to deteriorate if used externally with no treatment (Clifton, 1990). There are a number of timber treatments used in current construction that, while efficient at prolonging the durability of timber (Pringle, 2021), have damaging effects on the environment and human health. Treatments such as borate, while not as toxic as previously used chemicals such as Copper Chrome Arsenate (Morais et al., 2021)., still pose a risk to human health when direct contact or ingestion occurs (Hadrup et al, 2021). As it is unknown where this timber may be used in life-cycles following this cladding system, this would prove an inappropriate treatment. Therefore, alternative treatments or coatings may be a more viable option.

3.4.1 Thermal Modification

Thermal modification is a process through which timber that is free from chemical treatment or paint can be used as a viable and durable cladding system (Abodo, 2022). This is achieved using large-scale kilns where, when oxygen is removed from the heating process, timber can be heated to temperatures exceeding 200°C without combusting (Sandberg et al, p. 200, 2021). These high temperatures alter the structure of cell walls in the timber (Fig 3.26), reducing its ability to absorb moisture, therefore reducing the risk of water-related decay (Reinprecht, p. 223, 2016).

Currently, no research has been carried out on the effects of thermal modification of Aotearoa's native timbers, due to these timbers falling from common use long before the utilisation of thermal modification. There are, however, a few important physical traits shared between common contemporary woods and native timbers that can help build an idea of the effects of thermal modification on certain reused timbers. As timber from state housing is being used as a basis for design in this research, it can be assumed that the majority of timber used will be rimu. As seen in Fig 3.16, rimu is similar to radiata pine in multiple physical properties such as density, moisture content whilst green, modulus of rupture, and modulus of elasticity. Most importantly, the similarities between density and moisture content suggest a similarity in the cell structures that hold moisture in green timber (Red Stag Timber, p. 2, 2022). This suggests that thermal modification, acting primarily on cell structure, could have a similar effect on rimu as it will on radiata pine, the timber often thermally modified for cladding in Aotearoa (Abodo, 2012) (JSC Timbers) (Tunnecliffes).

One potential issue with this treatment option is the tendency for thermally modified wood to increase in brittleness (Kubojima, p. 14, 2000) (Sandberg et al, p. 225, 2021). As rimu is generally a brittle timber, thermal modification is likely to accentuate this. If thermal modification is to be presented as a viable option for this system, it will need to be done so with a design that avoids the machining or tooling of fragile elements.

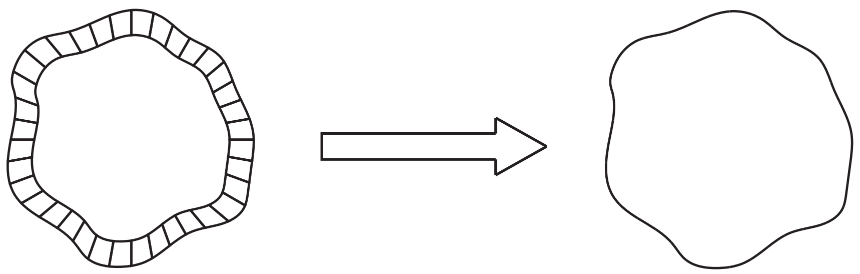


Fig 3.26 Collapse of cell walls during thermal modification

3.4.2 External Coatings

There are a series of potential finishes to improve the durability of timber. If timber is to be reused outside of the context of this cladding system, in areas where it is in closer proximity to people, then the treatments must leave a product that is not potentially harmful. Plant oils and waxes have been applied to timber as a means of preservation in vernacular construction across history (Janesch et al, 2020) (Petrovic et al, 2017). Commonly used are seed oil, such as linseed or tung, which can be painted onto the timber and create a water-repellent surface (Hill et al, 2022). These treatments have also proved reliable in repelling insect infestation along with fungal infections (Teaca et al, p. 4877, 2019). One downside to natural oil and wax is a lack of ability to fill voids (p. 4882), meaning they must be used in conjunction with alternative gap fillers. Another limitation is the frequency with which they must be maintained, requiring re-coating every 6 months to 2 years (Black et al, p.58, 2006). A circular cladding system may prove an aid to this, however, as the ease with which circular systems can be disassembled, recoated, and reassembled may create a new approach to cladding maintenance that is more thorough and complete. Coats could be applied not only to the face of the system, but to the back, as well as crevices, slots, and connection points. Additionally, the use of solvents can be used to increase the penetration of natural oils and create a more inert treatment, reducing leakages into run-off water (Wypych, p. 1000, 2019). D-limonene, a natural solvent produced as a by-product of citrus fruits (Vieira et al, 2018), can be used as an alternative to turpentine or other solvents more damaging to occupant health and the surrounding environment (Wypych, p. 1003).

More reliable is the use of non-permeable painted finishes. However, many of these are acrylic or petroleum-based (Black, p. 59). The issue with these paints, beyond emissions and pollutants at production, is the barrier they provide to reuse. If the wood is to be used without paint in its next life cycle, the resulting removal of a non-permeable coating will inevitably create a waste product that is difficult to reuse. There is also a decrease in the connectivity between the occupant and the qualities of native timber when paint is used.

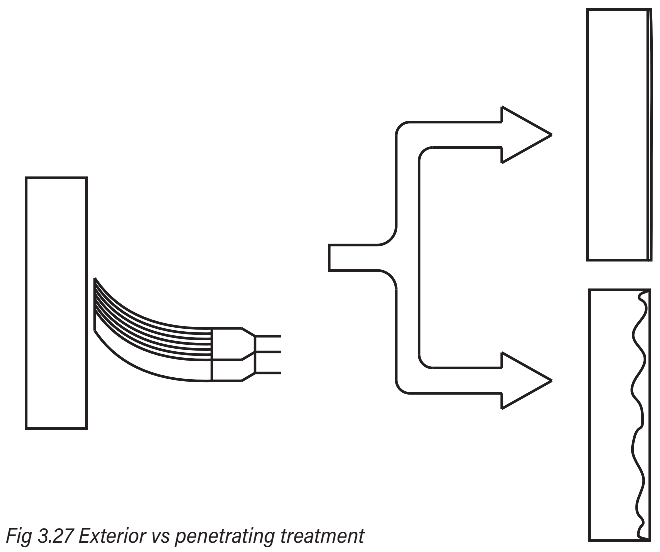


Fig 3.27 Exterior vs penetrating treatment

3.5 Findings of Material Context Investigation

The findings of this area of research have reduced the design scope. The design will be aimed towards state-based reuse. A focus on off-site fabrication allows for more complex machined parts but places an emphasis on efficient and convenient assembly so that specialist craft skills are required only in the fabrication stage. Due to caution around insect infestations, timber with visible signs of borer will not be used during this design process. Design systems should aim to include a range of timber elements found in state houses, excluding weatherboards, to create a more total reuse.

While access to the facilities needed for thermal modification of timber is unavailable, it is recommended that the system be treated with a combination of thermal modification and a plant oil and d-limonene solution. This will provide a treatment that avoids harmful chemicals while protecting and preserving native timber for future reuse.

4. Initial Iteration

The process of designing initial iterations was carried out through a combination of digital drawings and physical modelling. Digital drawing was used to devise drafts of systems based on standardised timber elements outlined in Fig 3.14 Small-scale physical modelling was then carried out with scrap wood (Fig 4.03) The purpose of using scrap timber as opposed to reused native timber, for early iterations, was to test the adaptability and circularity of a design without using the more valued resource of native timber. A larger model was then incorporated for the third design iteration with limited native timber elements as a means of testing workability and a partial assembly process.

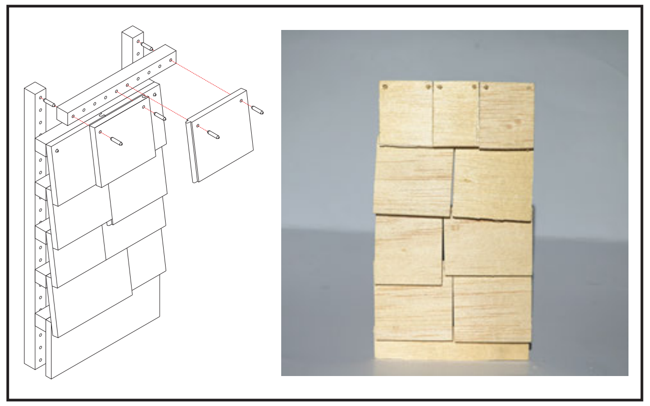


Fig 4.00 Modular shingle system

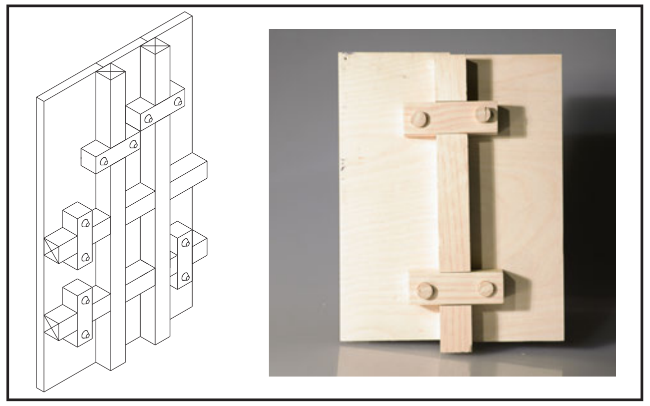


Fig 4.01 Patchworked board and batten system

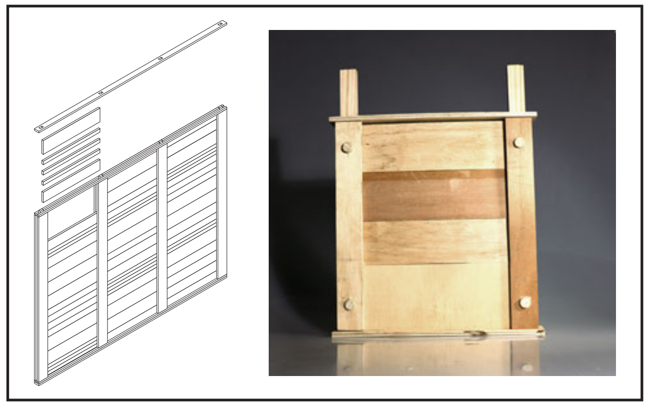


Fig 4.02 Slotted board and batten system

Opposite page - Fig 4.03 Timber off cuts

4.1 Modular Shingles

This system is based around facilitating the reuse of boards that have frequent damage and cannot be reused in long lengths. Horizontal battens can be shifted and secured on vertical battens, using dowels, at 50mm spacings (Fig 4.04). This allows battens to be shifted to allow for a variety of different-sized shingles. Horizontal dowel holes facilitate varying widths of shingles at the same 50mm spacing. This would mean that shingles can be used at a variety of dimensions and matched together to create a cladding, provided they are cut above 100mm and are consistently a width that is a multiple of 50mm (Fig 4.05).

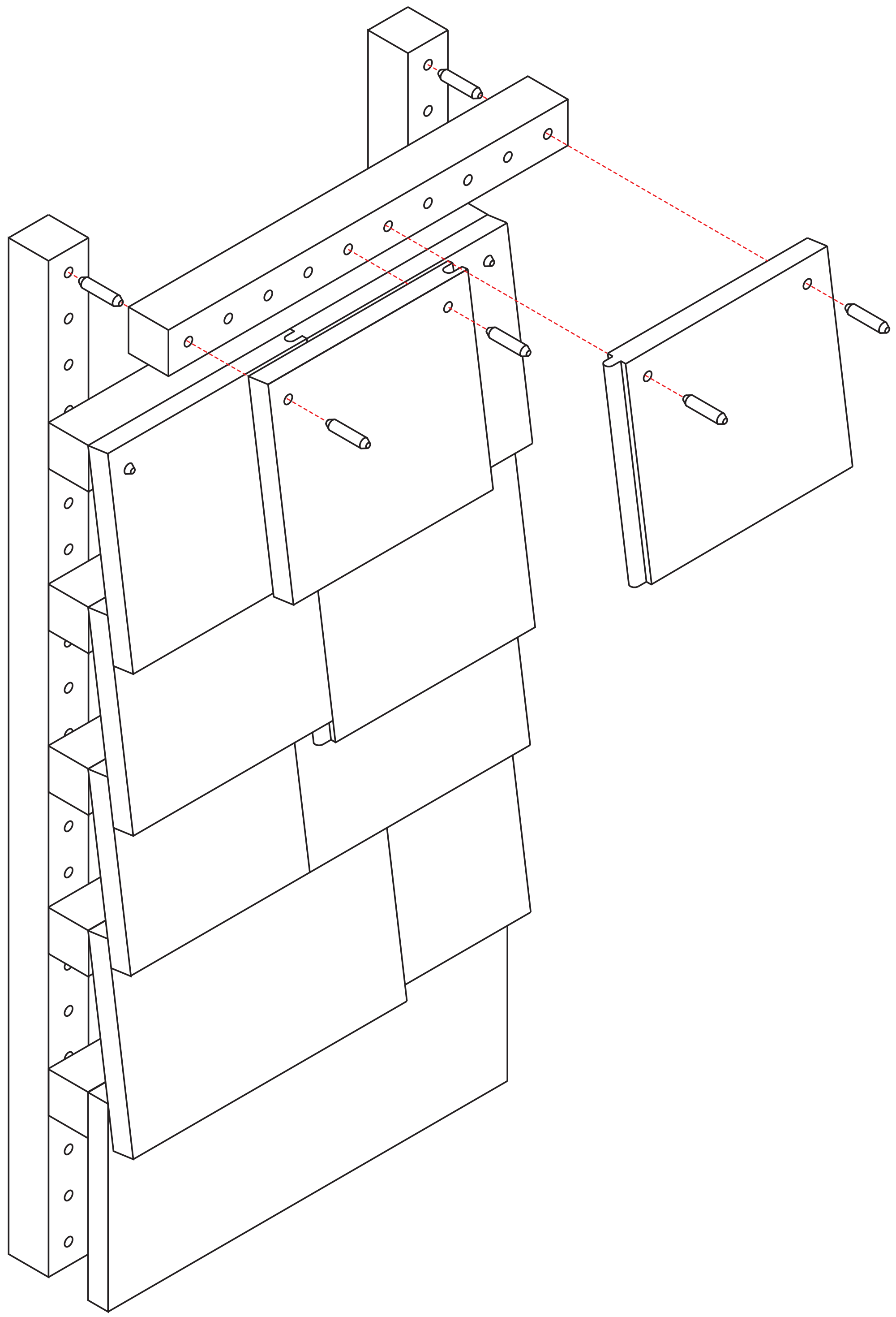


Fig 4.04 Modular shingle and batten system.

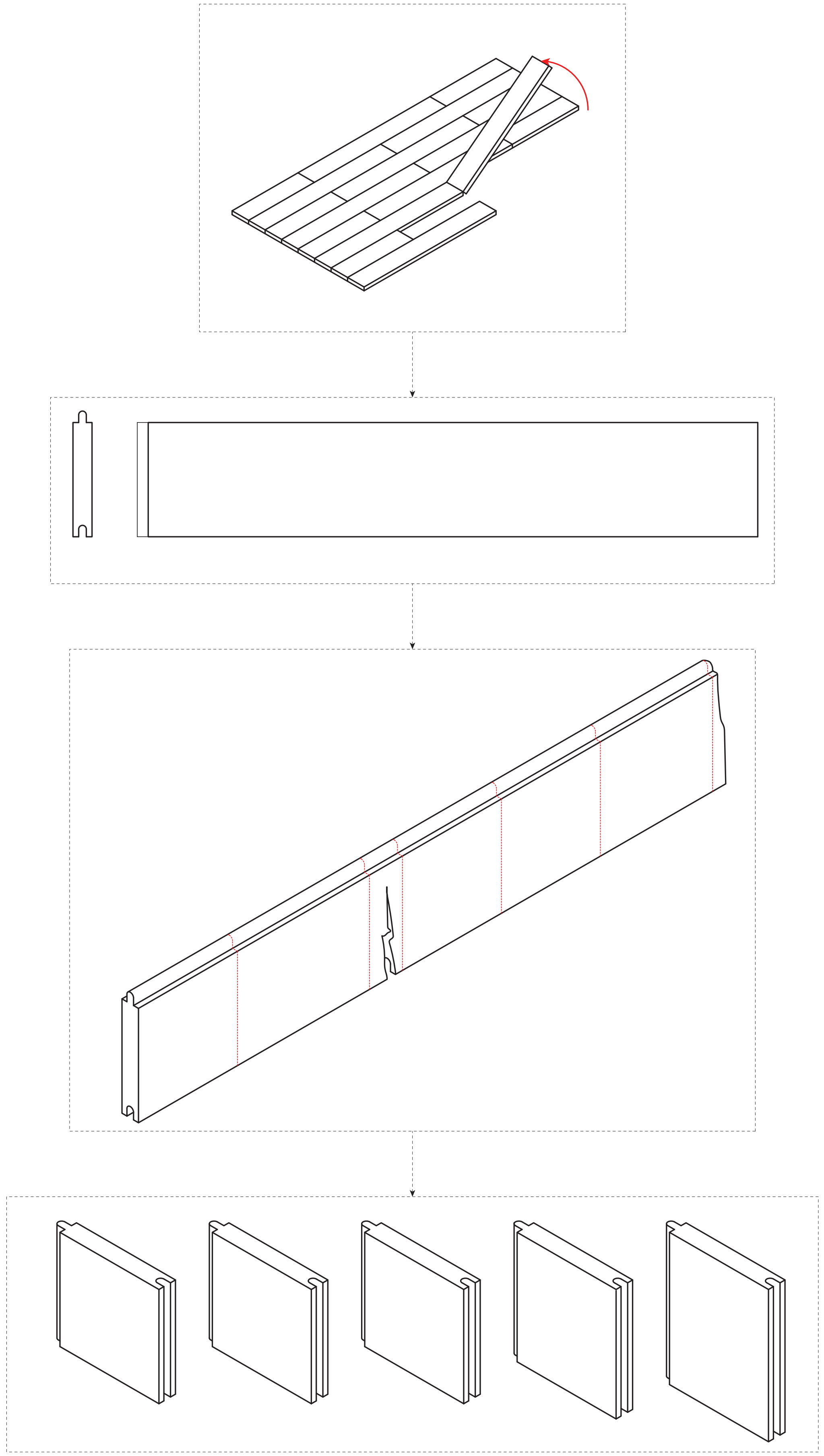


Fig 4.05 Process of floorboards to shingles.

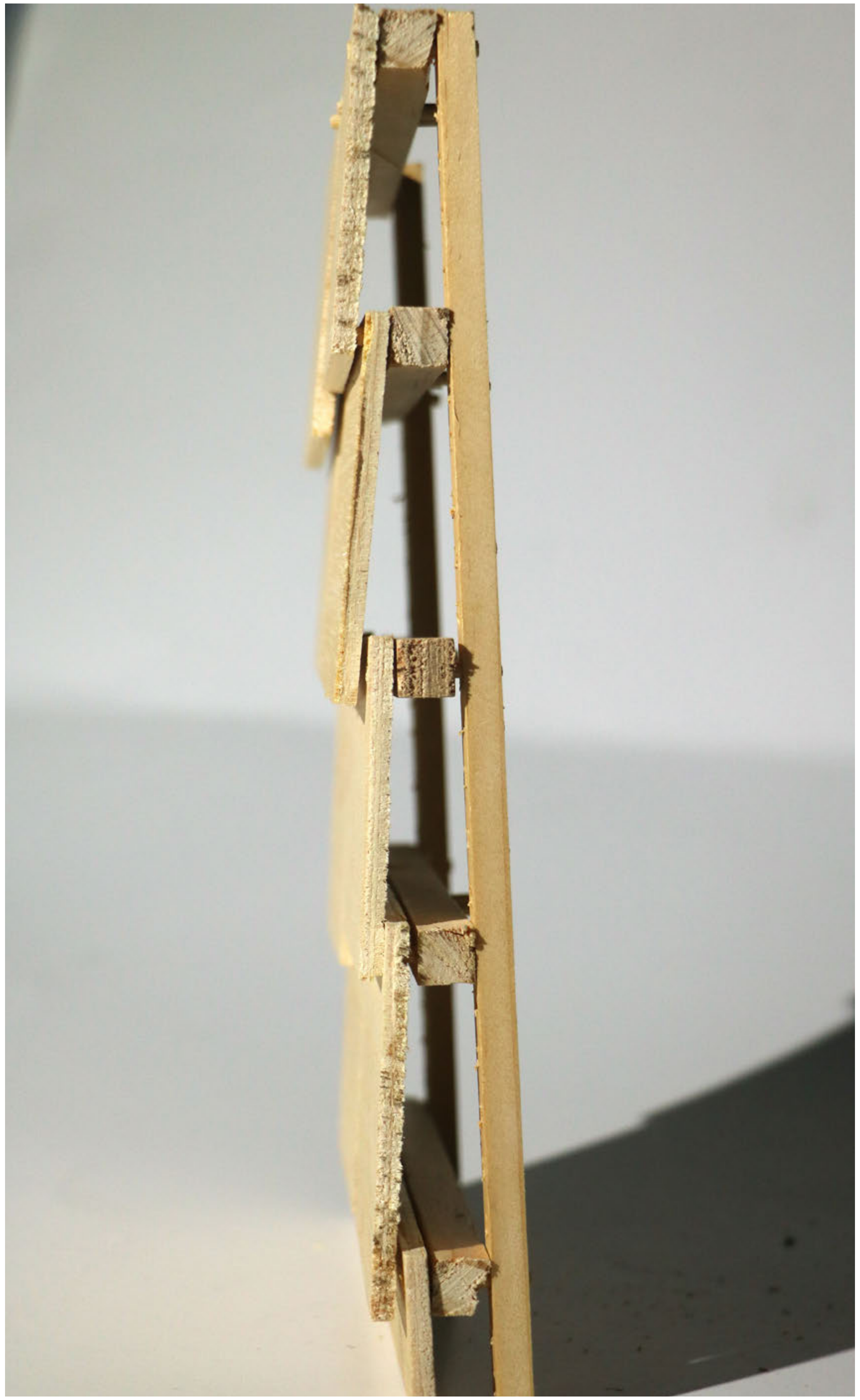


Fig 4.06 Modular shingle system 1:10 test model

Fig 4.07 Modular shingle system 1:10 test model detail


Fig 4.08 Replacement of shingle row

4.2 Patchworked Board and Batten

This design is aimed at creating a cladding system that can be applied around a wide variety of penetrations and design features. The use of battens on two axes allows boards to be attached together regardless of their height and width so that all areas of a façade may be covered and all dimensions of timber board may be used (Fig 4.09, 4.10).

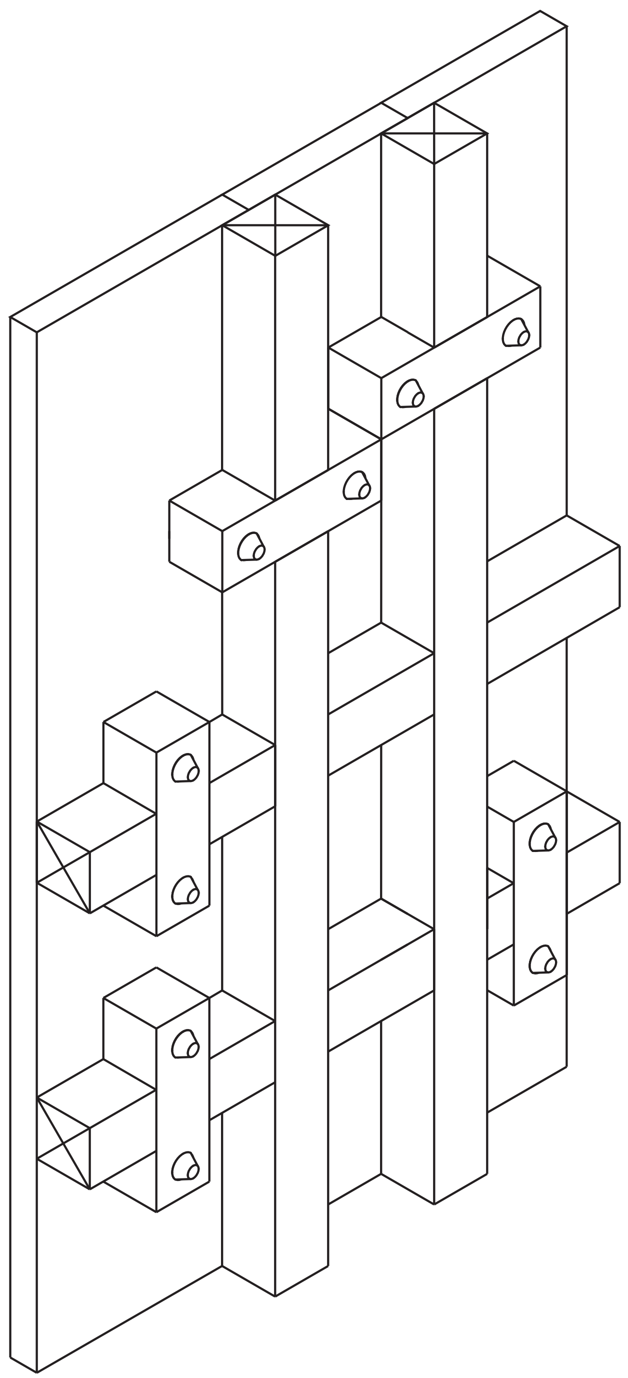


Fig 4.09 Patchworked board and batten system

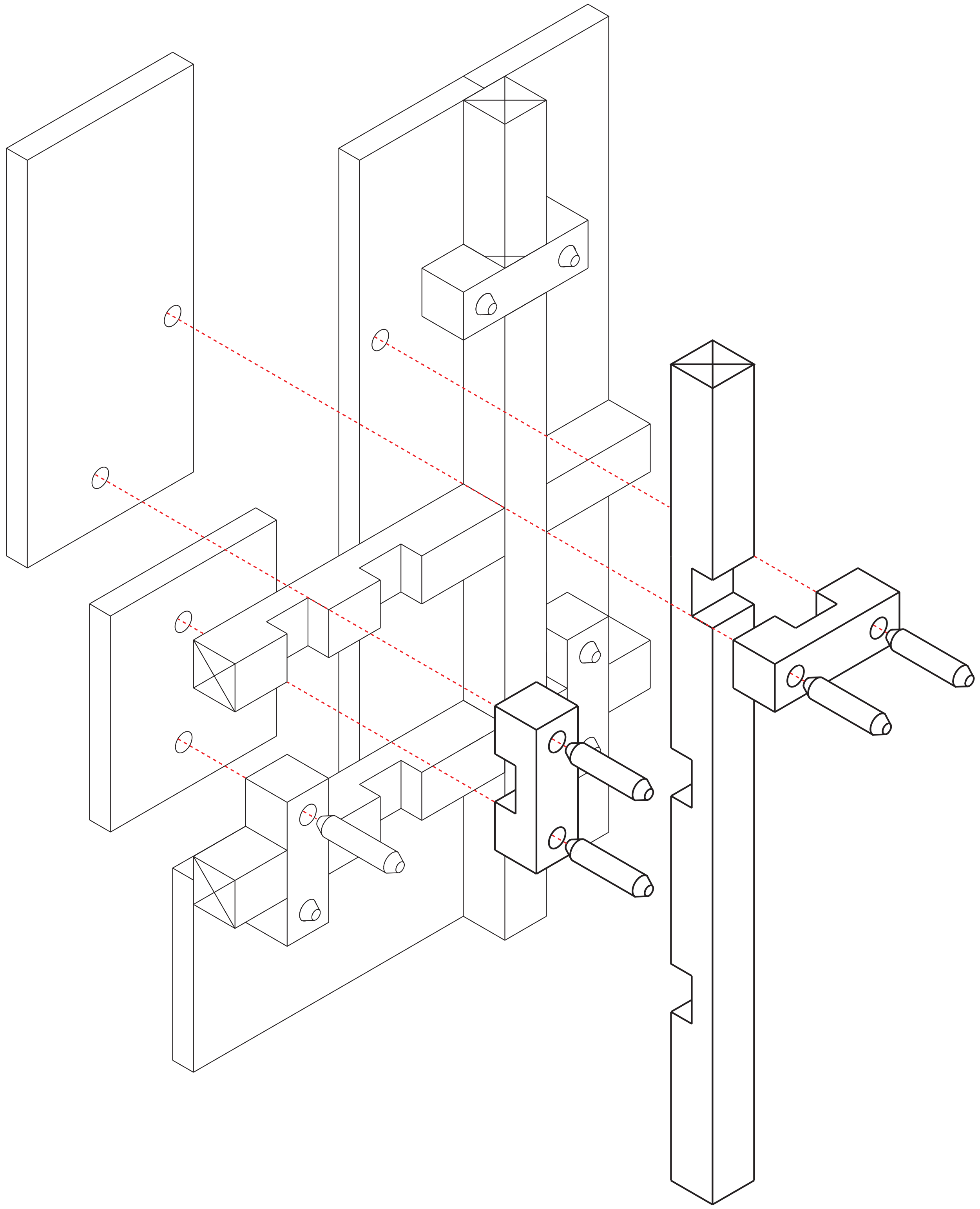


Fig 4.10 Patchworked board and batten system exploded

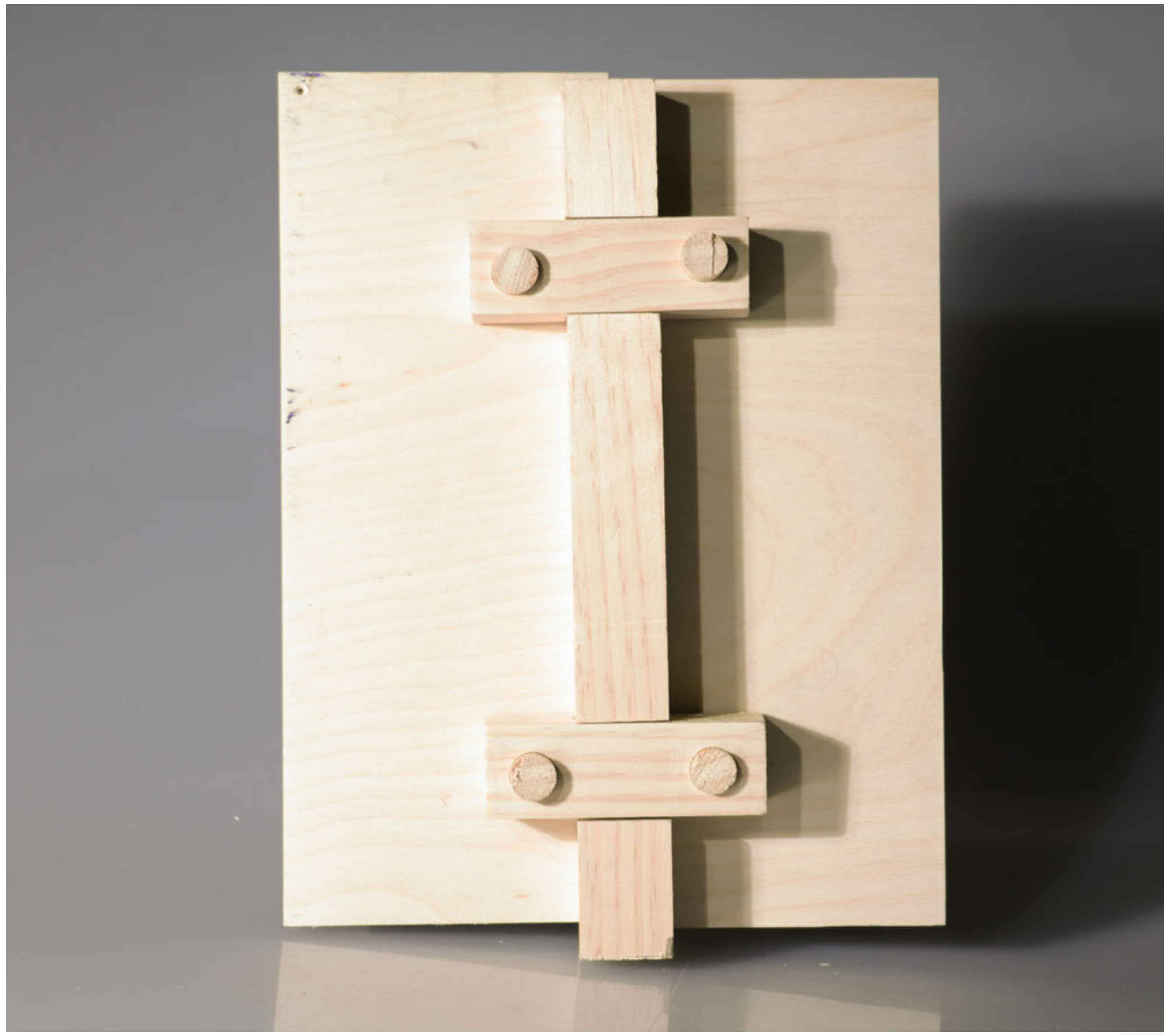


Fig 4.11 Patchworked board and batten 1:1 test model

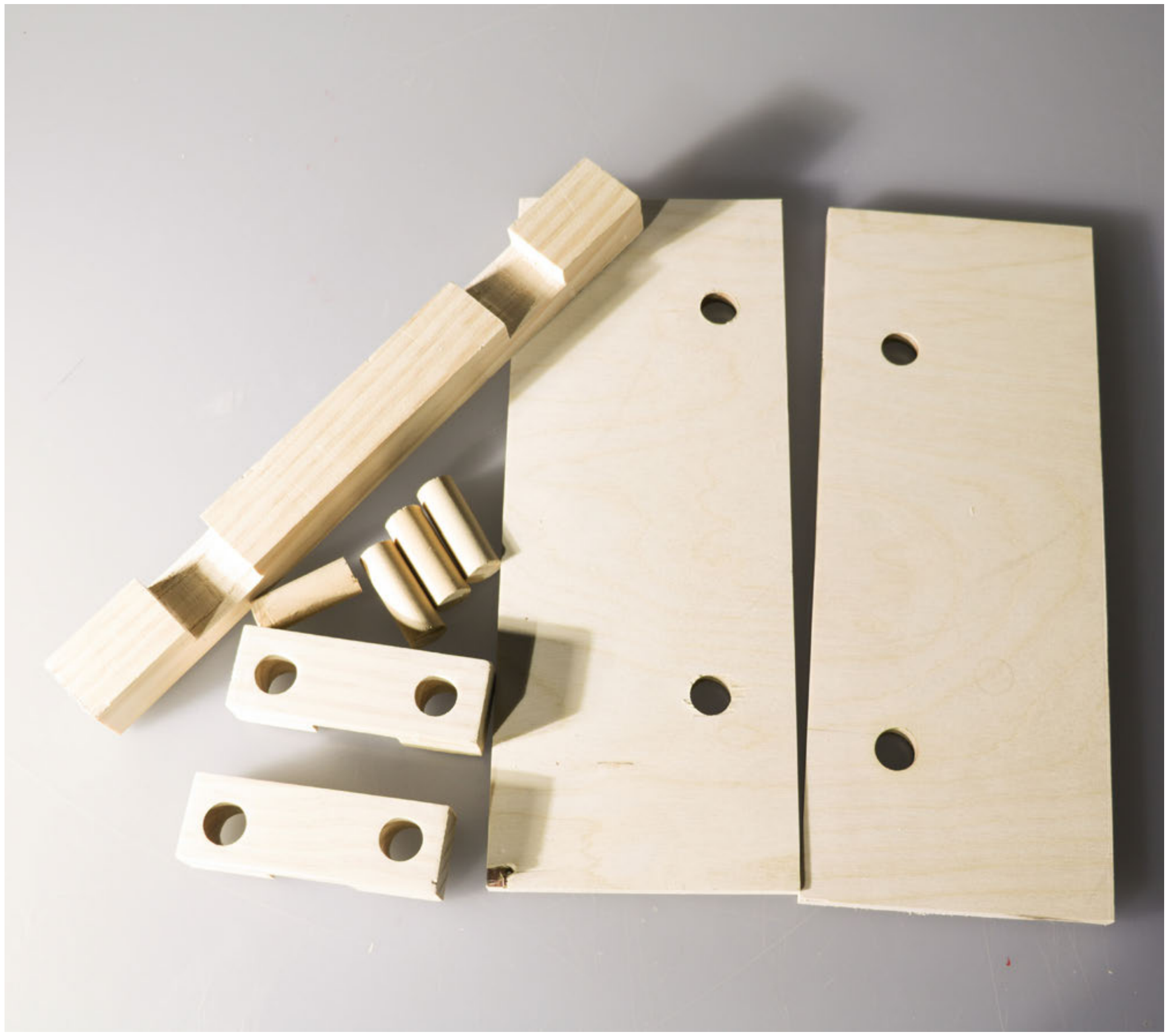
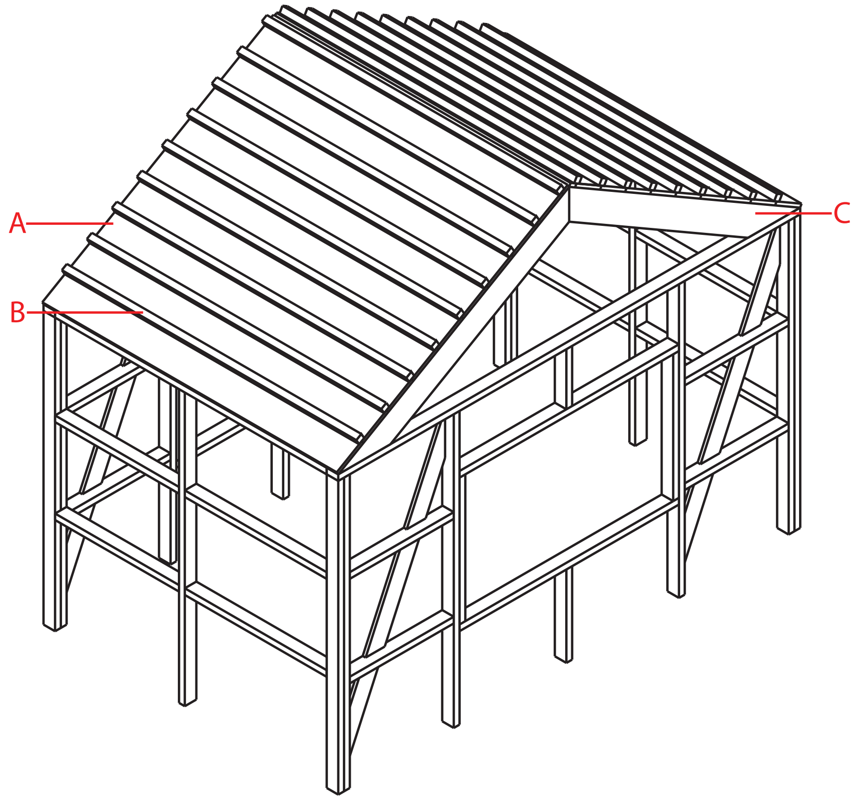


Fig 4.12 Patchworked board and batten 1:1 test model components



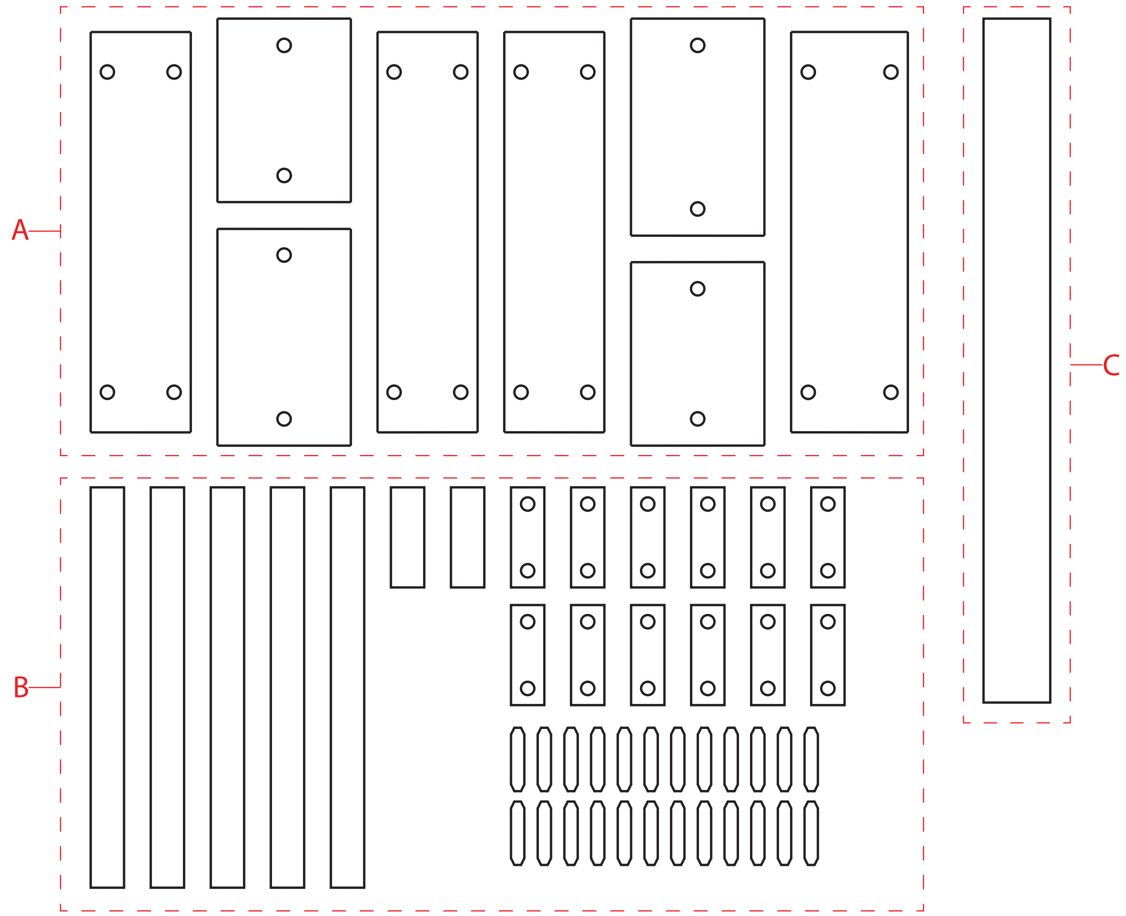


Fig 4.13 Elements from house involved in patchworked board and batten

4.2.1 Adjustment to Common Dimensions

The readjustment of this system according to standard board widths in state houses has meant that this system becomes less effective, due to the high number of components for the wall area clad (Fig 4.13,4.14).

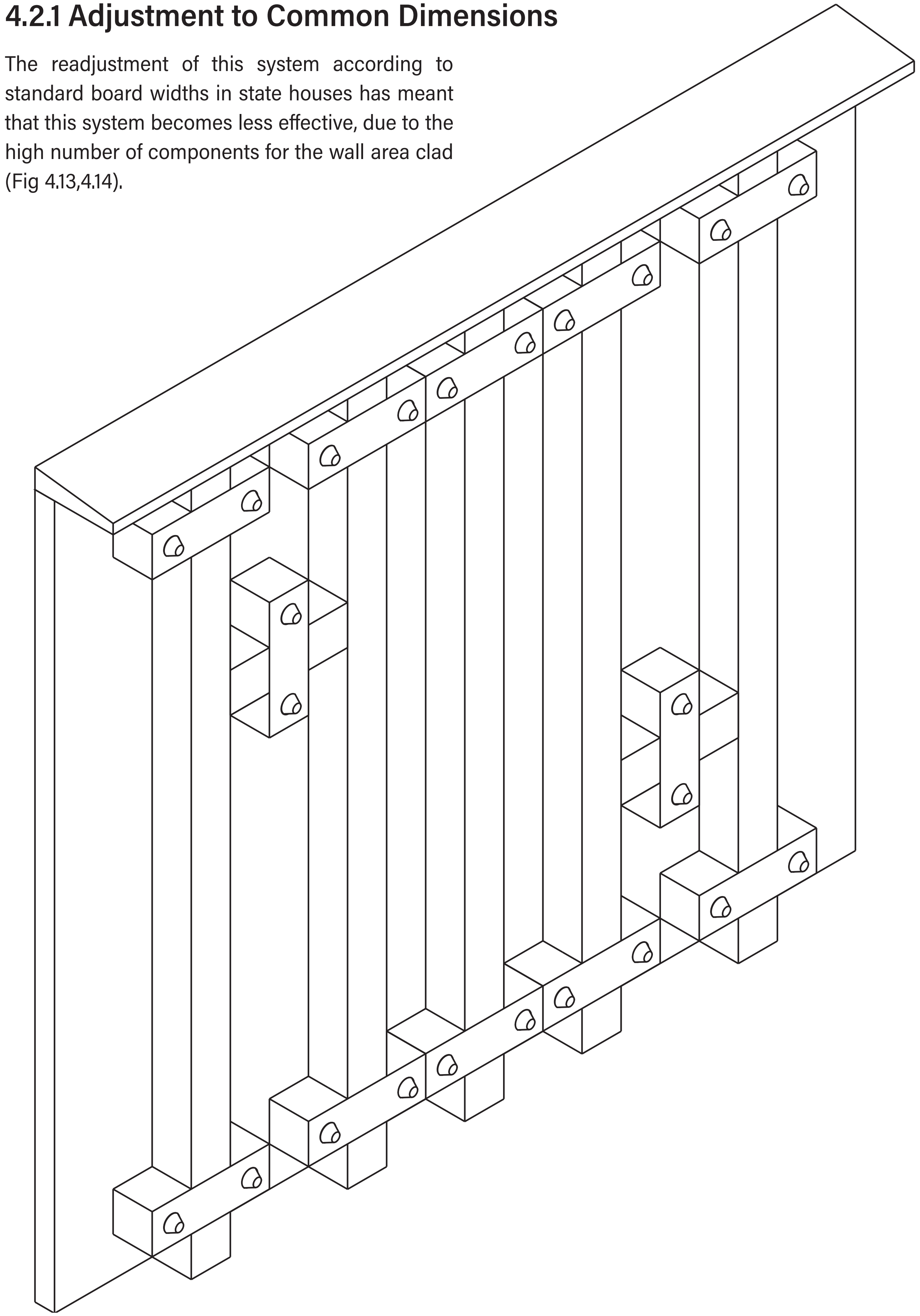


Fig 4.14 Patchworked board and batten according to common timber elements

4.3 Refinement of Circular Approach

One of the central aims of this project is to create a system that not only reuses materials but facilitates continuing future reuse. It cannot be assumed that the architecture that is functional and practical today will be in the decades to come. Early design iterations developed during this research have been circular only in the respect that they can be disassembled and reassembled in an architectural context without damaging the individual elements or introducing any new fixings or hardware. However, if each of the elements included in these systems is overly specified, the circularity of these cladding systems becomes limited to a singular design, shifted between the context of different buildings. To redefine the approach to circularity used in further iterations, Peter Zumthor's Swiss Sound Box has been examined as an additional case study.

The Swiss Sound Box was a temporary pavilion that explored sustainable construction in temporary architecture. Standing for 5 months in 2000, the pavilion makes use of its short life cycle to explore concepts of temporary architecture. Modelled off the simple form of an outdoor timber drying pile, the box is composed almost entirely of square profile Douglas Fir beams stacked upon one another (Fig 4.15). These are held together by steel tension cables (Fig 4.16), allowing the beams to be "held together by pressure and friction alone" (Zumthor, 2000, p.224). Because of this "there are no nail holes, drill holes, screw holes or other damage. This means the timber can be dismantled at the end of the Expo 2000 and reused" (p.224).

The pavilion is allowed a great deal more room for experimentation than other circular architectural systems as it has to be neither insulated nor completely weatherproofed. This potential experimentation is employed in the creation of a building that uses almost completely untouched construction materials and offers an incredibly versatile product at the completion of its lifespan.

During the initial design phase of this thesis, this research has taken an approach to circular design with an architectural application as the predominant design driver. This means that reused timber is processed into architectural elements that can be adjusted within the restraints of a singular system across different buildings. While this creates circularity within the context of the built environment, it begins to close certain avenues of reuse in non-architectural contexts if elements of the system are overly specific.

The overarching issue with these first two design iterations is that they are attempting to answer the wrong question. Circular systems that are aimed predominantly at a continuing architectural application ask us to question how waste is designed into the systems we use currently and the ones we will use in the future. However, by shifting architectural systems to consider the circular economy as a whole, design obsolescence does not have to equate to waste. This approach to circularity integrates the ideals of Peter Zumthor's pavilion. The cladding system developed in this research should provide, at the end of its lifespan, material for use in future applications not limited to cladding or architecture specifically. Additionally, just as Zumthor's pavilion utilizes small quantities of steel to allow a majority of reuse overall, so should this research carefully consider each alteration made to every piece of timber and incorporation of new products to ensure that avenues for future use remain open.

This content is unavailable. Please consult the figure list for further details.

Fig 4.15 Swiss Sound box stacked wall

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Fig 4.16 Swiss Sound box tensile coil springs

4.4 Slotted Board and Batten

This system is designed according to the refined definition of circularity. The use of I-shaped posts, shown in Fig 4.17, allows floorboards or other elements cut to thickness to be completely free from perforation, with machining applied to the top and bottom edges (Fig 4.18). This means that the only pieces machined specifically for this system are the posts and the top and bottom rail, which while reusable in a context outside of this system, are less versatile than the boards.

Fig 4.17 Assembly of slotted board and batten

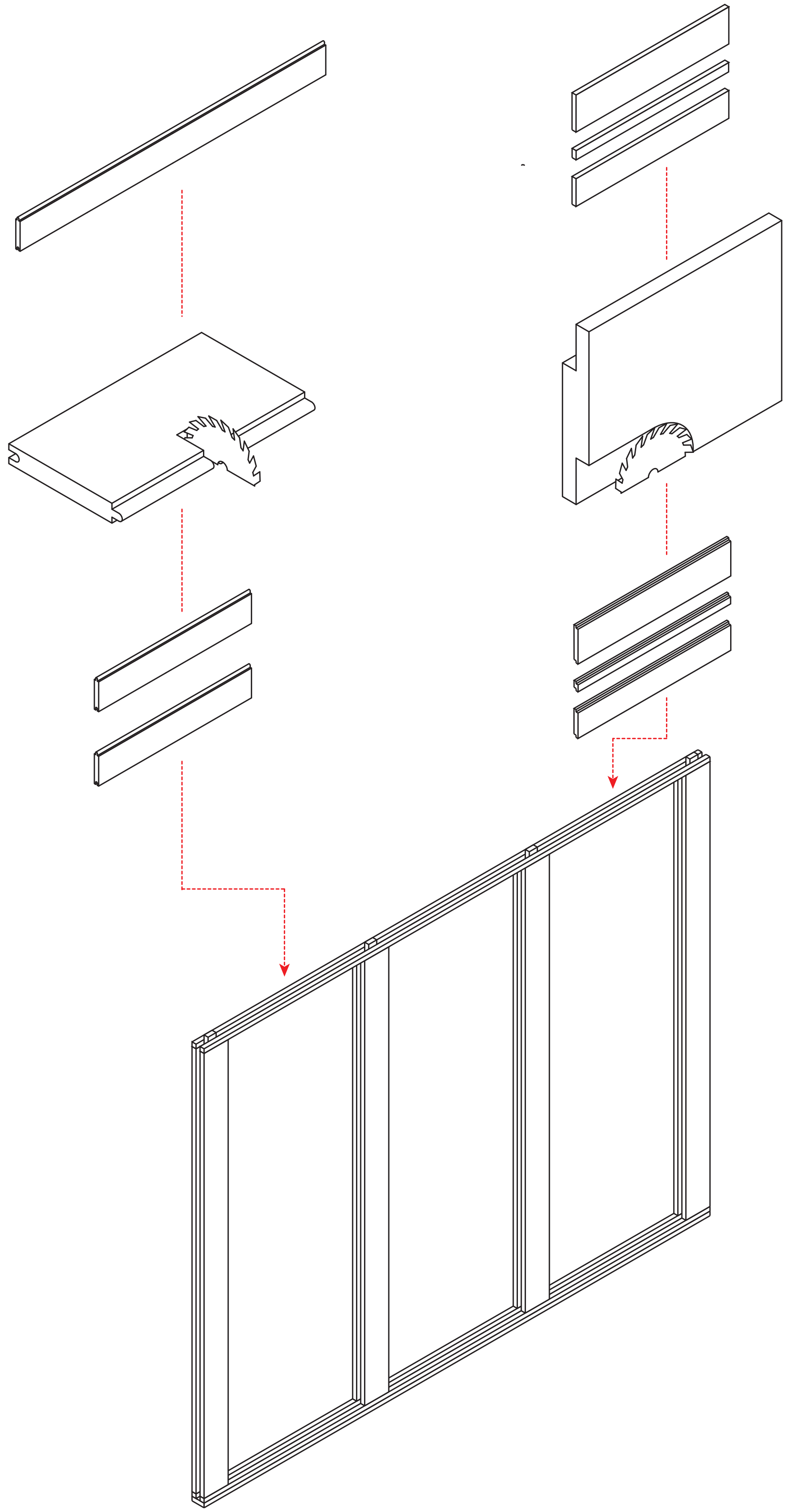


Fig 4.18 Process of timber elements to boards

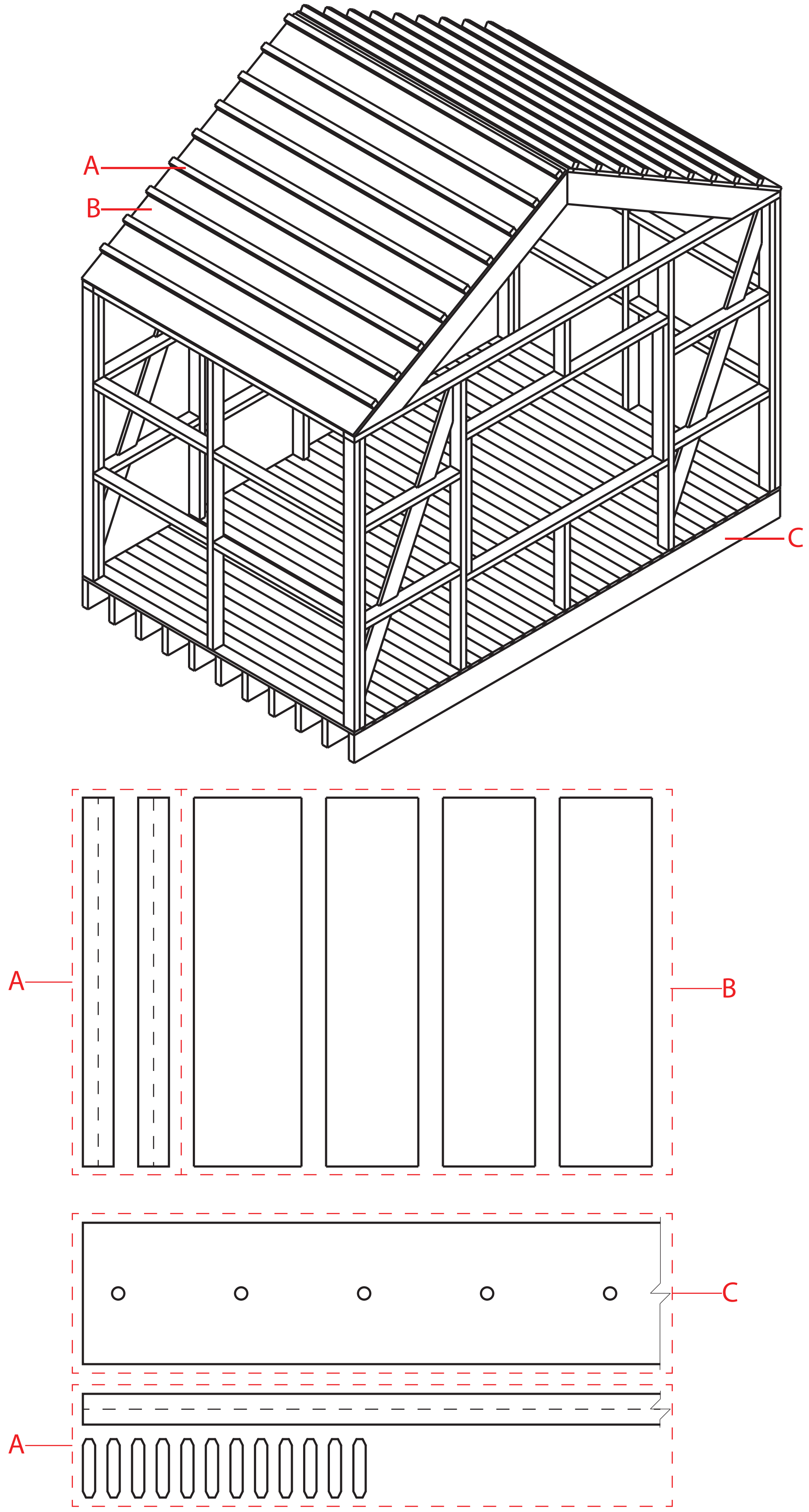


Fig 4.19 Elements from house involved in slotted board and batten

4.4.1 I-Post Construction

This method of holding beams uses a mortise and tenon system to a central batten, cut in half to the standard 25mm board thickness (Fig 4.19, 4.20). This provides a consistent use for battens, while the cover boards can be made from elements of any width, provided they allow enough cover to hold the horizontal boards in place.

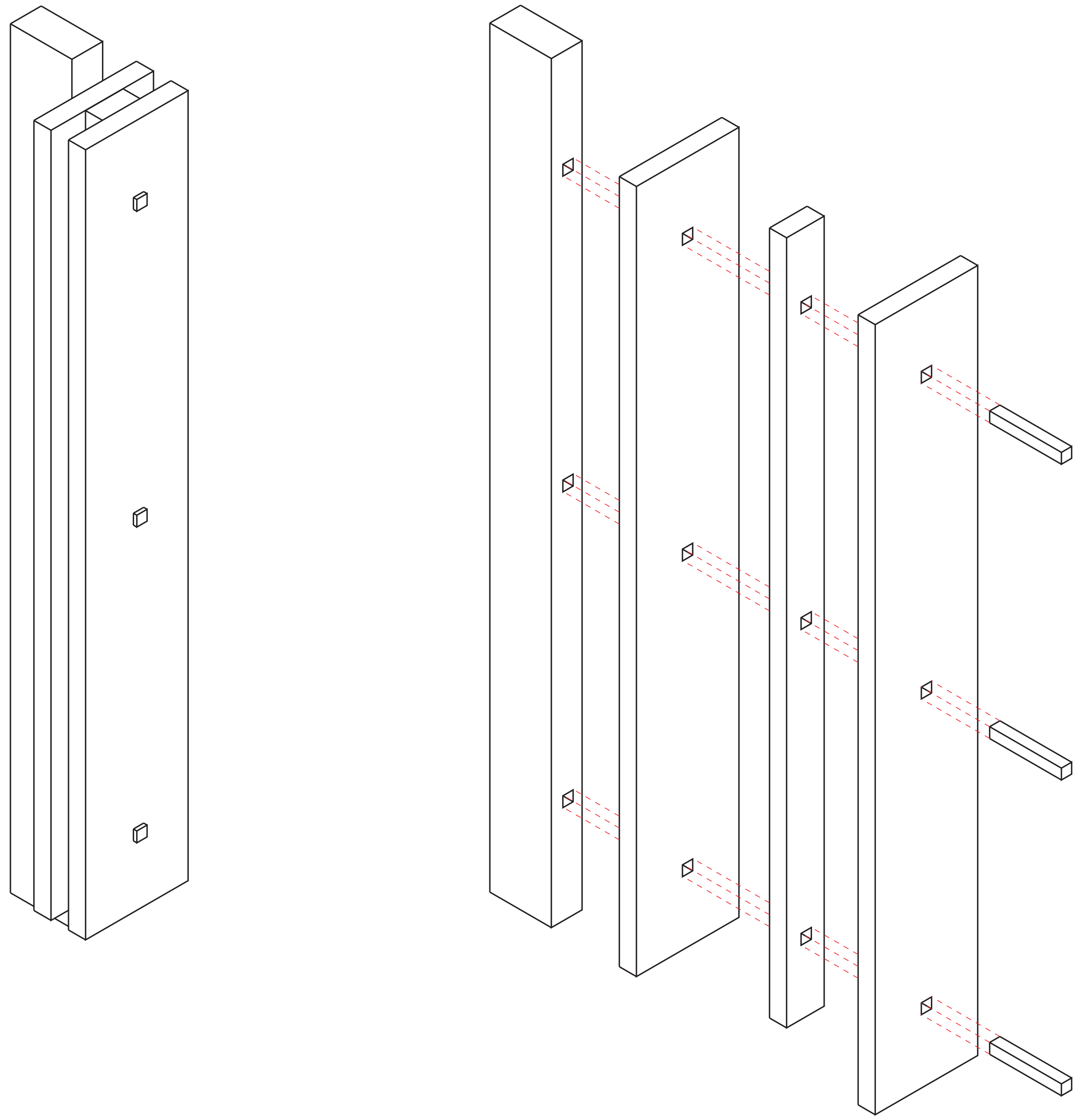


Fig 4.20 Assembly of posts

4.4.2 Compression of Rails

This proposed method of tensioning top and bottom rails is intended to adjust for variable board edges. By applying pressure vertically onto boards, a more weathertight seal is created.

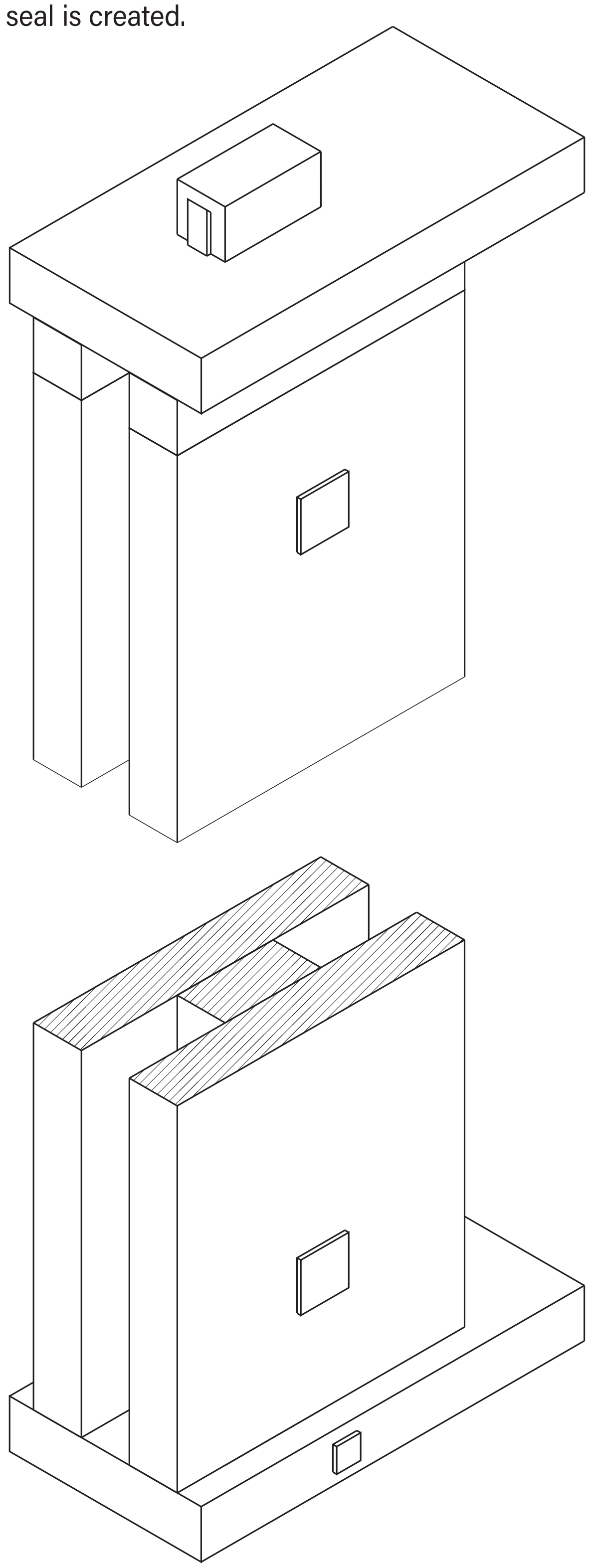


Fig 4.21 Explorations of fixings at junctions

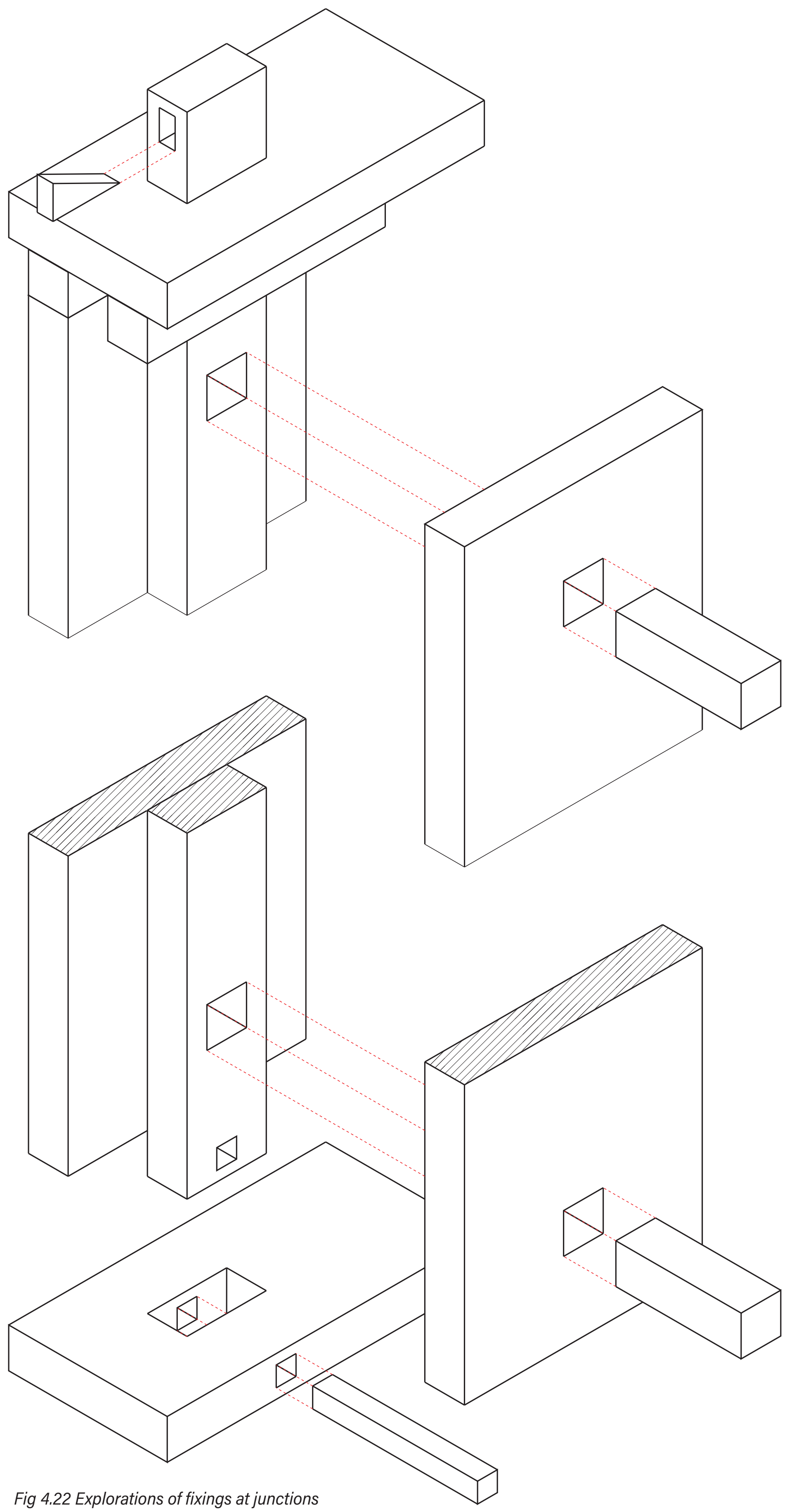


Fig 4.22 Explorations of fixings at junctions

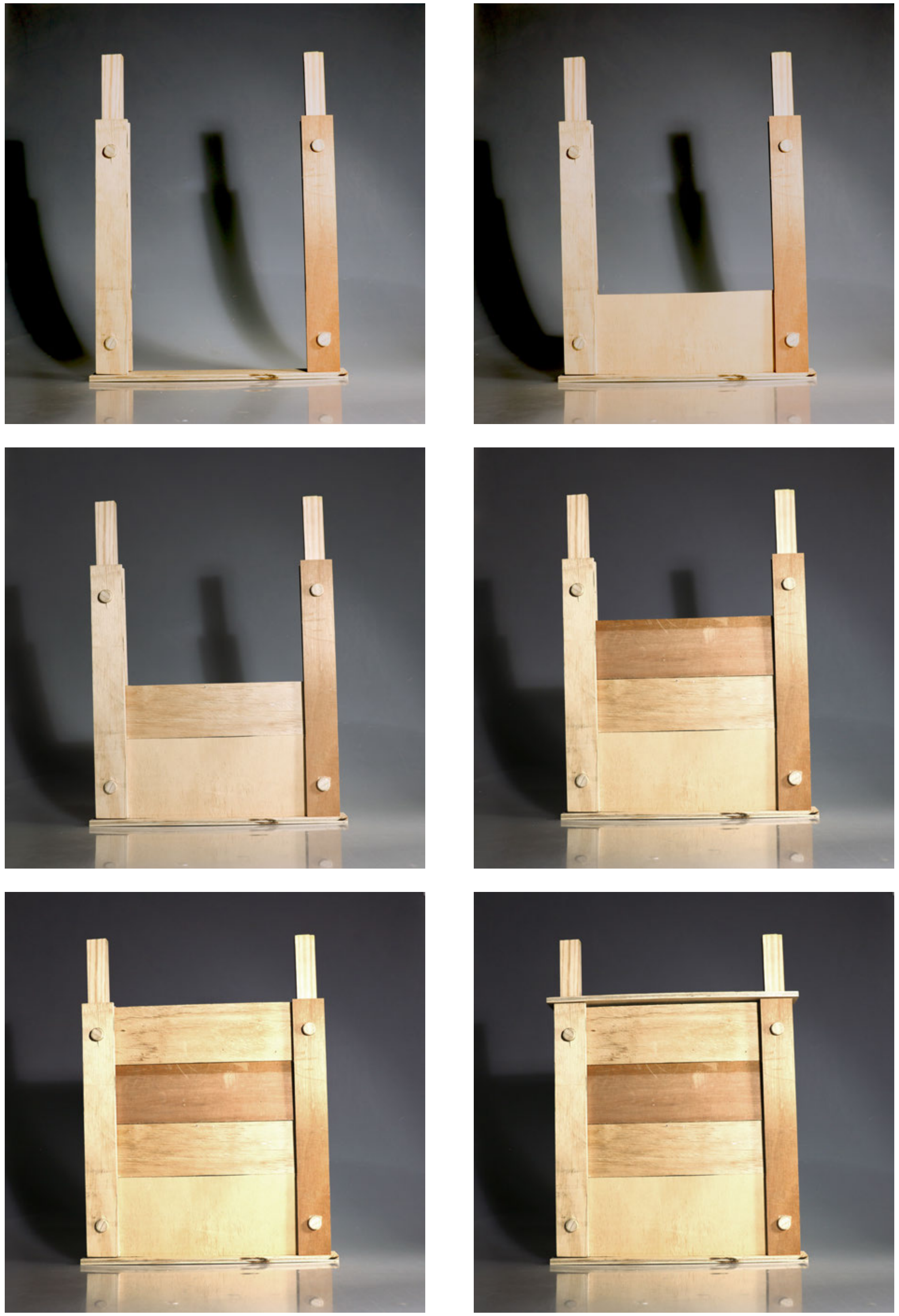


Fig 4.23 Slotted board and batten 1:2 test model

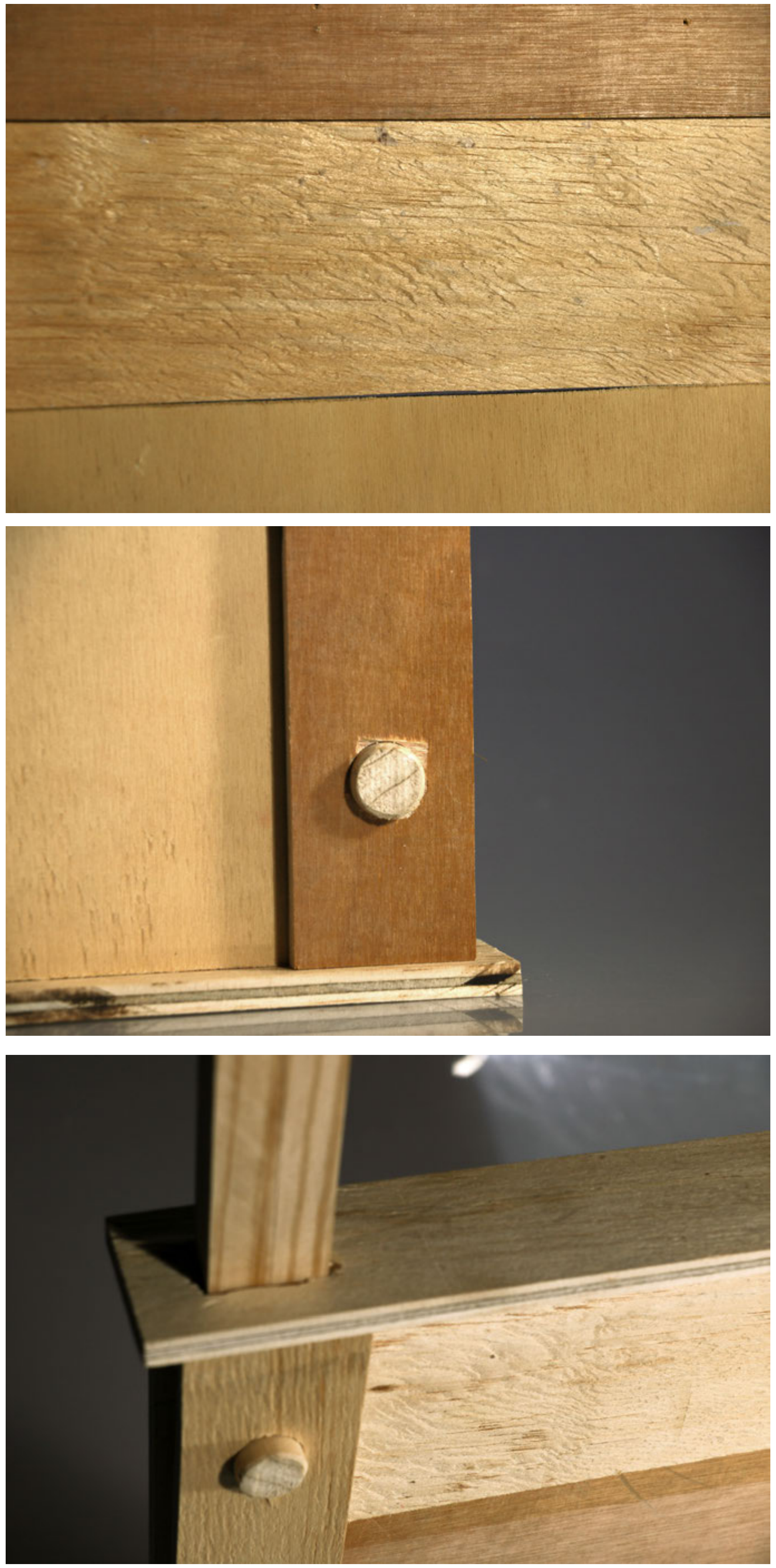


Fig 4.24 Slotted board and batten 1:2 test model detail

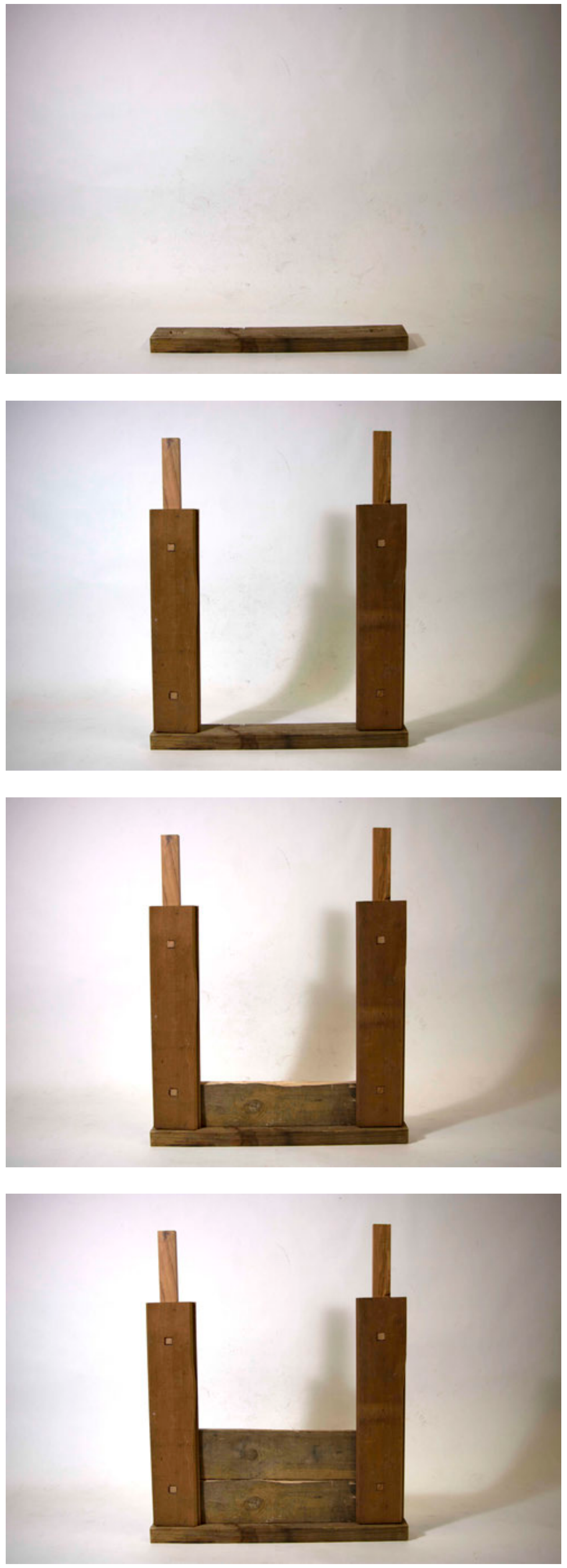


Fig 4.25 Slotted board and batten 1:1 test model assembly

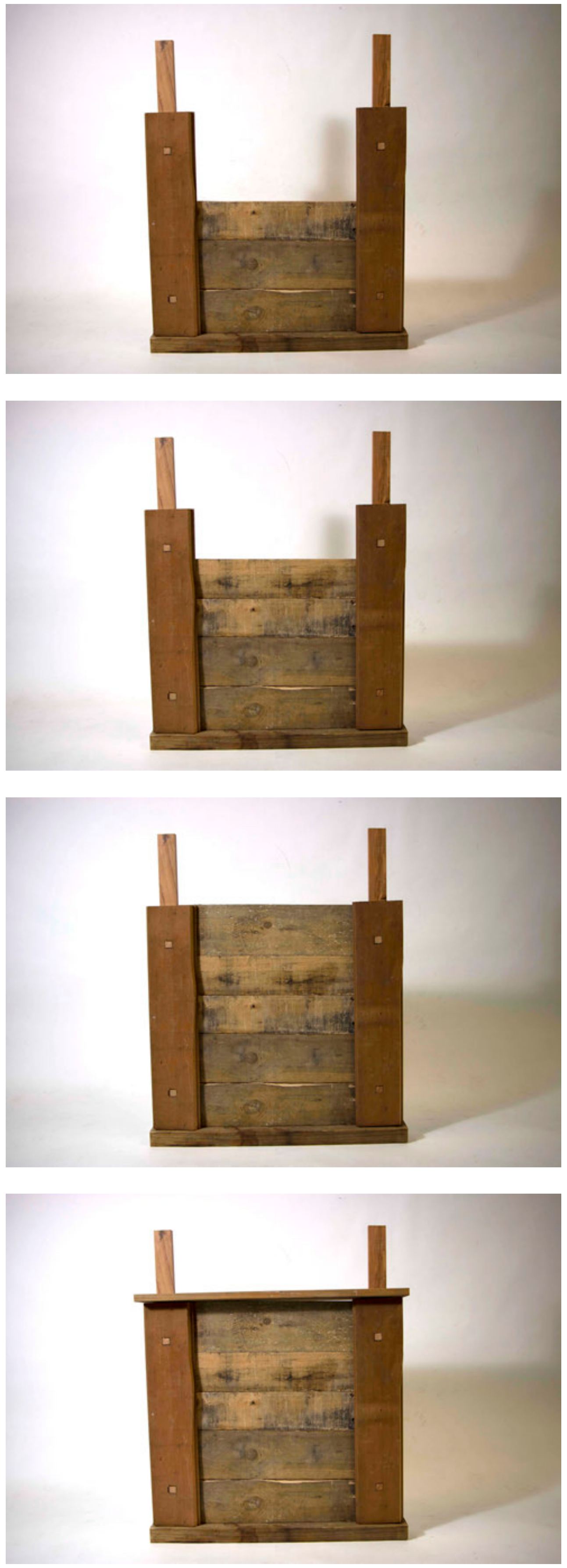


Fig 4.26 Slotted board and batten 1:1 test model assembly

Fig 4.27 Slotted board and batten 1:1 test model post assembly

Fig 4.28 Slotted board and batten 1:1 test model board assembly

Fig 4.29 Slotted board and batten 1:1 test model board assembly

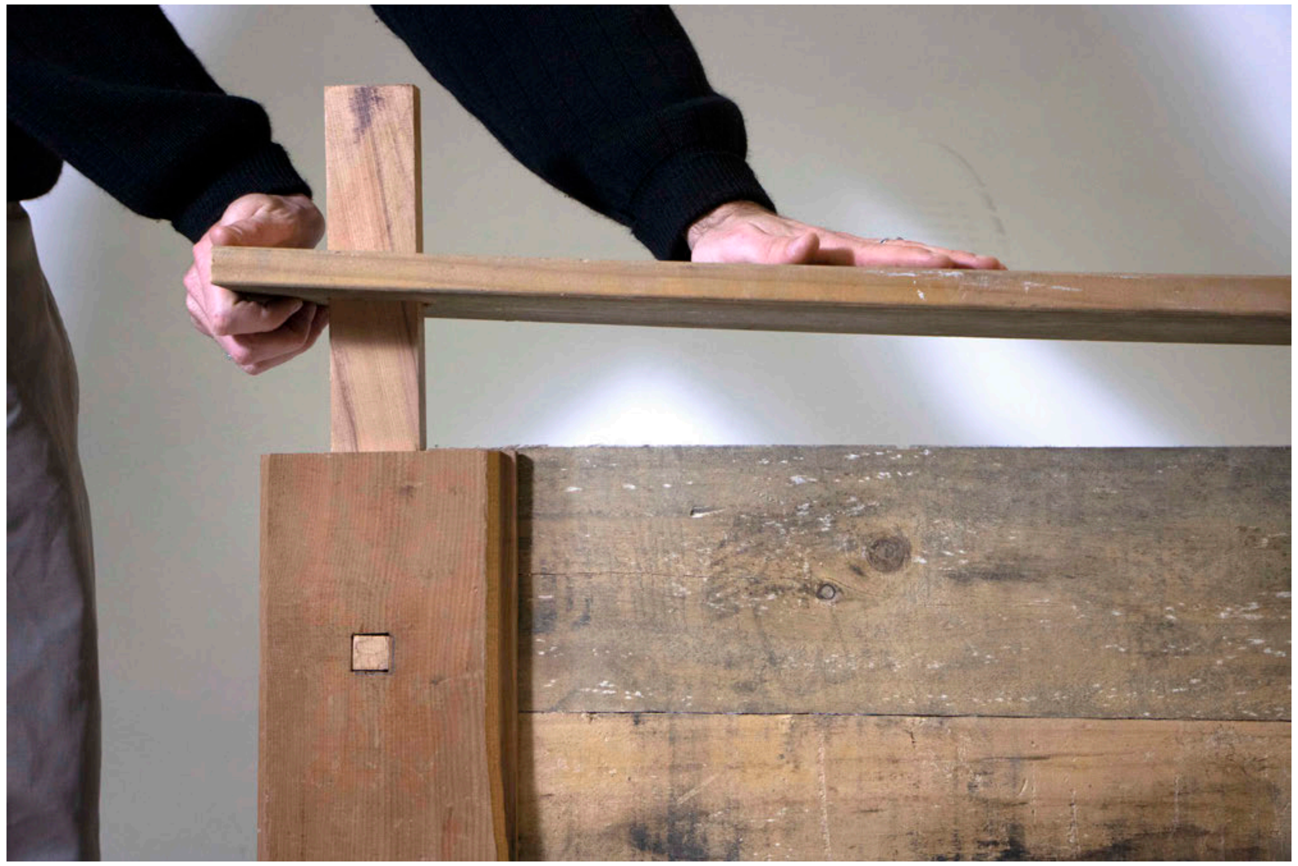


Fig 4.30 Slotted board and batten 1:1 test model top rail assembly

4.4.3 Offcuts and Components

It is difficult to determine the efficiency of this system by its offcuts when it is not tested at a large scale. What can be examined is the function of the offcuts and wastage produced by this model in the context of this research. The timber offcuts, as well as the disassembled model, will provide material for later test models and could potentially be incorporated into the finished system. This is not the case, however, for the nails pulled from the timber used in this model (Fig 4.33). As the use of nails is a hindrance to deconstruction (particularly in the case of ring nails), they will not be reused in combination with native timber.

Fig 4.31 Components from slotted board and batten 1:1 test model

Fig 4.32 Offcuts from slotted board and batten 1:1 test model

Fig 4.33 Nails pulled from slotted board and batten 1:1 test model

4.4.5 Considerations of Slotted Board and Batten

This third design is the first to be 1:1 scale. Additionally, this is the first model to use native timber to construct some of its elements. The model explores only a partial section of cladding, around 600x650mm. This physical exploration has lent insight into some immediately apparent issues at this stage of the design process.

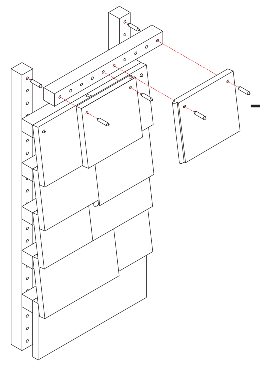
The first and most obvious issue is time consumption. To make only a small section of wall from the timber available took two full days of working for one person. This included pulling nails, putting some timber through a thicknesser, cutting beams down into battens, and chiselling mortises. This time could be reduced significantly by more carefully selecting the timber used as many workarounds were needed for the limited supply of material used. Additionally, moving towards a more heavily machined design will create a more efficient process when production is being carried out on a larger scale.

The second major issue with this design is the use of through-tenons. These tenons were used to fix together the I-Posts and in turn fix these to the studs of a building. This provides major breaches in the weatherproofing of the system. Additionally, to create a high level of accuracy the mortises must be cut with extreme care. This takes a great deal more time and accuracy than if dowels are used, as a drill press can be used to obtain a much more accurate fit in a much smaller amount of time.

The following iterations of the slotted board and batten system will streamline the initial design by incorporating more consistent use of 2x4 framing. The creation of a three-part post was intended as a means of using 50x50mm battens as they are a common element in state houses that are not particularly efficient as boards due to their small profile. However, any use of these battens would require a large degree of alteration, including large holes cut directly through the batten, reducing their reusability. By constructing the entire frame for the boards from 2x4s routed to create slots, a system is created that leaves more unaltered timber when it is deconstructed. It will also result in a design with a reduced profile which should allow for more efficient construction on-site and a more versatile application across different construction types.

4.5 Initial Iterations - Findings

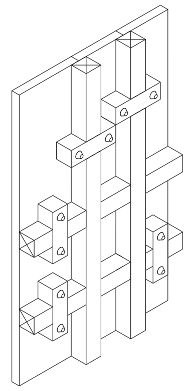
Modular Shingles



Benefits:
The modular shingle system offers efficient possible reusability specifically as an architectural system. Its modularity and simplicity mean that replacing parts when they age or are damaged is a simple process. It would also effectively facilitate the use of a greater range of offcuts.

Limitations:
The issue with this system is its lack of circularity in a broader context. The shingles would not provide a particularly useful resource at the end of the cladding systems lifespan. Additionally, if batten were to be pre-drilled to allow for a modularity on both axis of the system, they would then hold little use outside of the system, perhaps less than if nails were used.

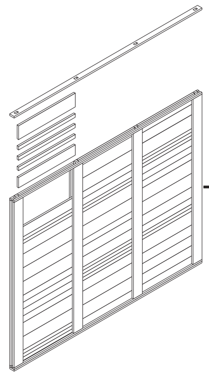
Patchworked
Board and Batten



Benefits:
The patchworked board and batten system has a great deal of potential in architectural application. Introducing alternative board sizes could allow for the potential accommodation of unique cladding penetrations. The system is also designed around accommodating smaller boards as space fillers.

Limitations:
While attempting to accommodate for smaller offcuts, this system became excessively complex. The additional machining needed to facilitate modularity of the system would make all components significantly less useful in non-architectural reuse. It has also become apparent as timber has been sourced for this research that while large lengths of timber are available, the maximum width tends to be around 200mm. This means that the battens extend over around 50% of the board, making an inefficient and bulky cladding.

Slotted
Board and Batten



Benefits:
The slotted board and batten system proved to be the most effective in terms of non-architectural application. The potential for using largely unaltered boards mean that the longest possible lengths could be reused from this system. The design also means that complex machining only needs to be applied to certain elements, streamlining some of the process. This system aligns closest with the refined circularity definition and for this reason it has been chosen to proceed with.

Limitations:
Junction points in this system at the top and bottom rail are currently too complex for the small profile from which they are machined. Additionally, excessive penetrations for tenons create moisture risk, so in order for this design to become viable, the design will need to be reworked through the introduction of new machining techniques.

5. Refined Iteration

The slotted board and batten system was refined through a series of design iterations relating to the profiles and junction points of posts and rails. This was done through digital drawings and modelling of 1:1 junction details. The purpose of using these mediums was to allow quickly generated designs through drawings that could be tested with small volumes of material to gain an understanding of the machining needed for the most detailed areas of the system. The initial slotted board and batten design was iterated to find an outcome that minimised areas for moisture to gather without excessively complicated profiles.

Opposite page Fig 5.00 Detail model components

5.1 Vernacular Craft

These further iterations have been informed by vernacular craft observed in state house joinery. Specifically, the techniques used to create doors with timber or glass panels have been used to inform a series of more complex posts and rails designed to minimise the number of timber elements needed for this system (Fig 5.02). This implementation of vernacular craft is also a means of further implementing material heritage when native timber is reapplied to new builds, influenced by Wang Shu's use of folk craftsmanship in the façade of Ningbo Museum (Chau, p. 360, 2015).

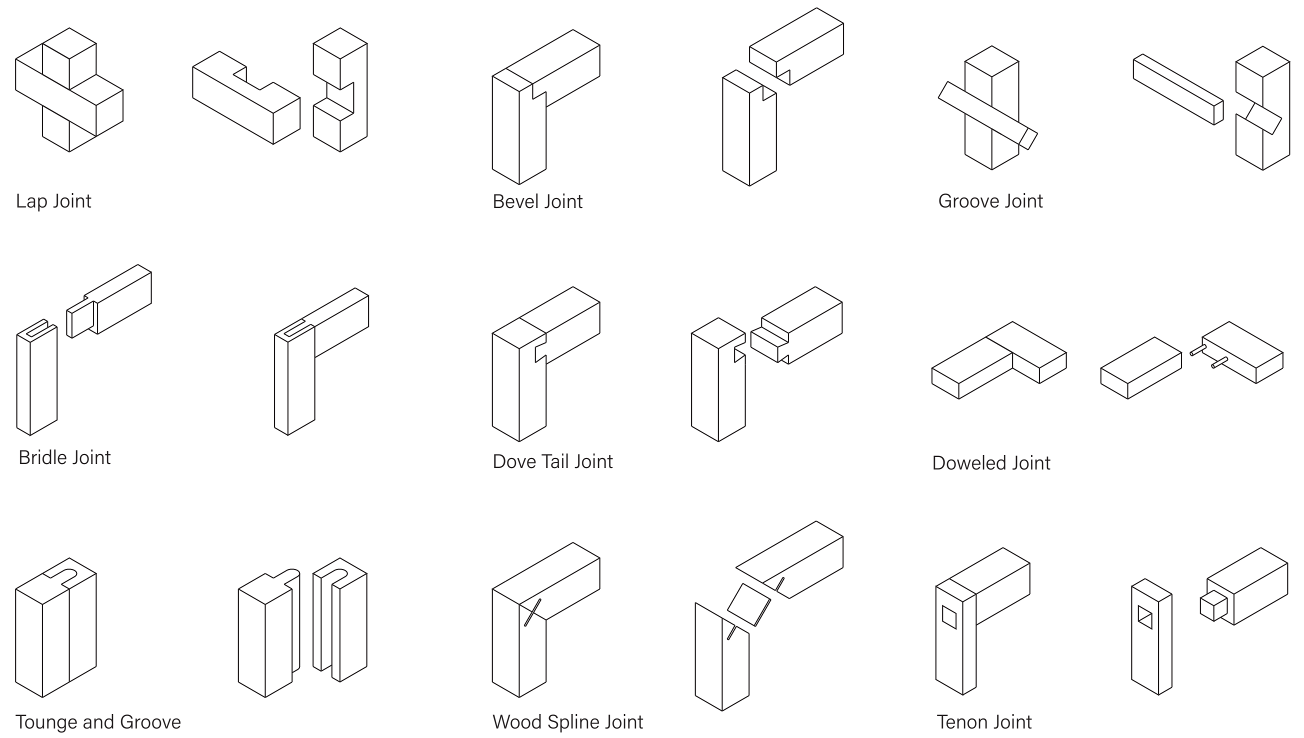


Fig 5.01 Exploration of Joinery

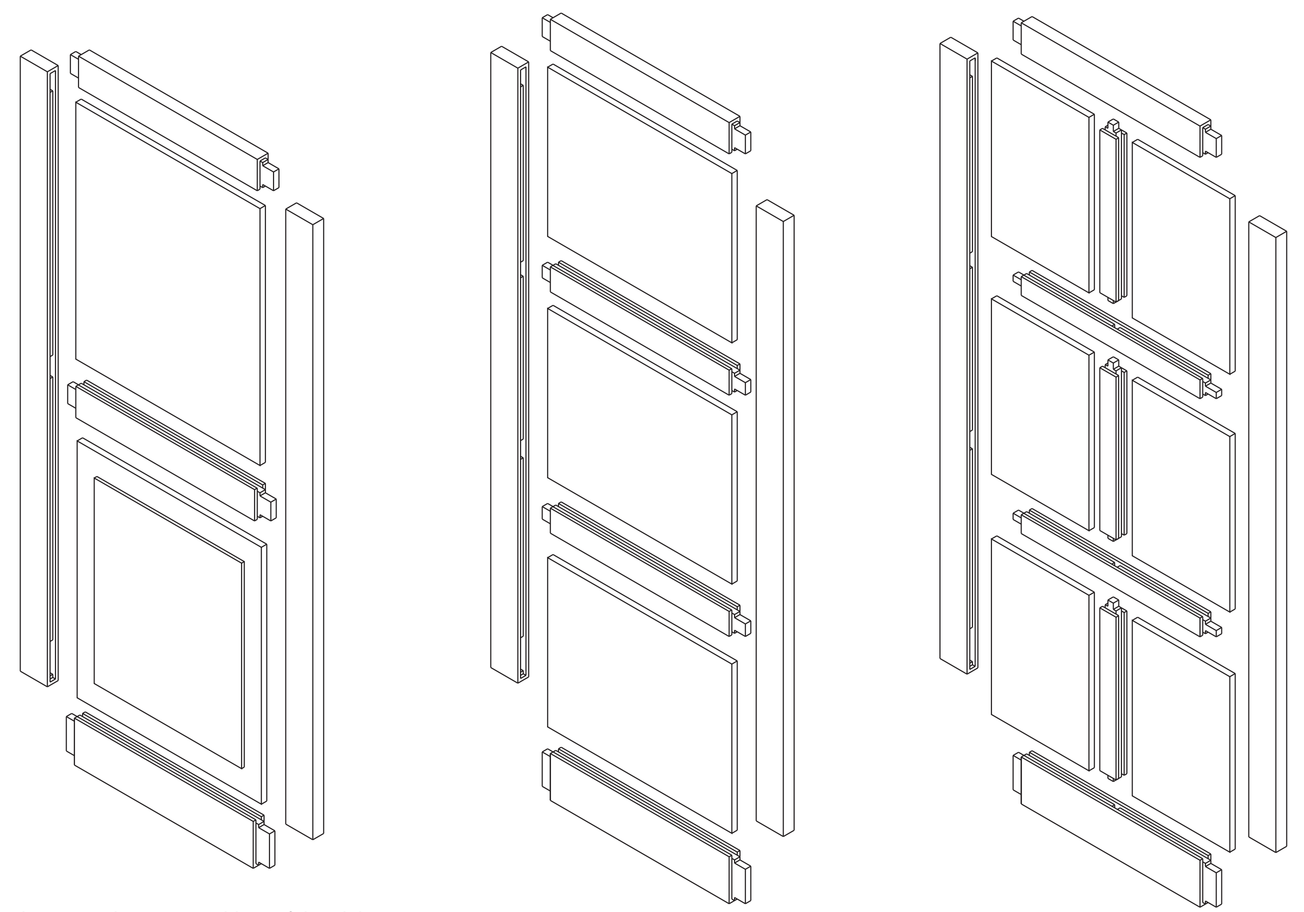


Fig 5.02 Various compositions of door joinery

5.2 Slotted Board and Batten - Routed

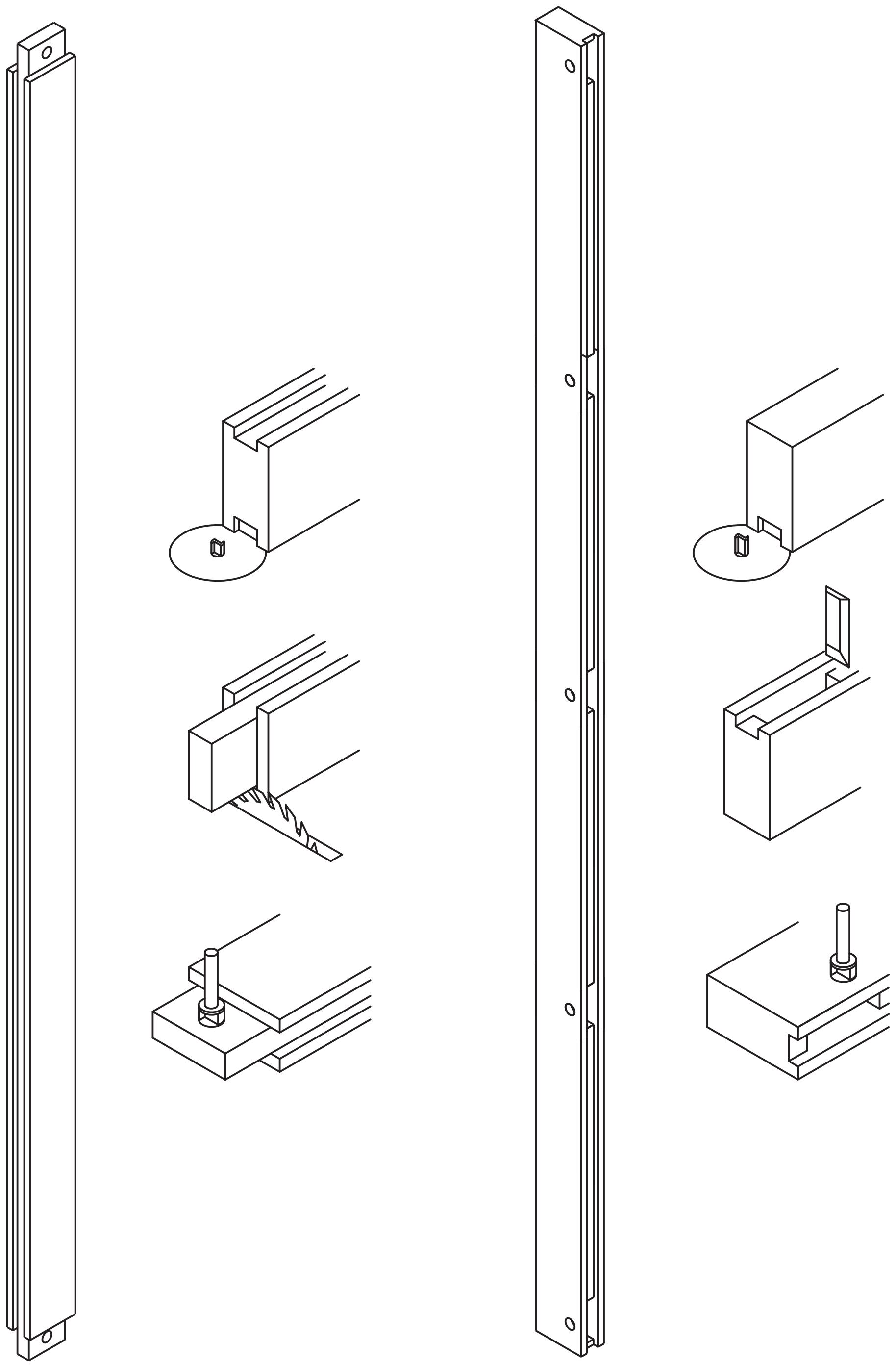


Fig 5.03 Process of frame construction

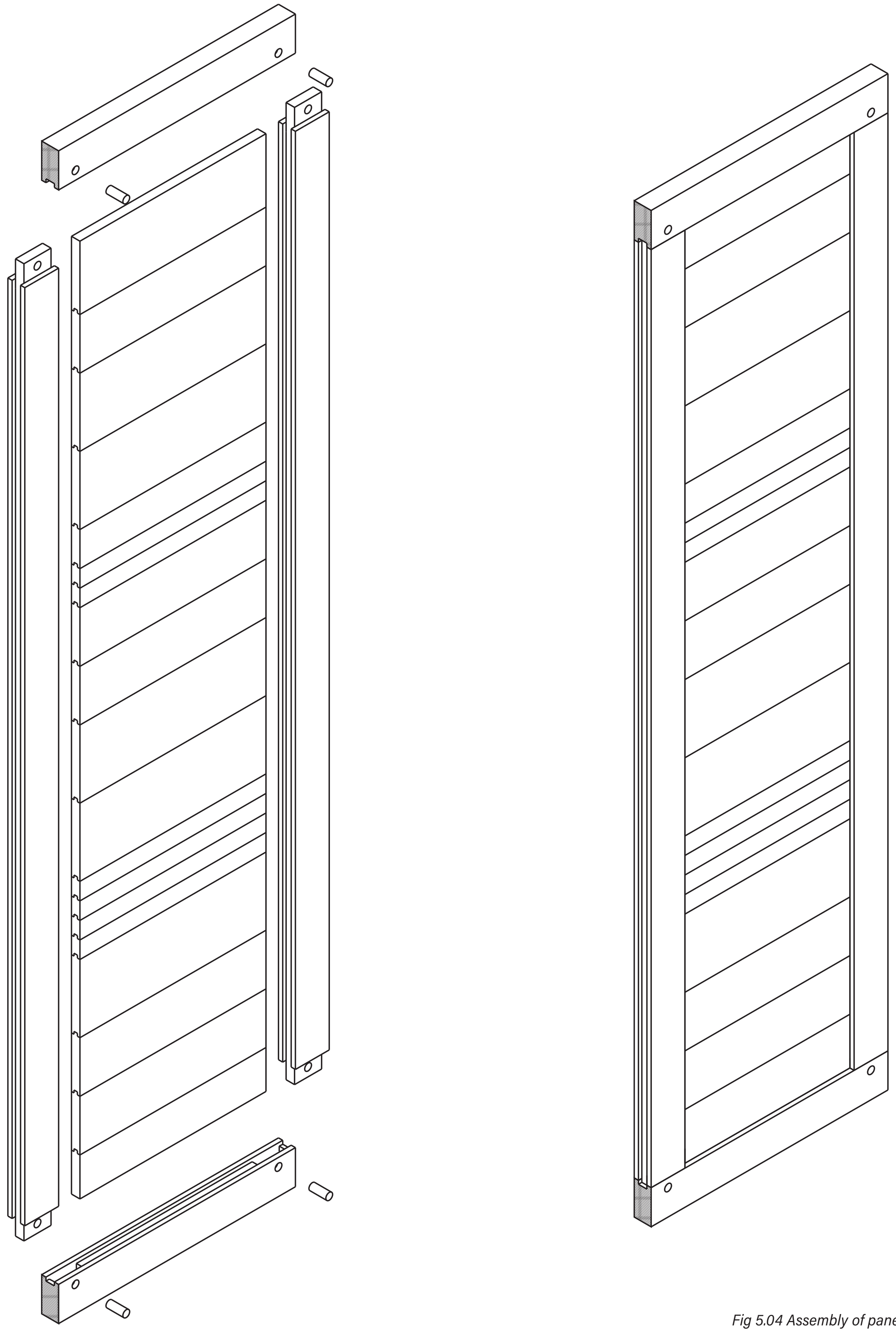


Fig 5.04 Assembly of panel

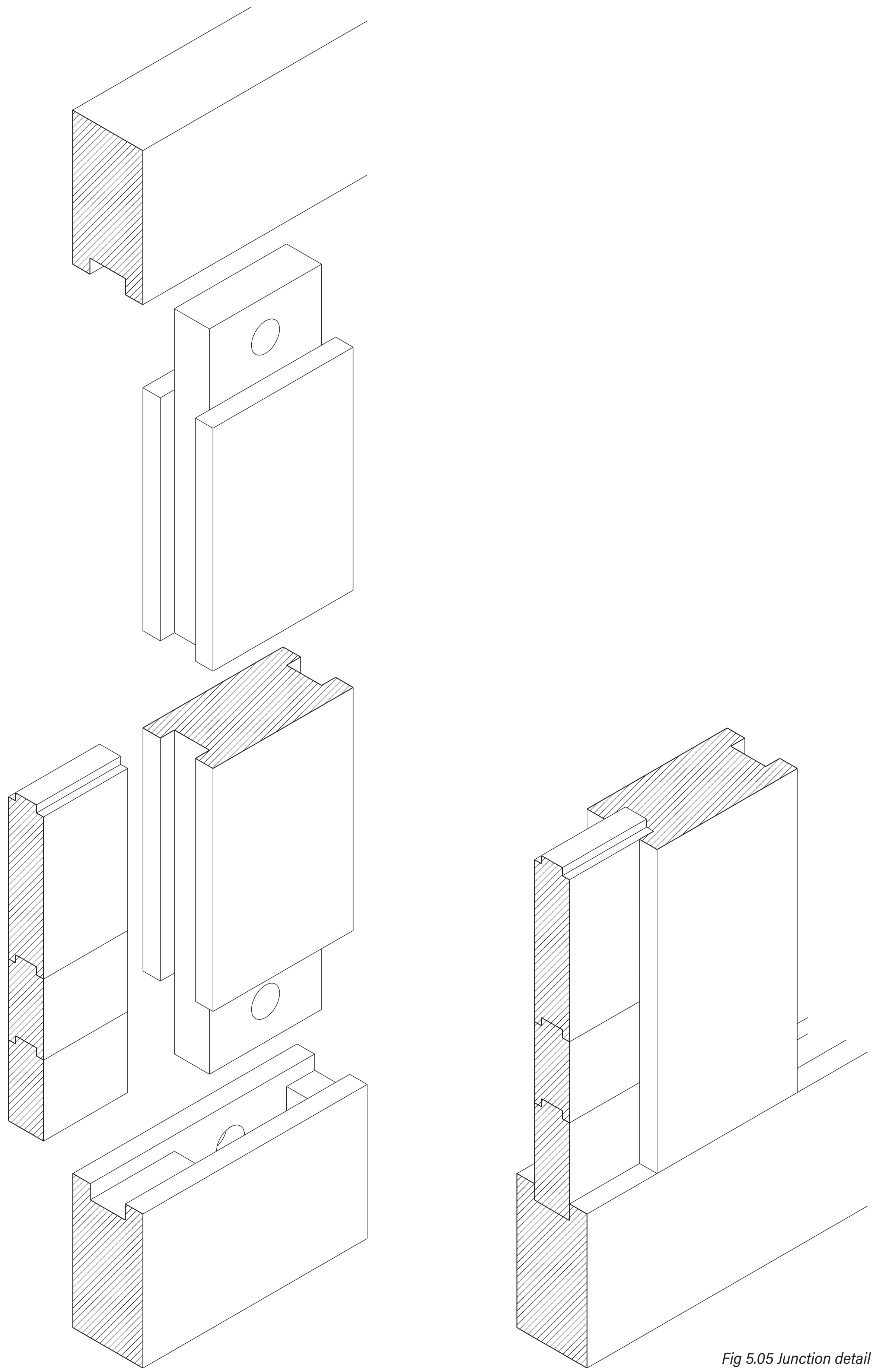


Fig 5.05 Junction detail

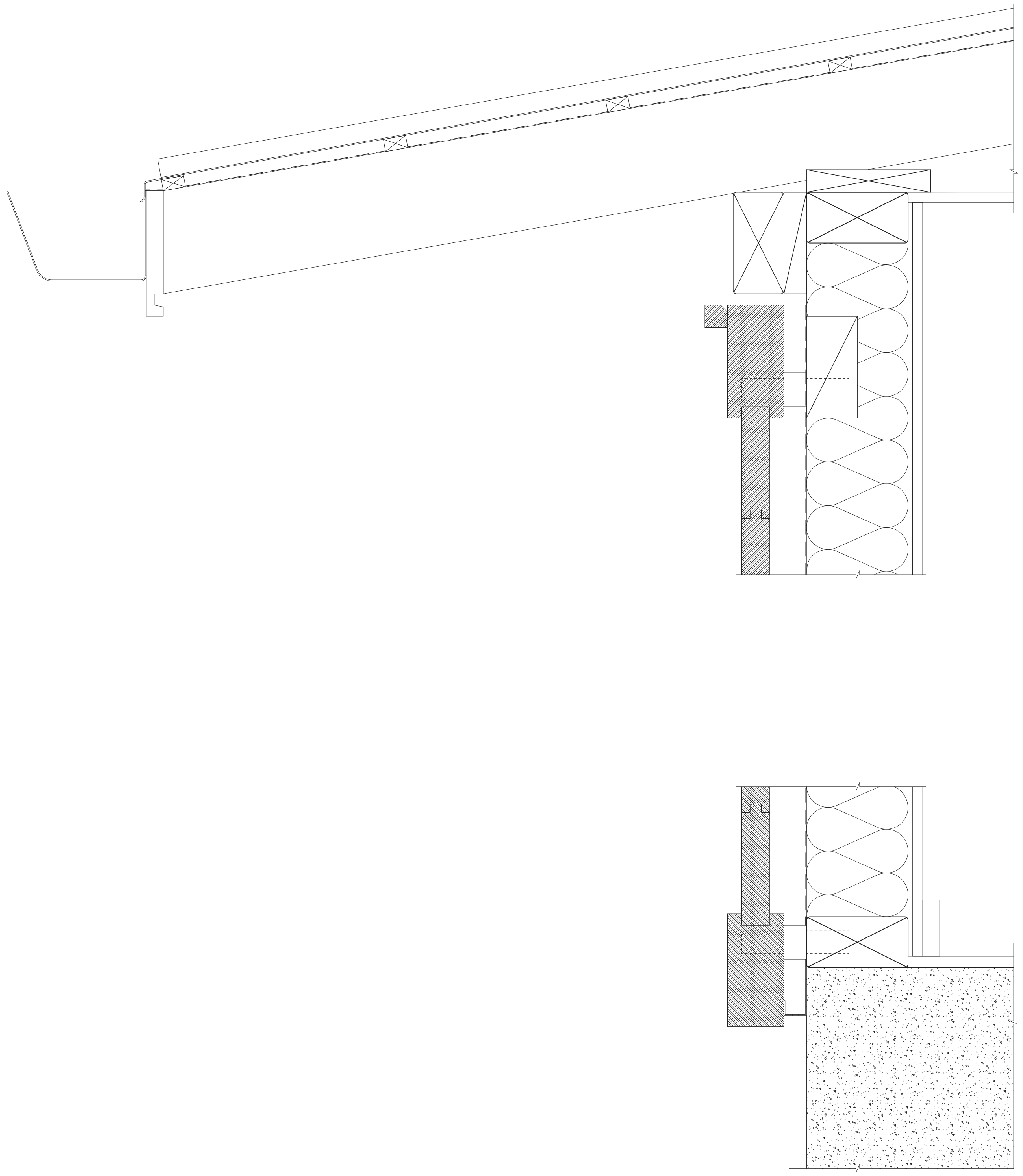


Fig 5.06 Doweled fixing

Fig 5.07 1:1 Detail model

Fig 5.08 1:1 Detail model

Fig 5.09 1:1 Detail model junction

Fig 5.10 1:1 Detail model tenon

Fig 5.11 1:1 Detail model mortise

5.2.1 Slotted Board and Batten- Routed - Findings

This initial iteration drew heavily on the techniques used in traditional door construction. The use of both slotted posts and rails, as well as a tongue and grove connection between boards, meant that a singular router bit could be used to achieve the majority of machining once this timber was dressed. The use of a through-dowel, however, provides a risk of moisture entering directly into mortises (Fig 5.07). The use of a slotted connection in the bottom rail also creates too great of a risk of moisture damage, as water would travel directly down the face of the horizontal boards to gather at this point, with no opportunity to drain.

Drainage holes were explored as a solution to this; however, the drilling process was found to be excessively time-consuming. Frequent penetrations along the length of the bottom rail would also dramatically reduce the potential reuse of this element (Fig 4.12, 4.13).

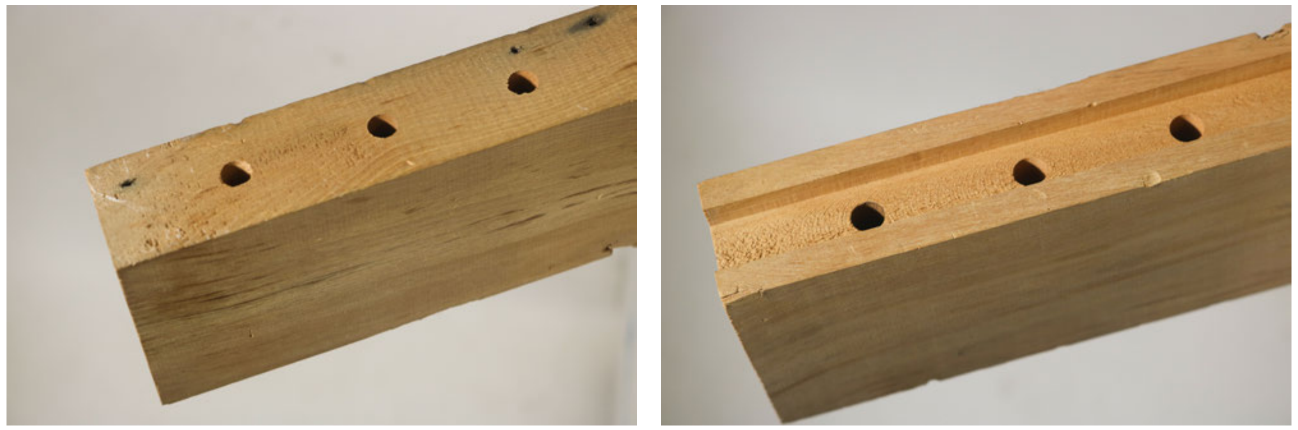


Fig 4.12 Drainage holes 1:1 detail model

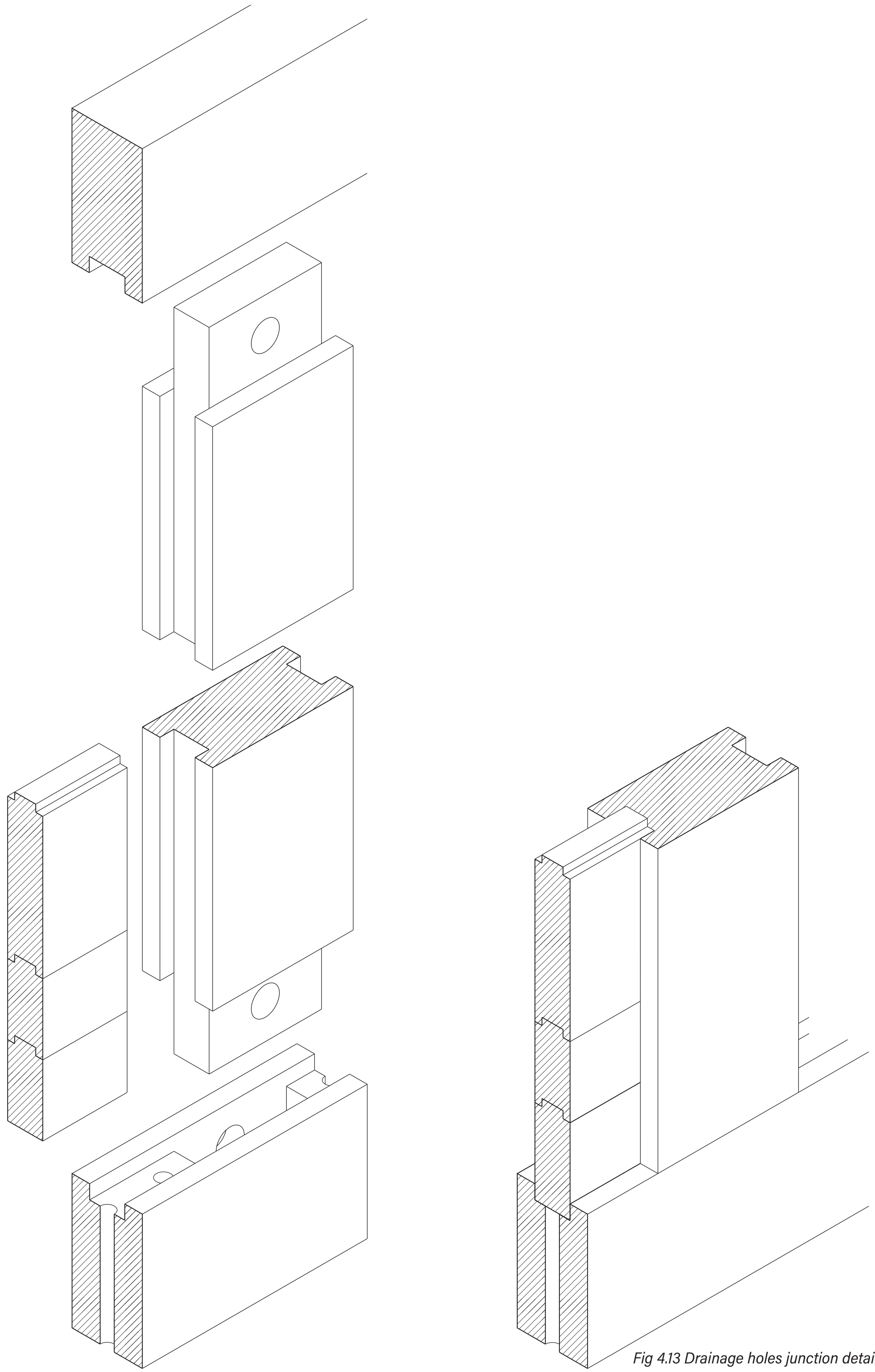


Fig 4.13 Drainage holes junction detail

5.3 Slotted Board and Batten - Flush Face

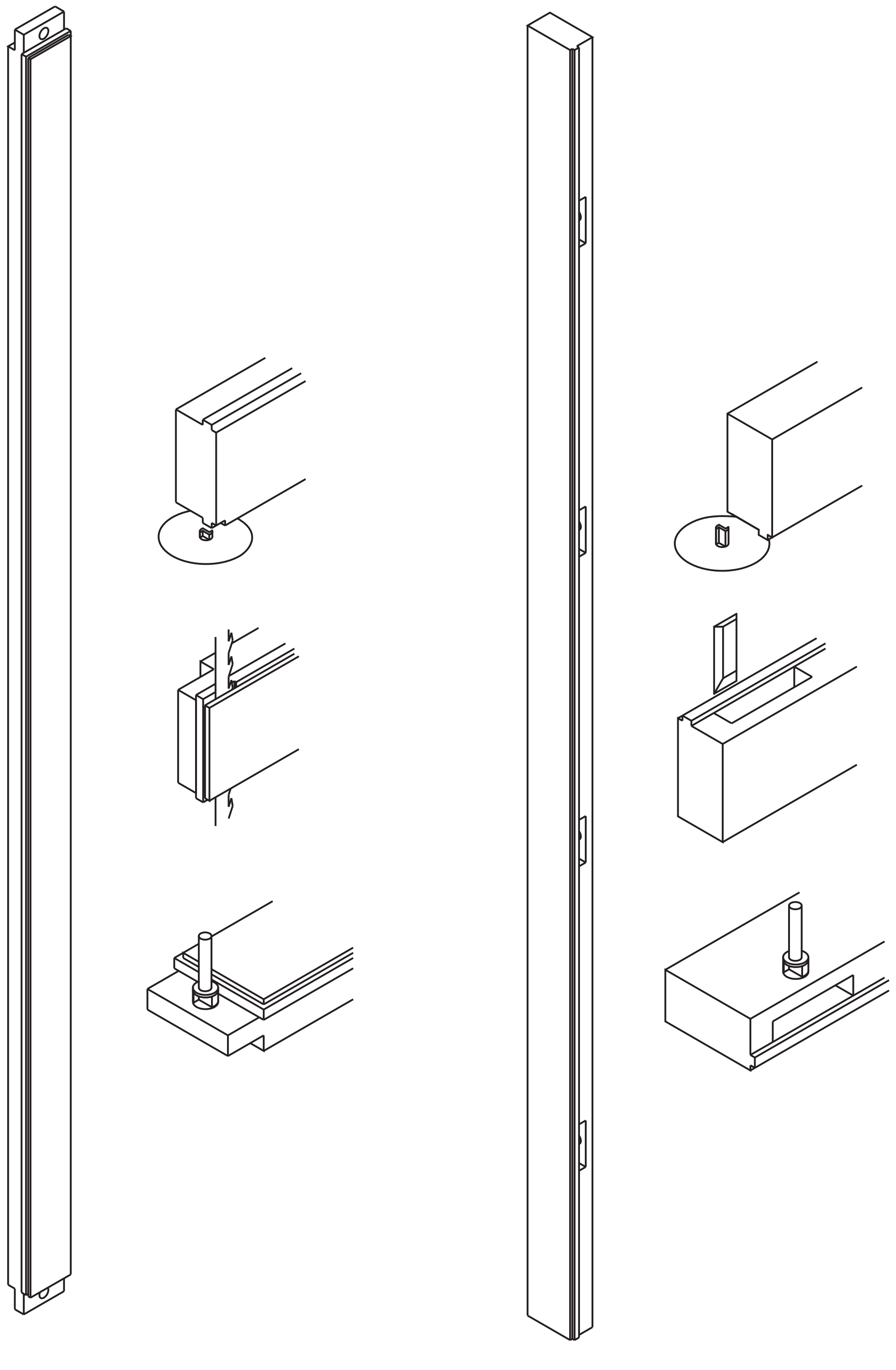


Fig 5.14 Process of frame construction

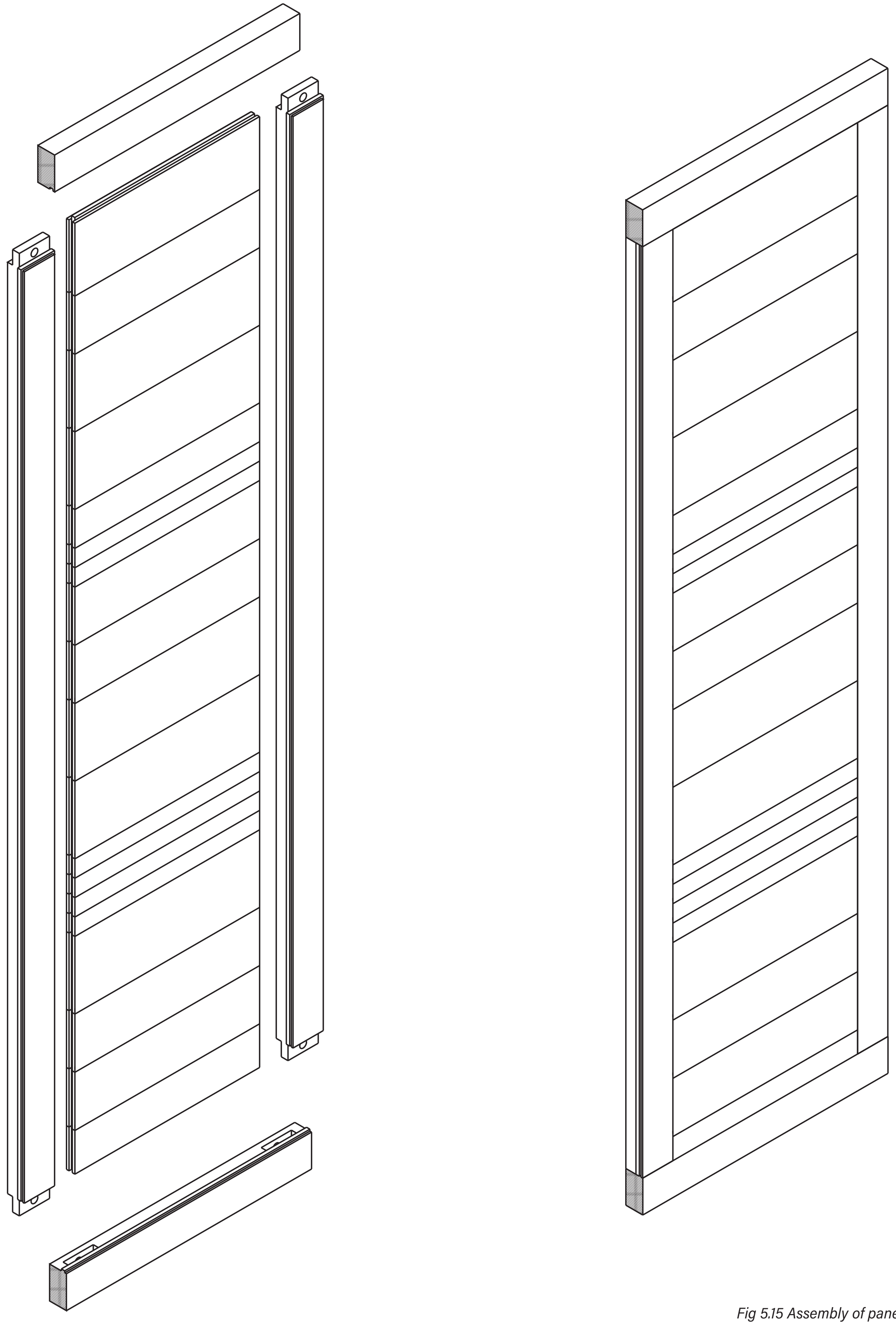


Fig 5.15 Assembly of panel

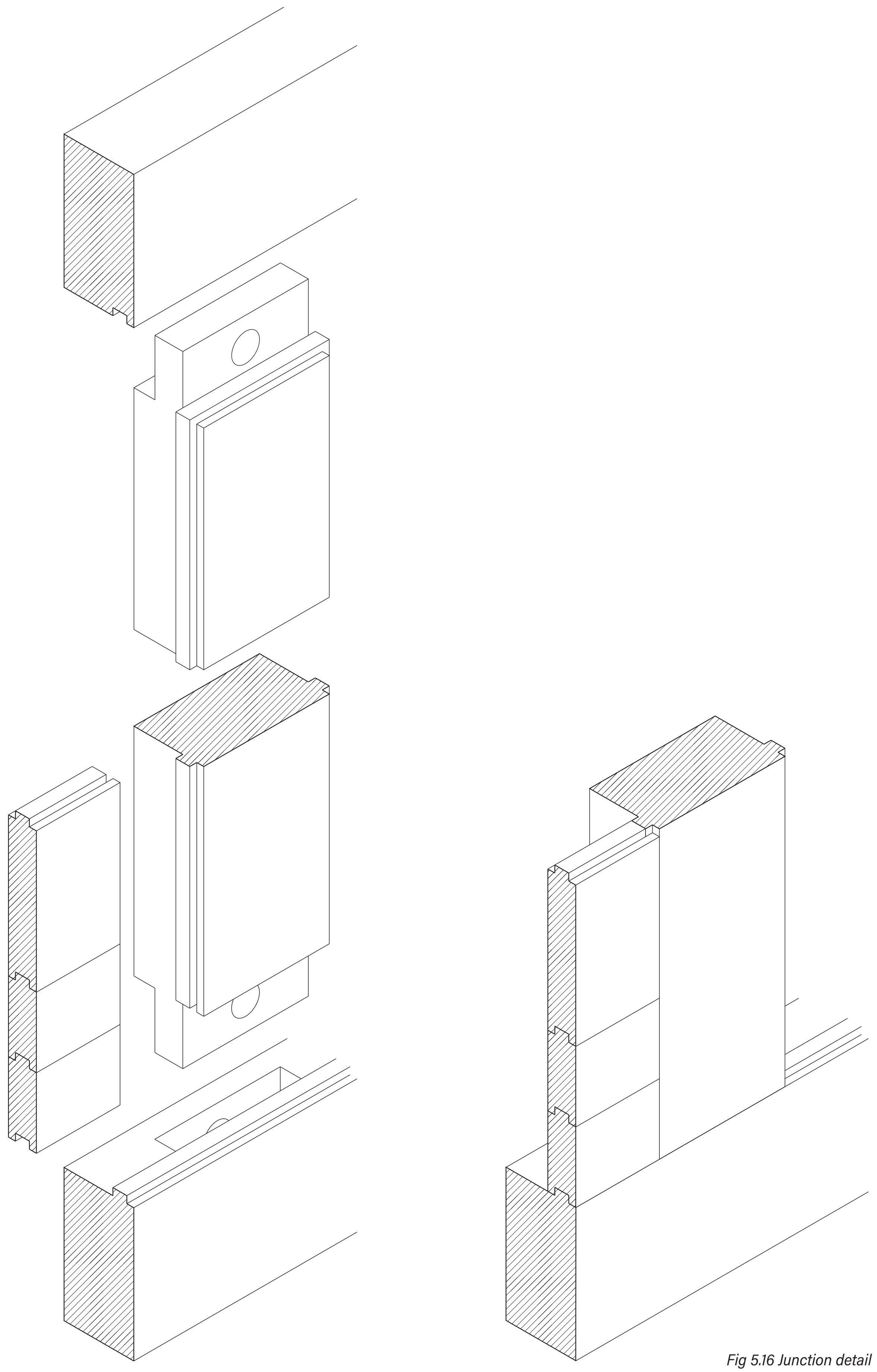


Fig 5.16 Junction detail

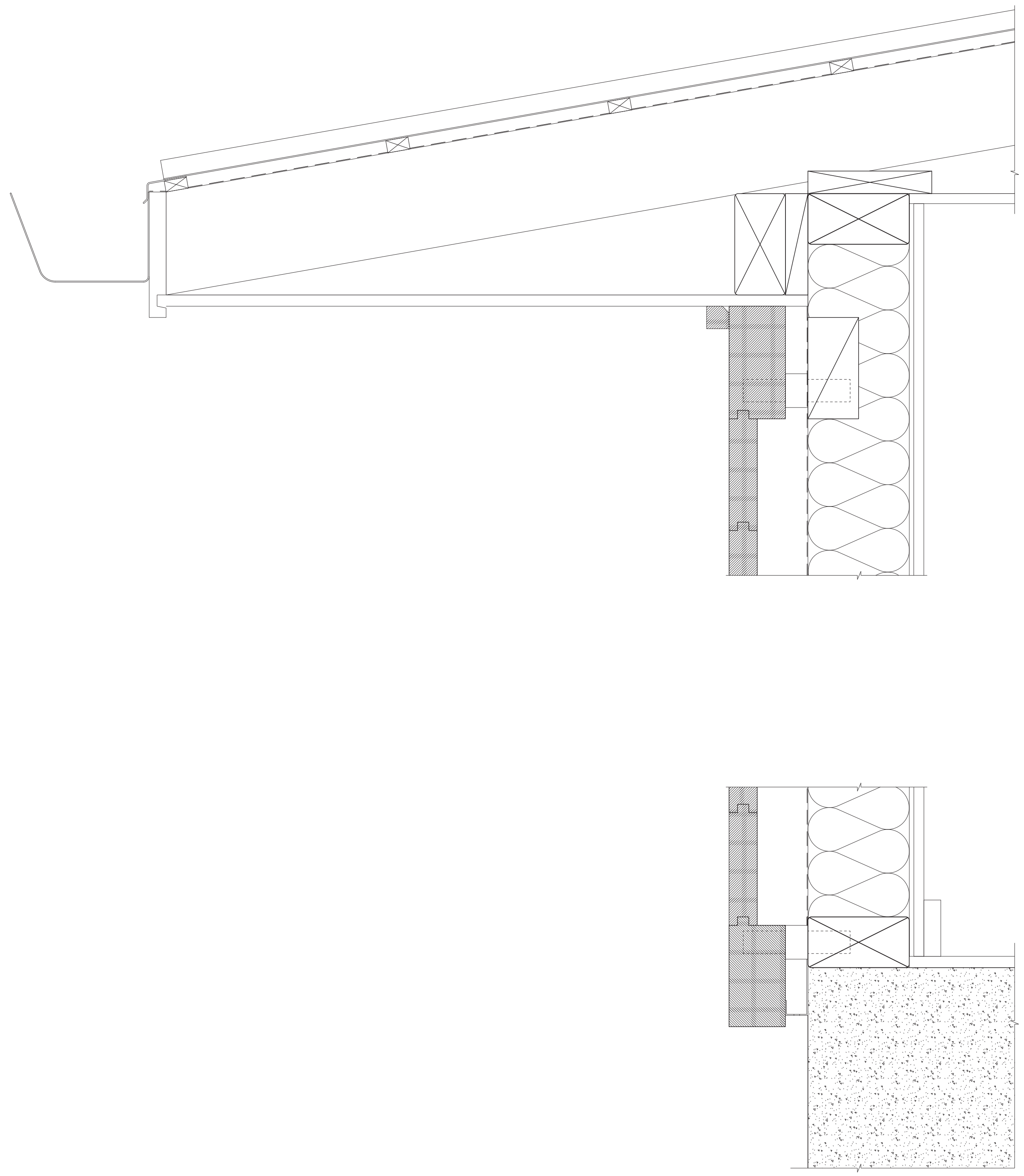


Fig 5.17 Doweled fixing


Fig 5.18 1:1 Detail model

Fig 5.19 1:1 Detail model

Fig 5.19 1:1 Detail model junction

Fig 5.20 1:1 Detail model tenon

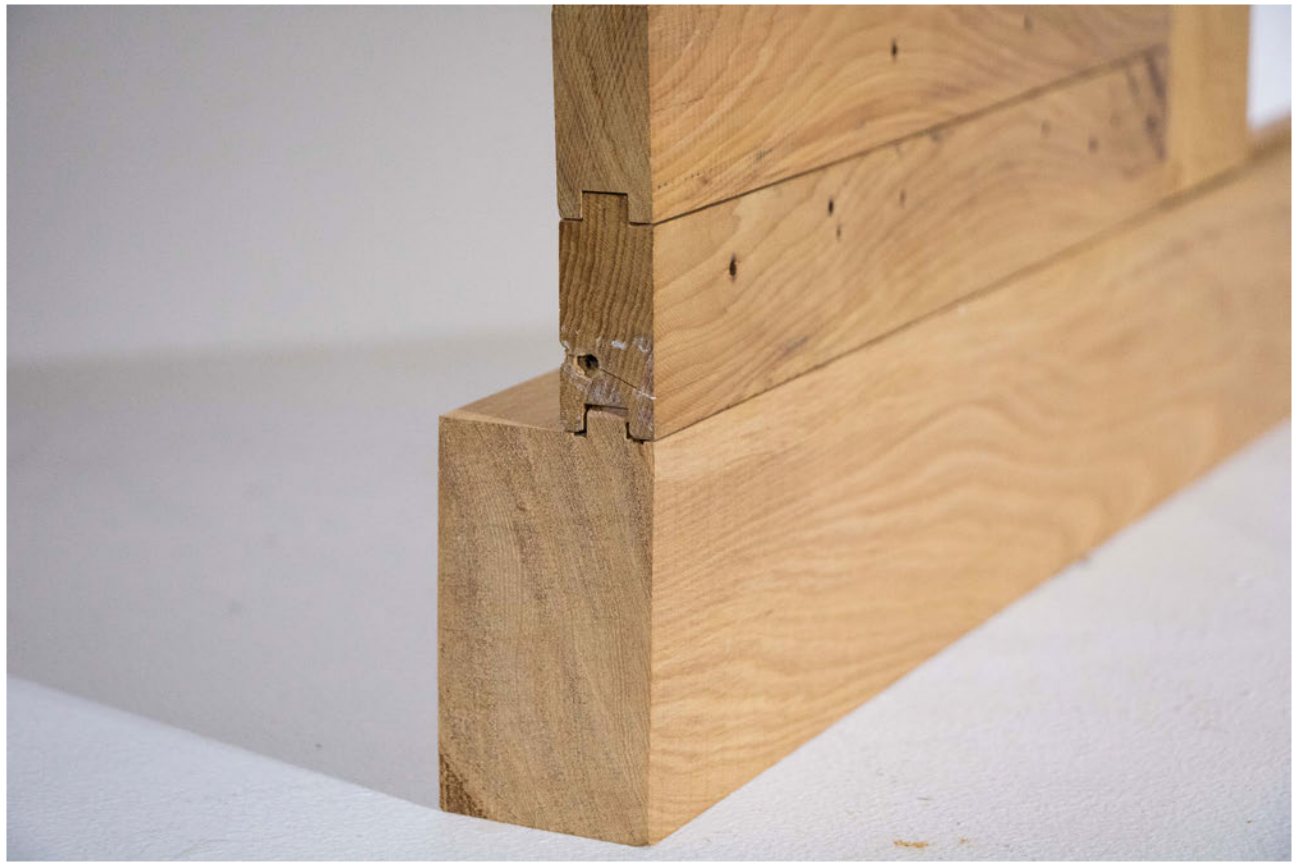


Fig 5.21 1:1 Detail model tongue joint

5.3.1 Slotted Board and Batten – Flush Face – Findings

The intention of this design was to create a continuous cladding face that would reduce areas in which moisture can gather (Fig 5.21). This was achieved using a system of tongue joints and introducing a more complex board profile with routing along all edges. This design also introduced a dowel system that penetrates only through the back wall of each mortise, reducing moisture penetration (Fig 5.18).

This design relies on the principle that water will not penetrate the cladding, which for cavity-fixed timber cladding is unlikely. This means that the profile used to create a flush face has created large surfaces on which moisture can gather. The creation of these profiles used a table saw that required adjustment for each cut, which was far more time-consuming and far less consistent than a router (Fig 5.22). The use of tongue joints was also found to provide a weaker connection than routed slots and was less tolerant to small variations in board dimensions

The timber used to create this profile was a juvenile sapwood, as opposed to the heartwood used in the previous iteration. The machining of this wood brought to light the limitations of certain reused native timber. Rimu is a generally brittle timber and the timber used in this model, suspected to be rimu, has likely had this brittleness exacerbated with age. When the complex profiles of this junction detail were modelled, a great deal of splitting and chipping occurred (Fig 5.23), to the point where a section of the post needed to be completely reattached (Fig 5.24). The findings from this iteration are that delicate or thin profiles both risk system damage and slow the process of making significantly and should therefore be avoided.

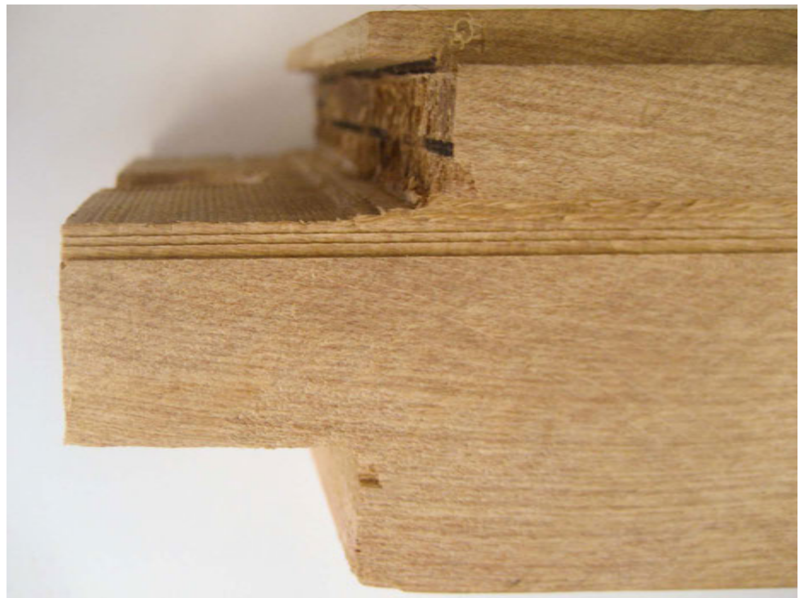


Fig 5.22 Board and batten - flush face profile


Fig 5.23 Board chipping from router

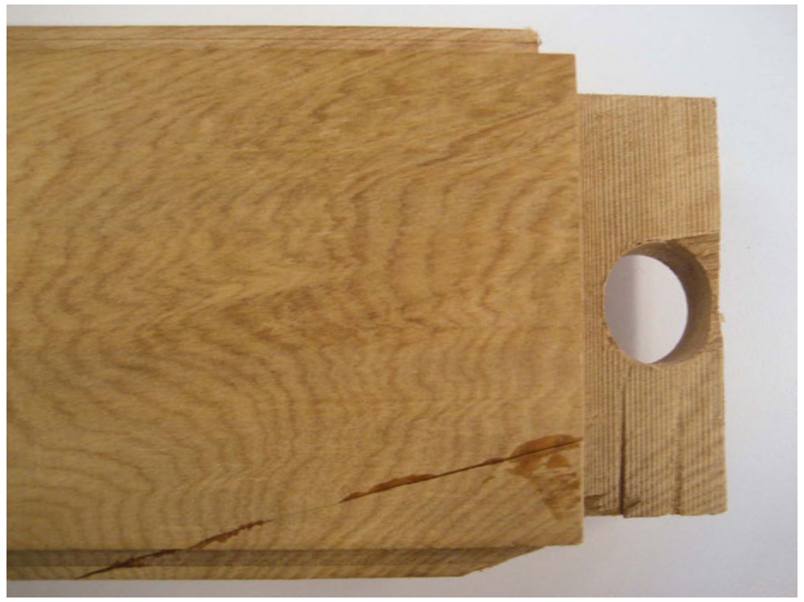


Fig 5.24 Repaired post splitting

5.4 Slotted Board and Batten - Chamfer

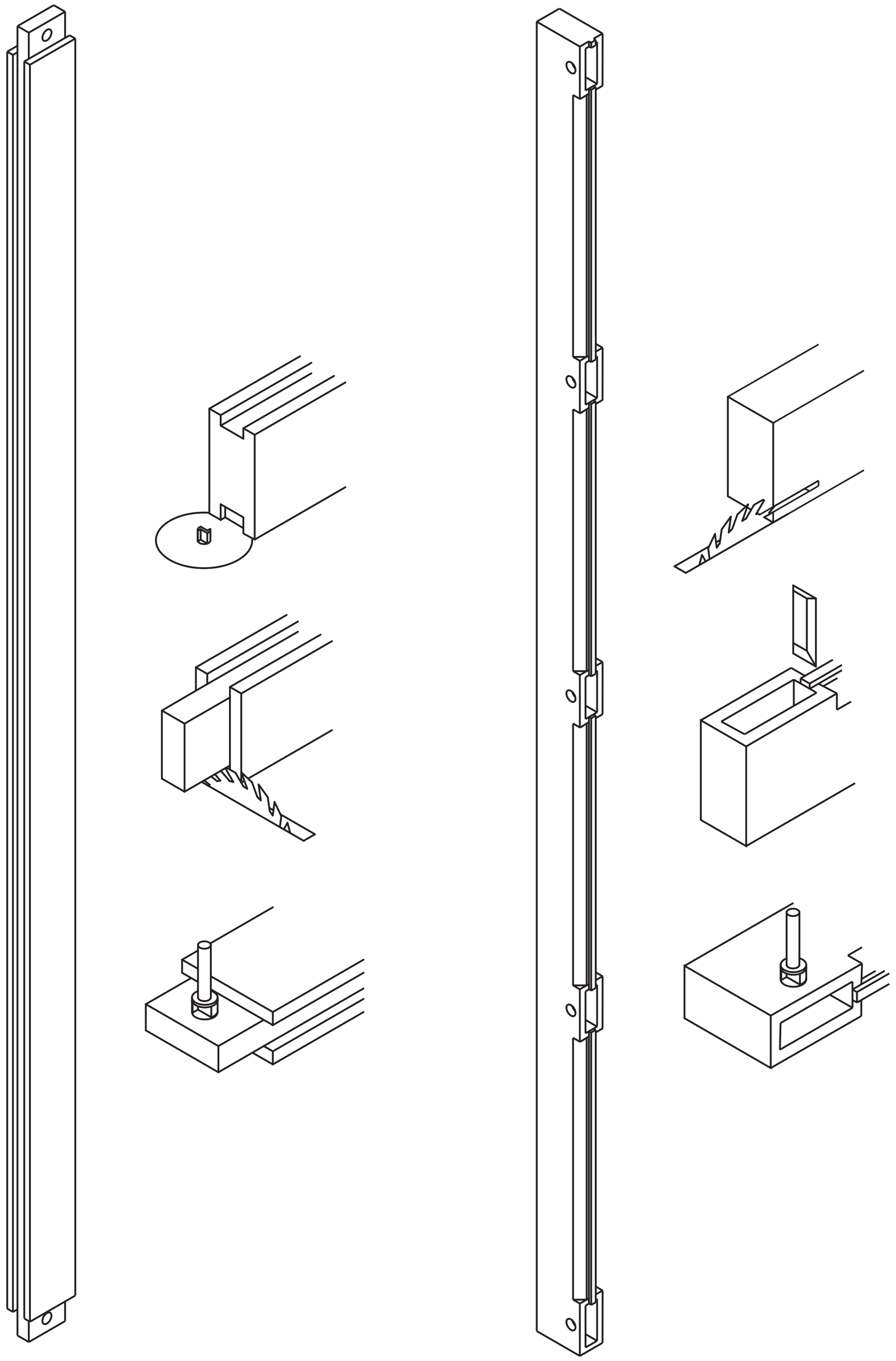


Fig 5.25 Process of frame construction

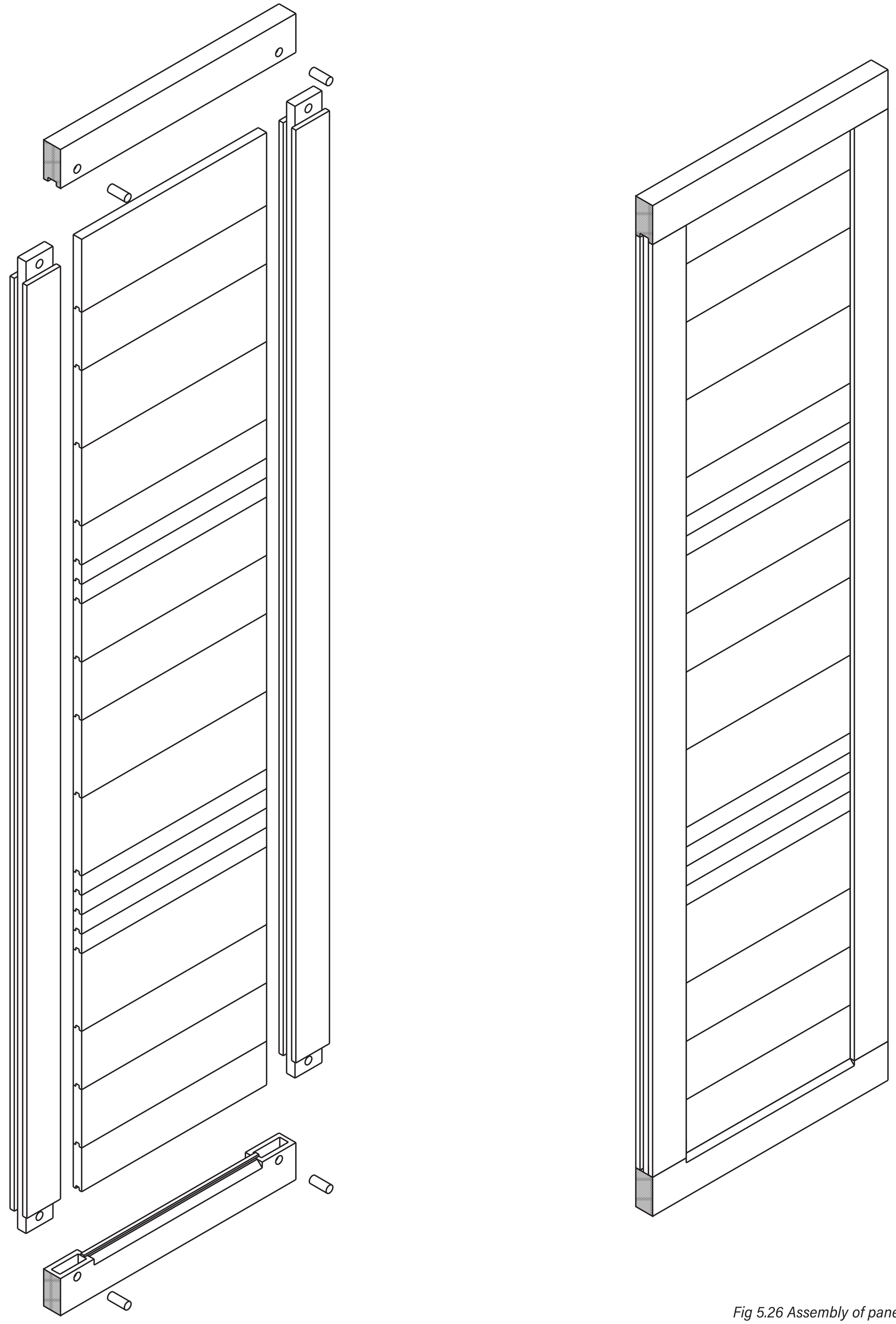


Fig 5.26 Assembly of panel

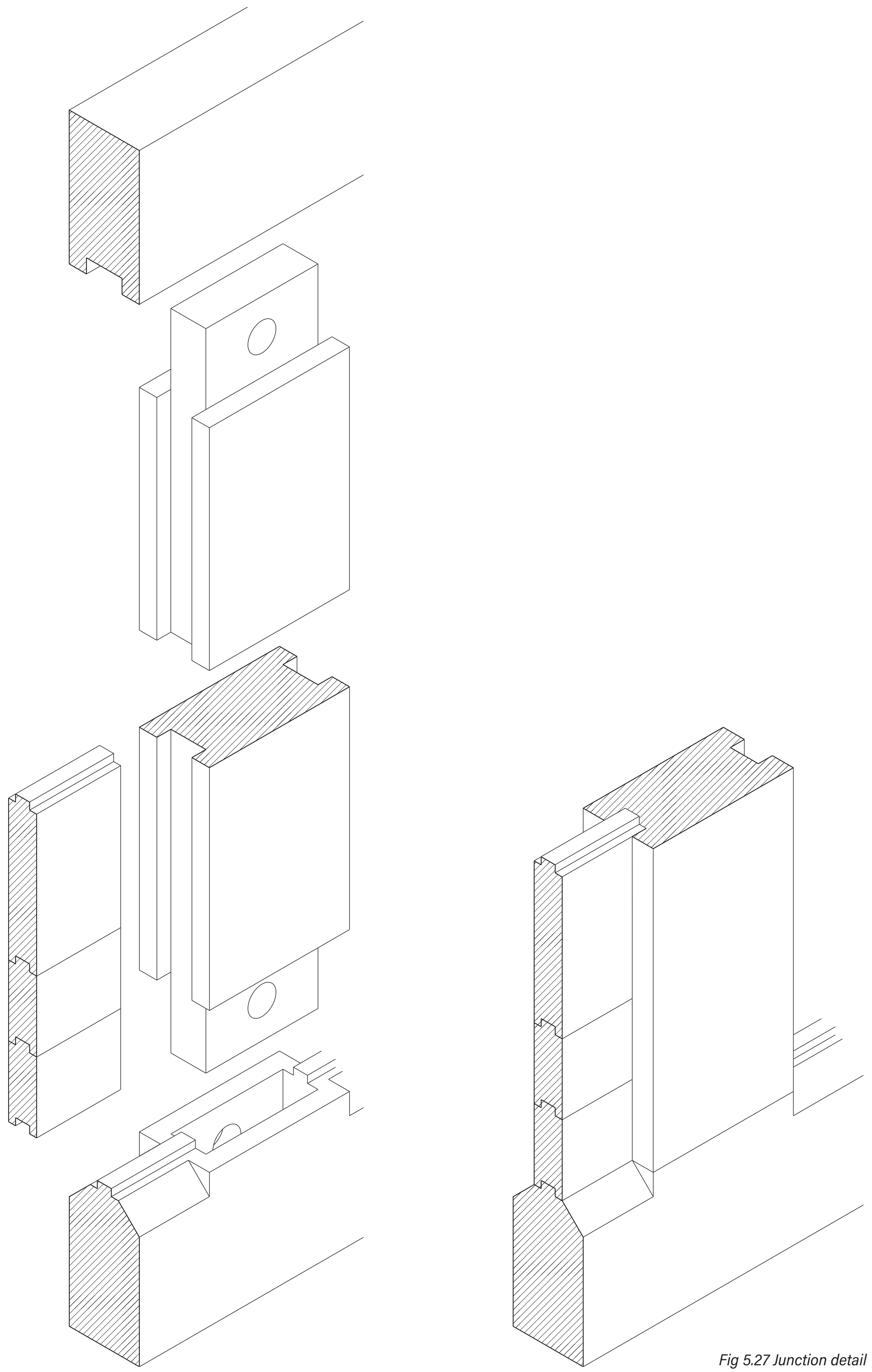


Fig 5.27 Junction detail

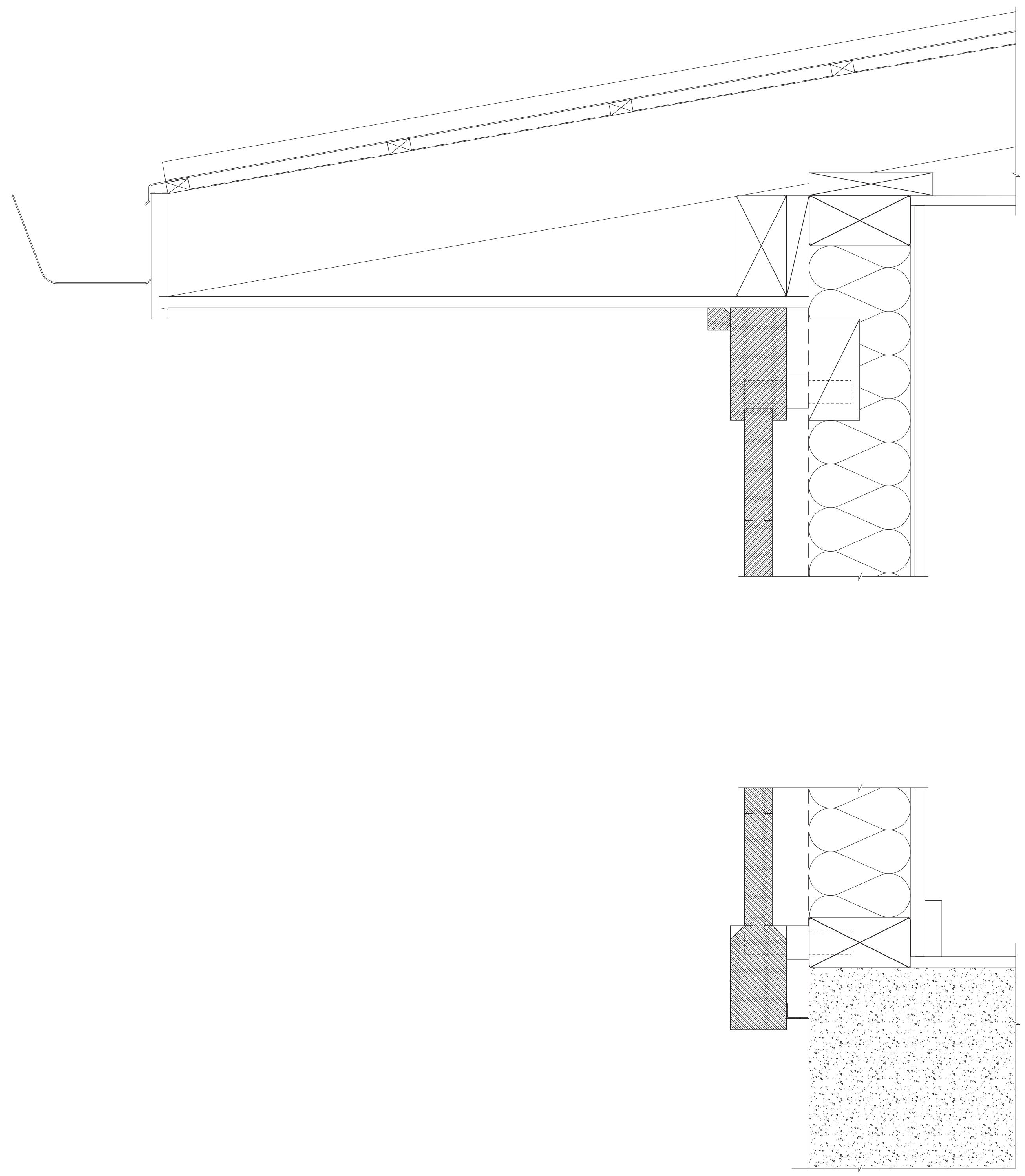


Fig 5.28 Doweled fixing


Fig 5.29 1:1 Detail model

Fig 5.30 1:1 Detail model

Fig 5.31 1:1 Detail model junction

Fig 5.32 1:1 Detail model junction

Fig 5.33 1:1 Detail model mortise

5.4.1 Slotted Board and Batten – Chamfer – Findings

This design attempted to find a middle ground between the previous iterations. The initial slotted post design was retained as a way of preserving the strength and simplicity of the profile. A table saw was then used to cut the tongue joint into the base and then rotated to 45° to cut chamfers (Fig 5.32). These chamfers were then finished using a chisel (Fig 5.33). This iteration required the most individual steps and tools used to create a profile and was far more time-consuming than the previous iterations. While the outcome has the least potential areas for moisture to gather, the process of machining is too inefficient to justify this iteration as a viable solution.

As a means of reducing frequent adjustments to the table saw in order to cut chamfers, a timber bead was considered. However, this would ideally be screwed in place to allow for circularity (Fig 5.34). Without the use of adhesives or sealant, this could potentially increase the risk of moisture retention at the meeting point between the bead, board, and base. Additionally, consistent profiles of timber mouldings in state houses could not be found, so it is likely this bead would have to be custom machined, increasing production time.

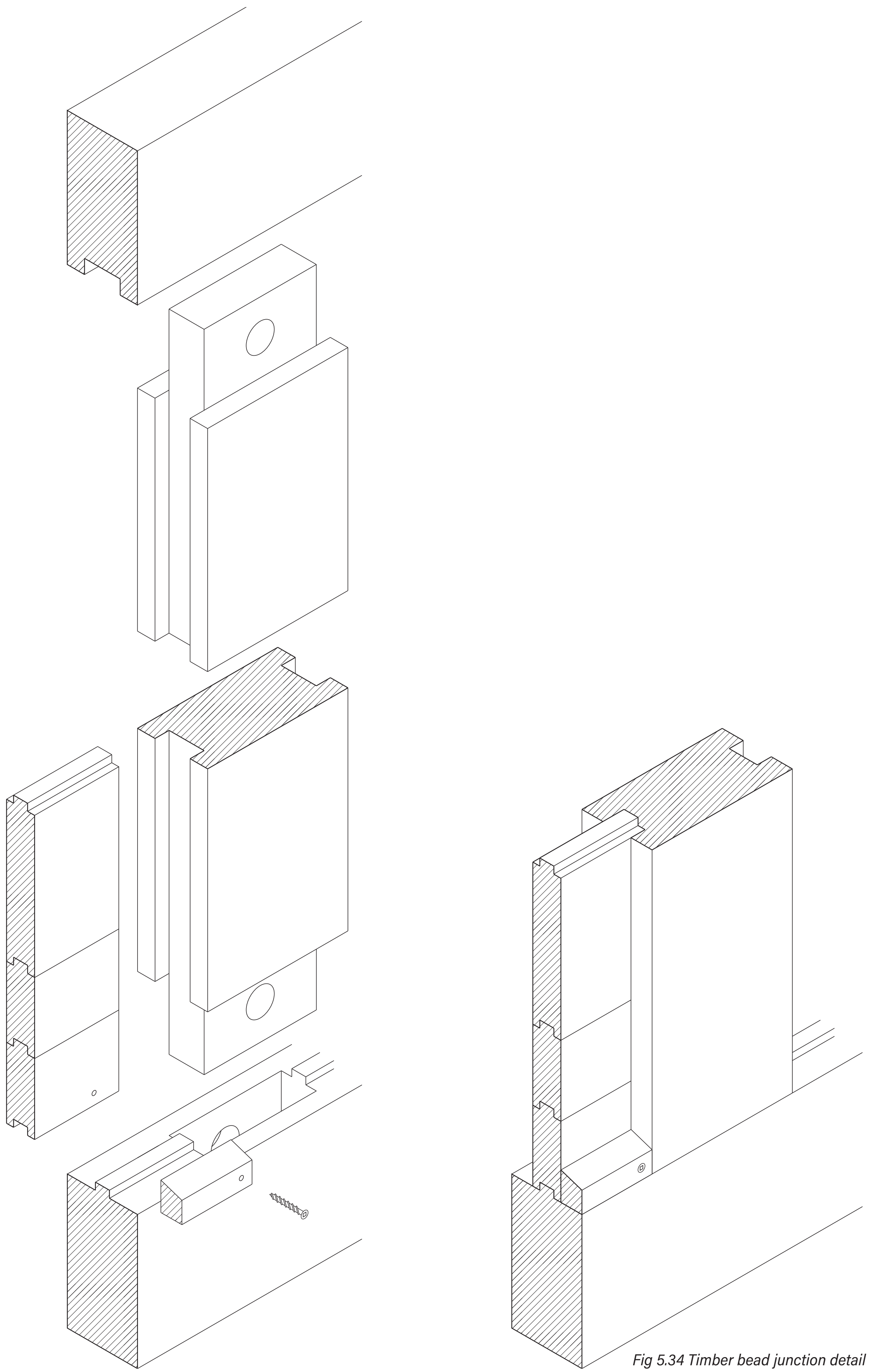


Fig 5.34 Timber bead junction detail

5.4.2 Rework of Chamfer

The inconclusive findings from initial iterations led to the reconsideration of the chamfered system. This was done with the idea that if an ideal alternative to a complex profile could not be found, refining the technique used to create a more effective profile would be an acceptable compromise. Shifting from an angled table saw to a hand router meant that no alteration to the setup of tools needed to be made in the middle of the process. It also allowed a cut that came closer to post edges without risking the integrity of the mortise (Fig 5.36). This meant that less material needed to be removed using hand tools, speeding up the process and reducing the risk of damage.

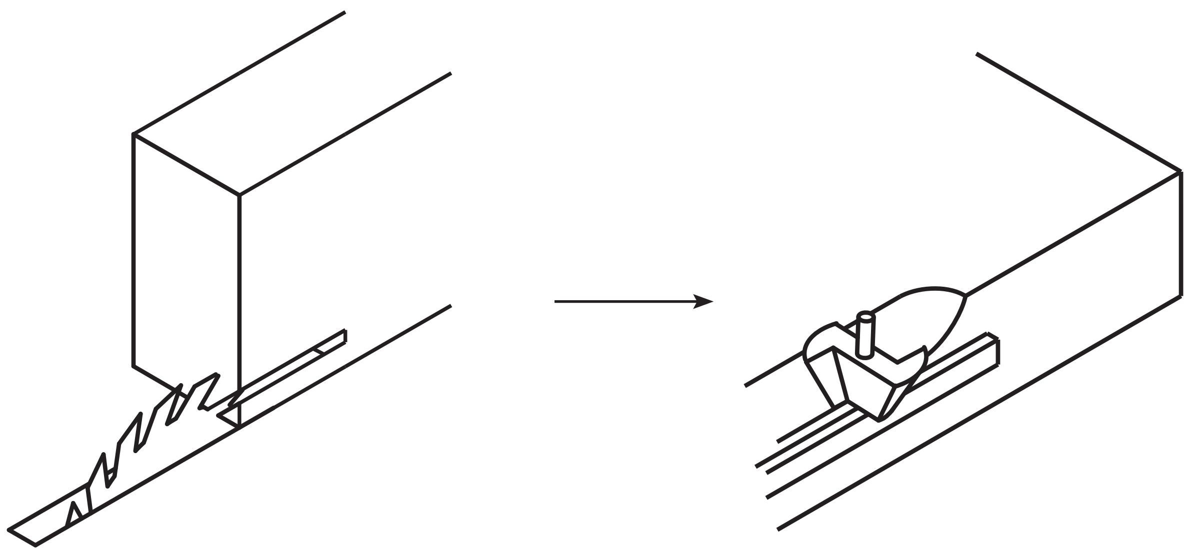


Fig 5.35 Adjustment of machining technique

Fig 5.36 Routed chamfer 1:1 model detail

6. Speculative Design Application

By examining the way in which a design outcome could be used in real-world applications, further refinements to the current system can be made. This process can be considered a speculative application, with continuous iterations to the system being made as its relationship to the building envelope is explored. This exploration also outlines the additional fixings and design decisions outside of the system that would likely be needed to apply it.

This research phase was carried out simultaneously with 1:1 prototyping. For this reason, there are occasional discrepancies between drawings and the prototype. As well as this, some areas of application were informed by ongoing making processes.

Fig 6.00 Profile of applied design outcome

6.1 Prefabrication

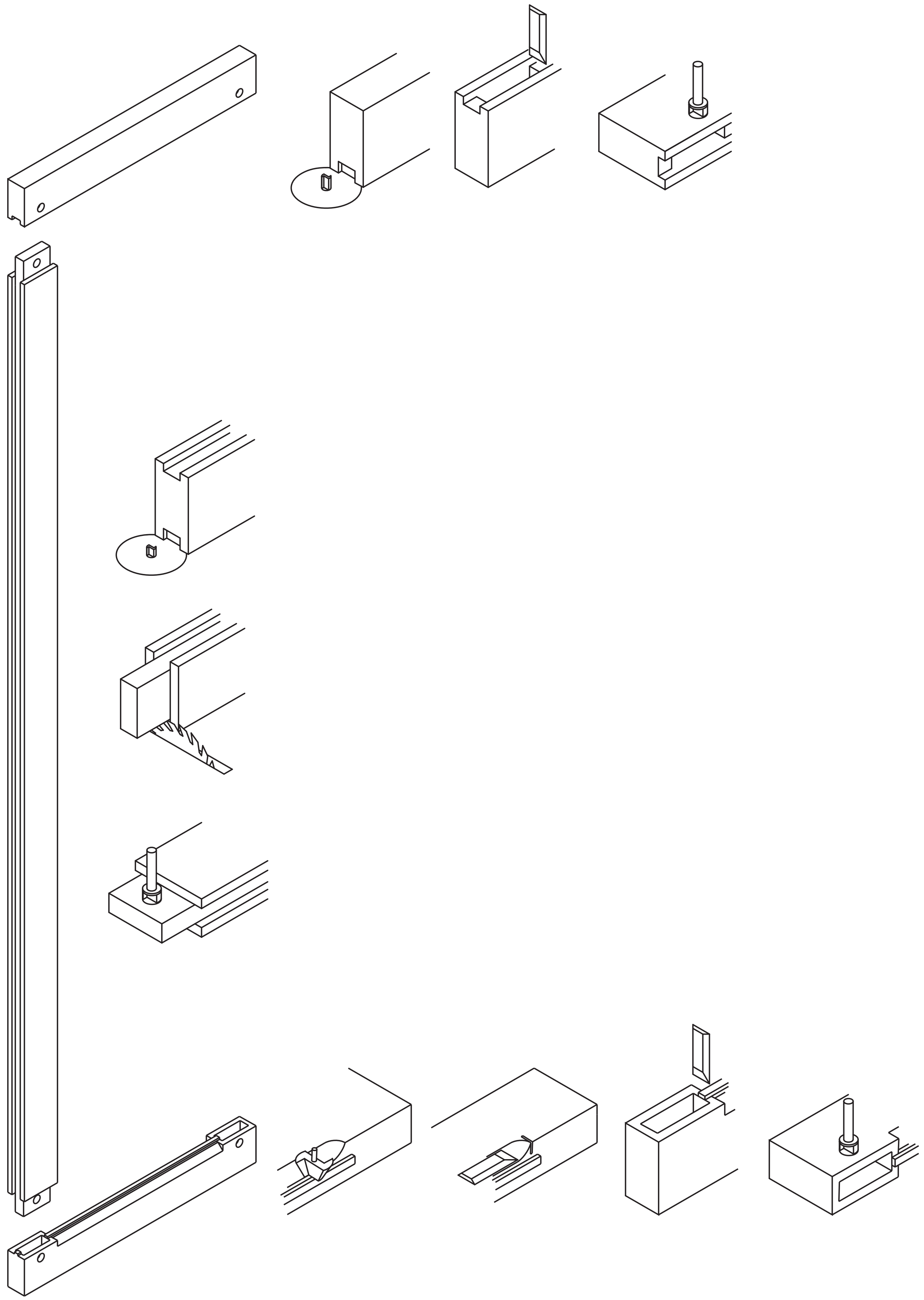


Fig 6.01 Process of frame construction

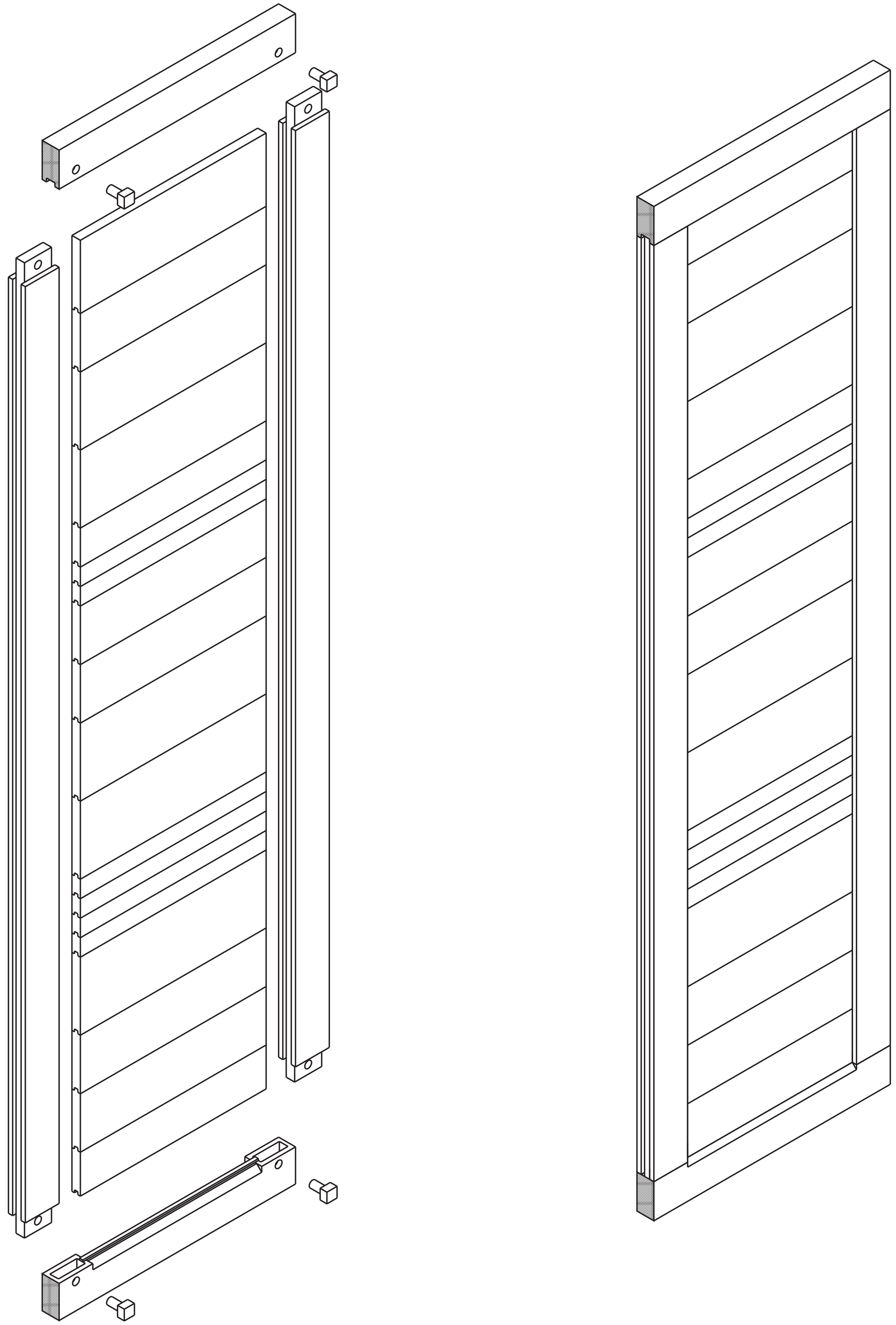
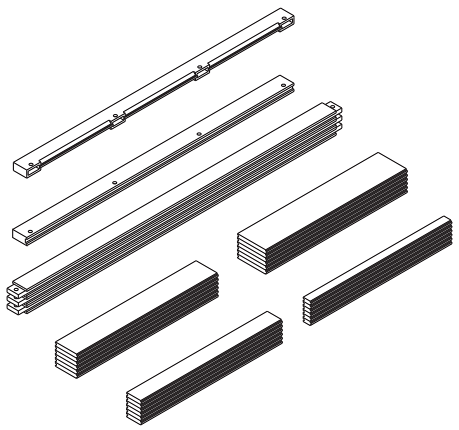
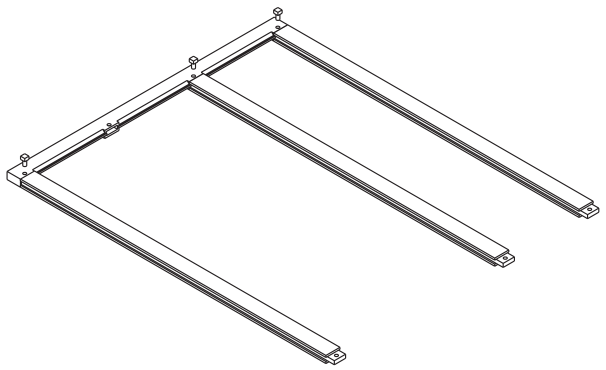


Fig 6.02 Assembly of panel

1.



2.



3.

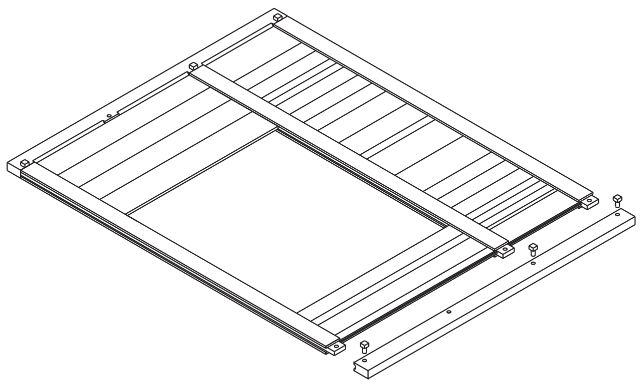
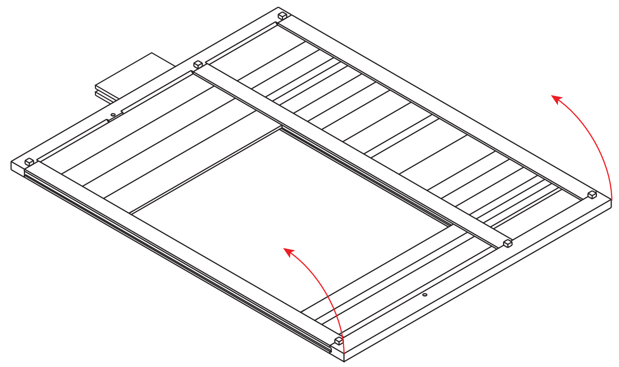


Fig 6.03 Single story on-ground assembly

4.



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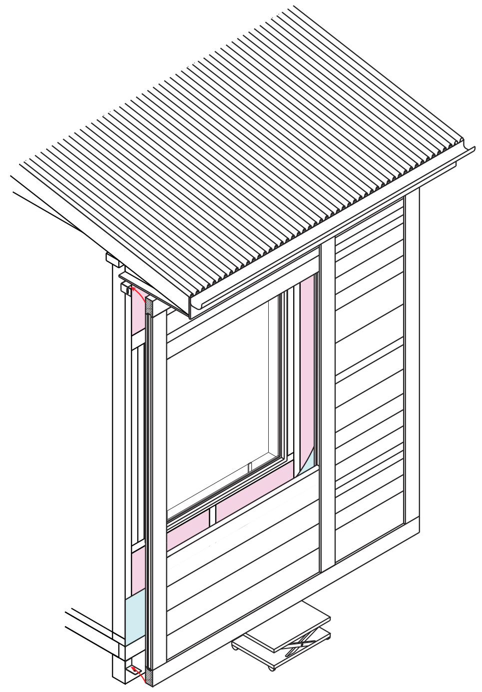


6.

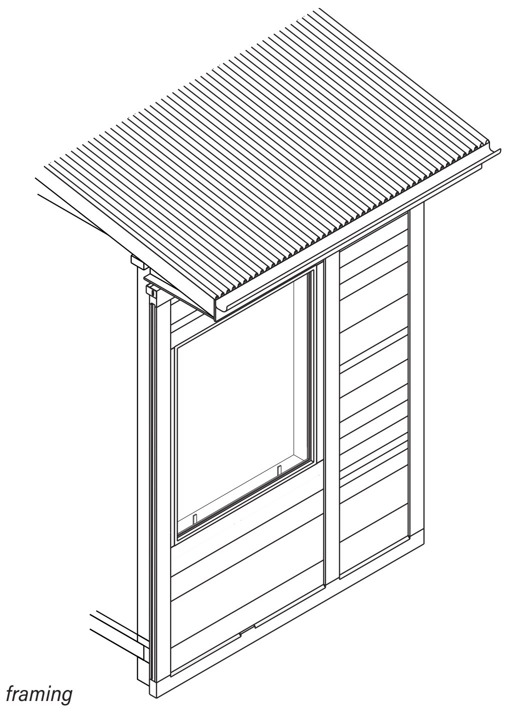
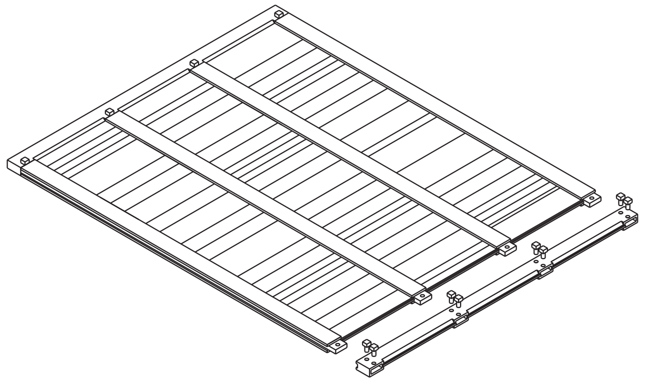
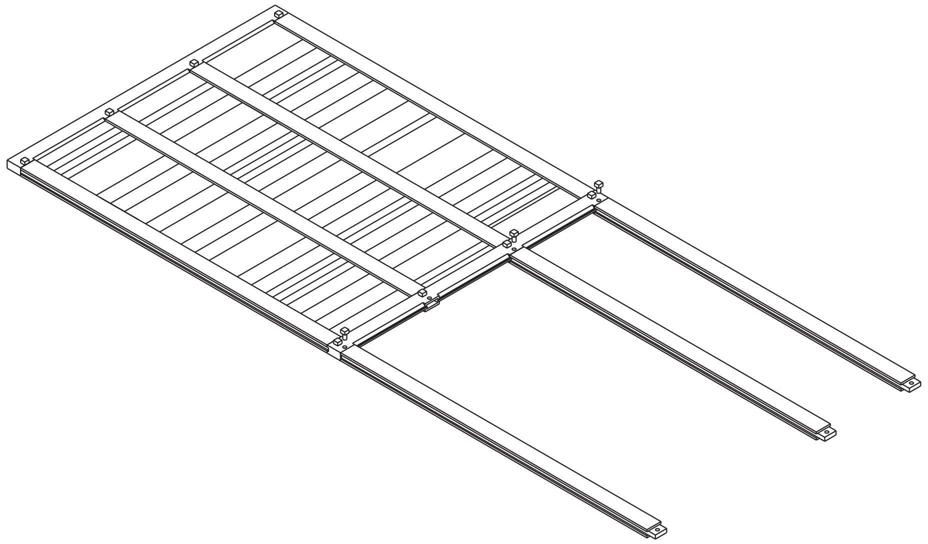


Fig 6.04 Single story assembly onto framing

1.



2.



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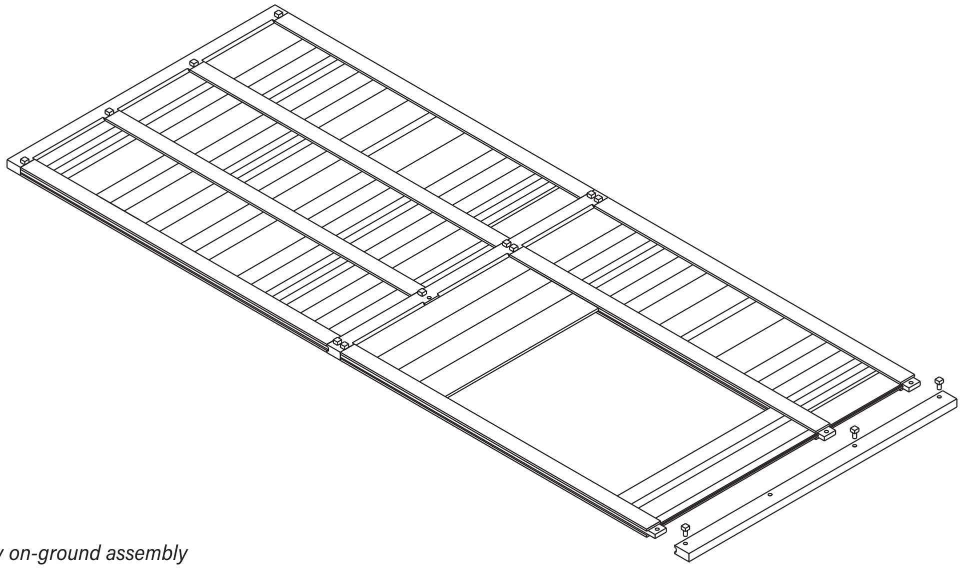


Fig 6.05 Multi story on-ground assembly

4.

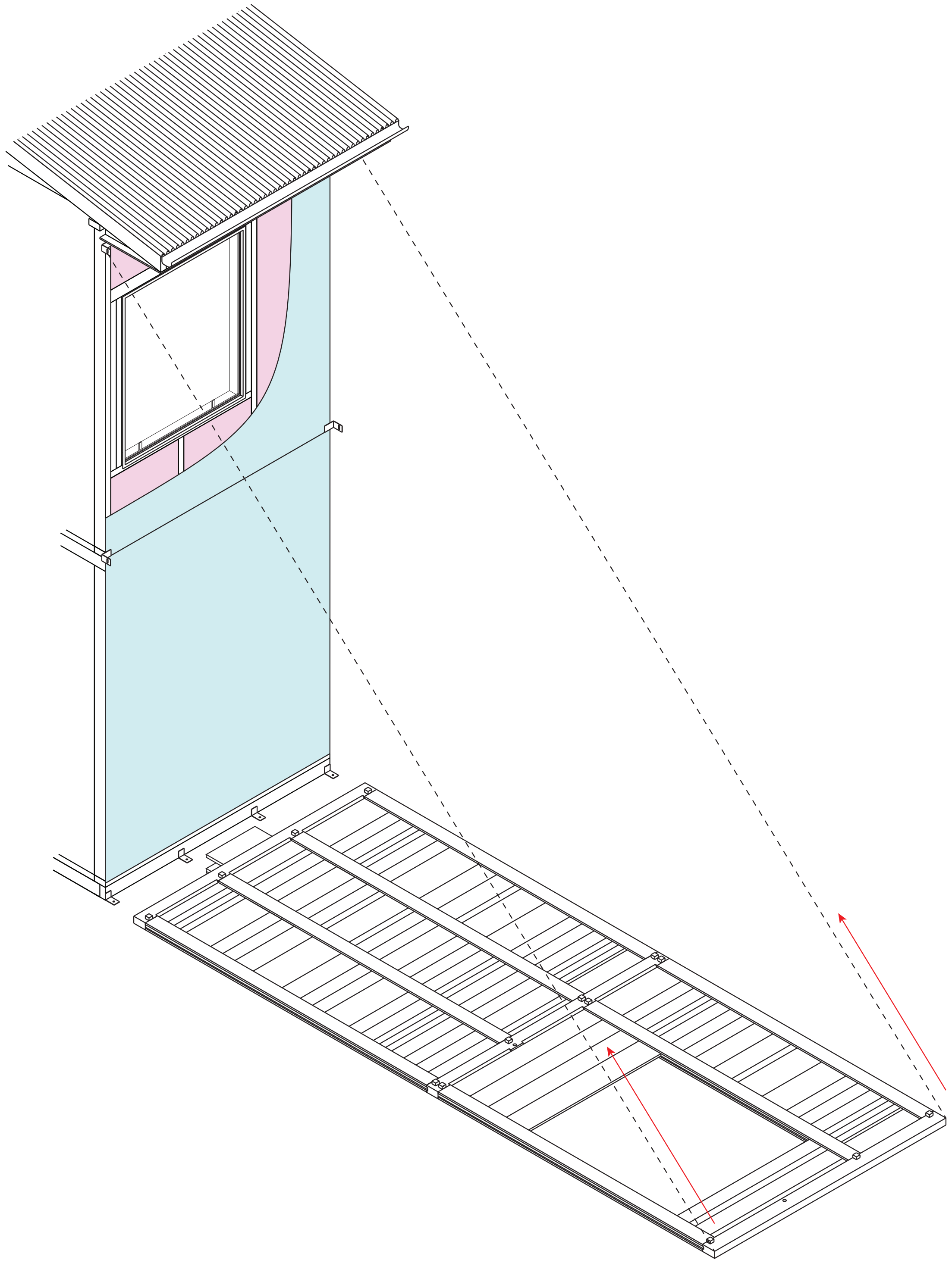


Fig 6.06 Multi story assembly using pulley system

5.

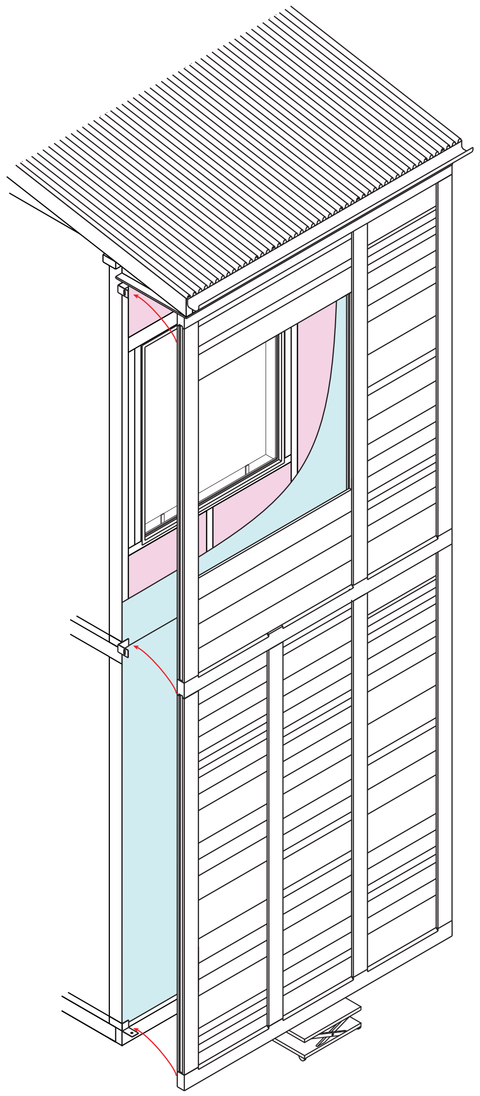


Fig 6.07 Multi story assembly onto frame

6.

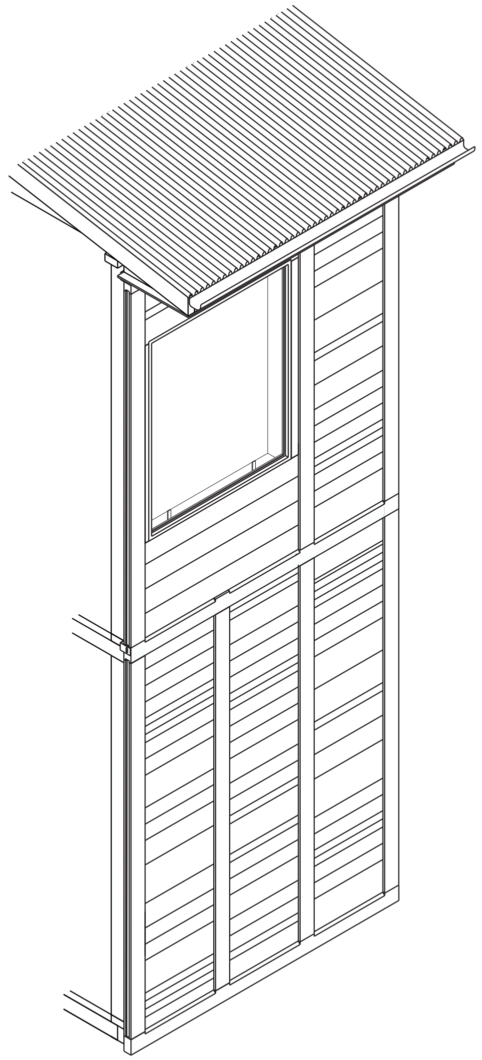


Fig 6.08 Multi story assembly onto frame

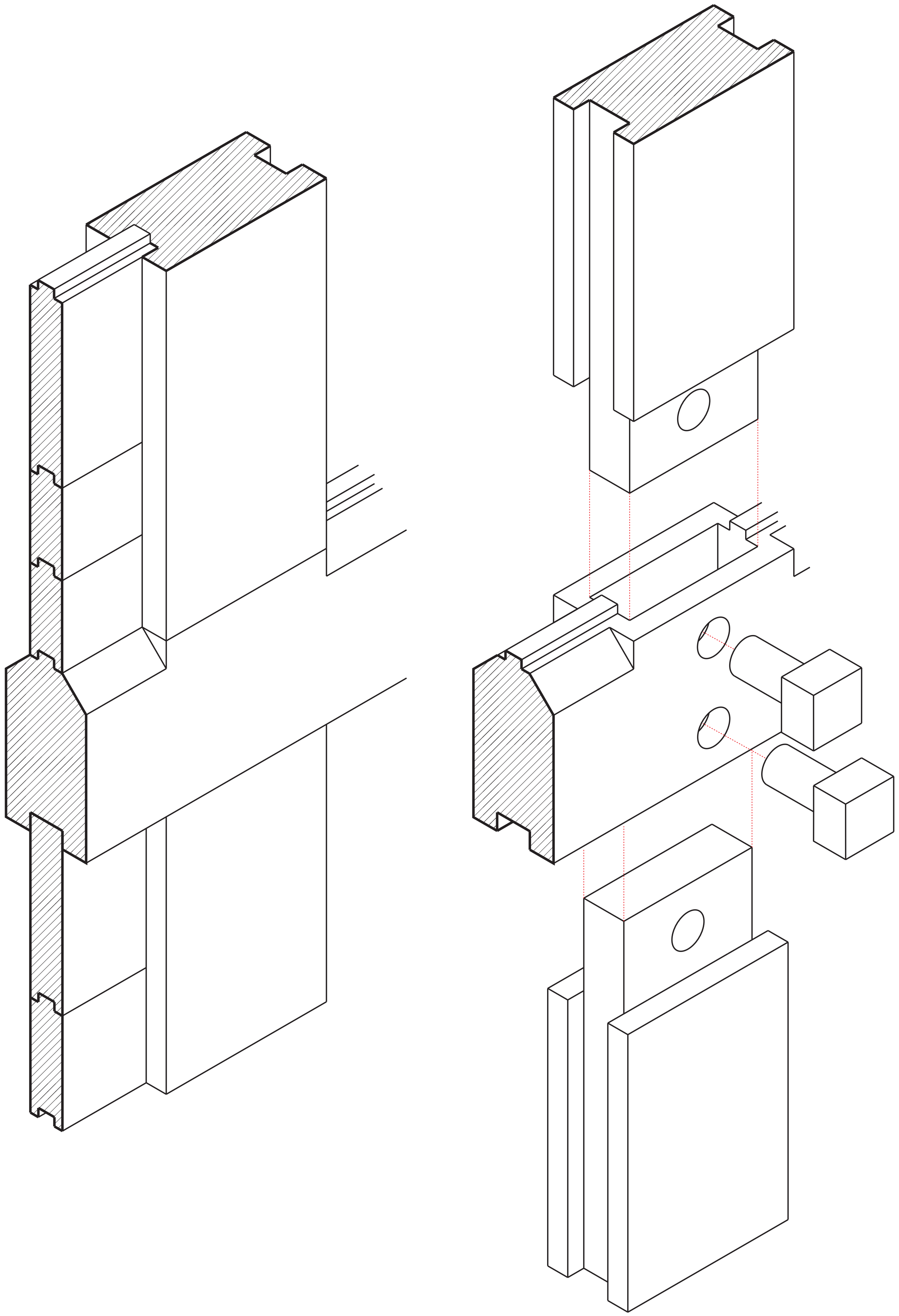


Fig 6.09 Multi story frame junction

6.1.1 Prefabrication - Findings

For this current design outcome, the use of prefabrication has been investigated as a means of application. As informed by the techniques used to efficiently construct state houses, the machining of parts is carried out off-site (Fig 6.01). These parts are then transported to the site and assembled flat (Fig 6.03, 6.05). This allows parts to be transported to a range of sites by hand if access is limited for vehicles in any way. This assembly process could, however, also allow for panels of cladding to be assembled off-site and transported on a flatbed depending on the span of each panel.

Based on the findings of the prototype model, single-story panels can be comfortably lifted by two or more people (6.04). Multiple-story panels should be lifted using a pulley system in combination with guidance from people (Fig 6.06). This ensures that the cladding does not flex excessively, as support is provided across each junction point. Both assembly techniques would likely require some form of scissor jack to apply vertical support while the system is fit comfortably in place (Fig 6.04,6.07).

6.2 Brackets and Fixings

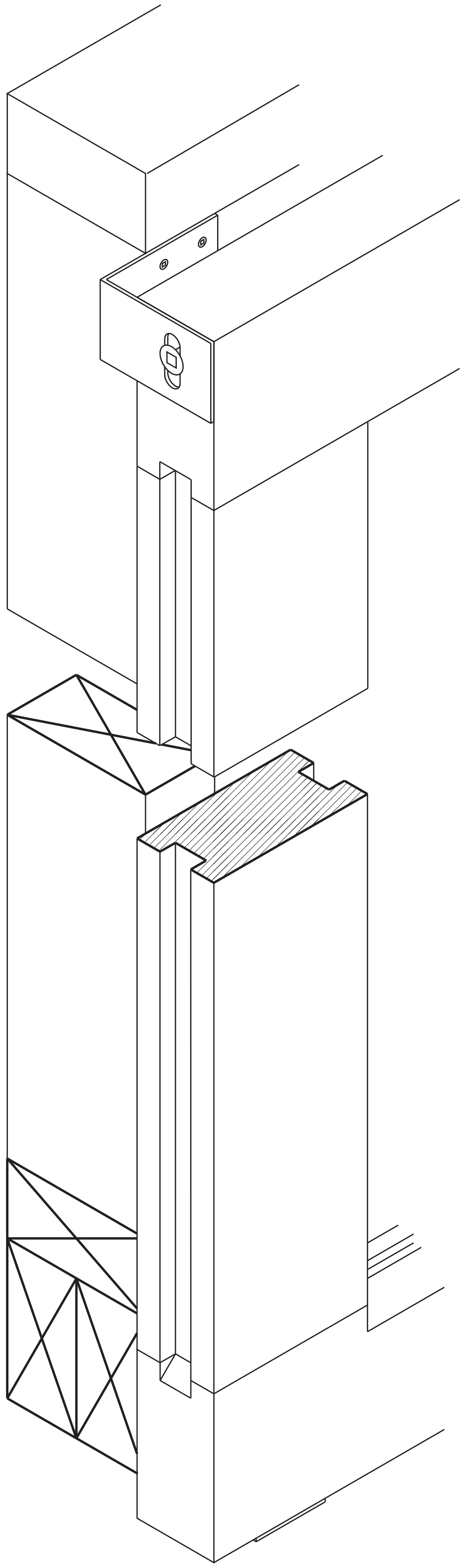


Fig 6.10 Bracket mounting on perimeter joist

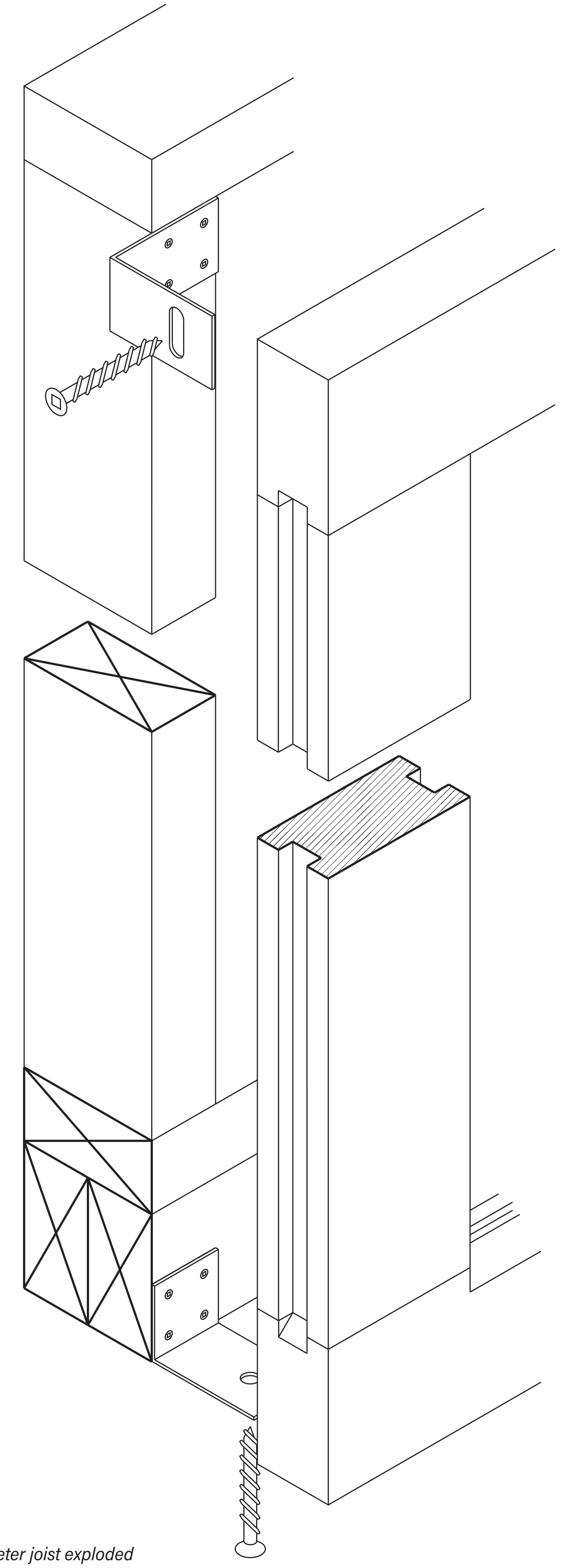


Fig 6.11 Bracket mounting on perimeter joist exploded

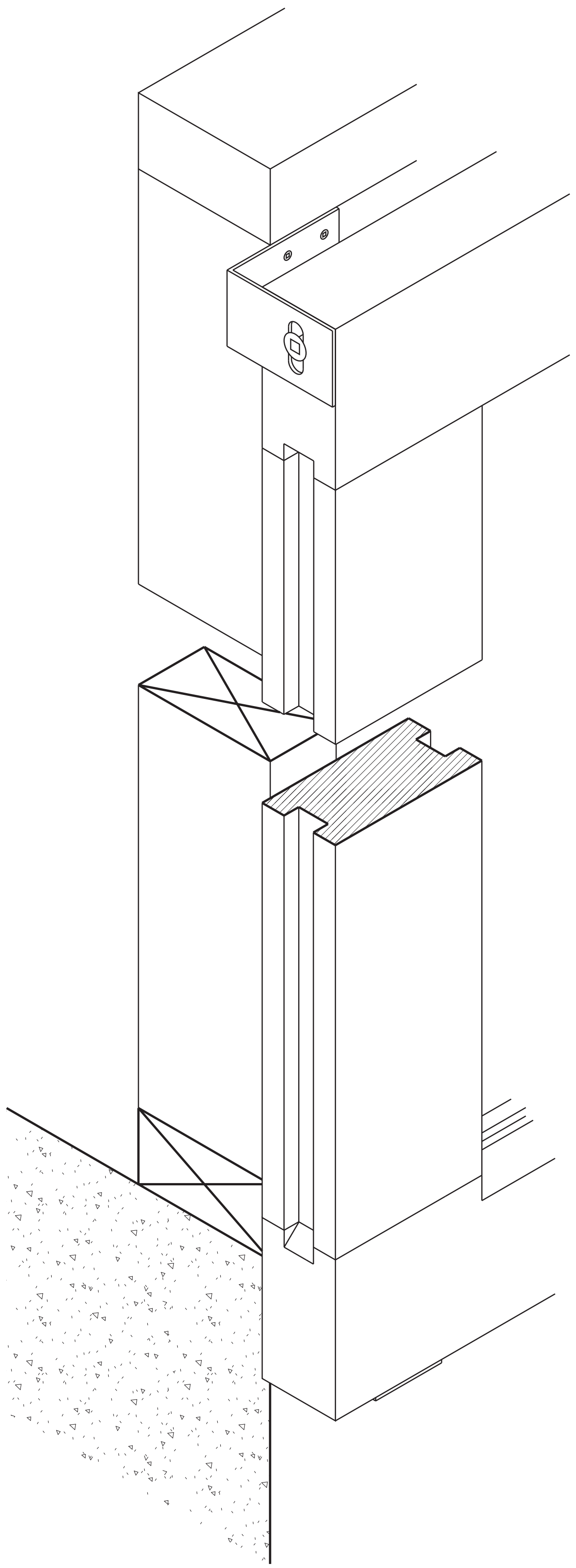


Fig 6.13 Bracket mounting on concrete slab

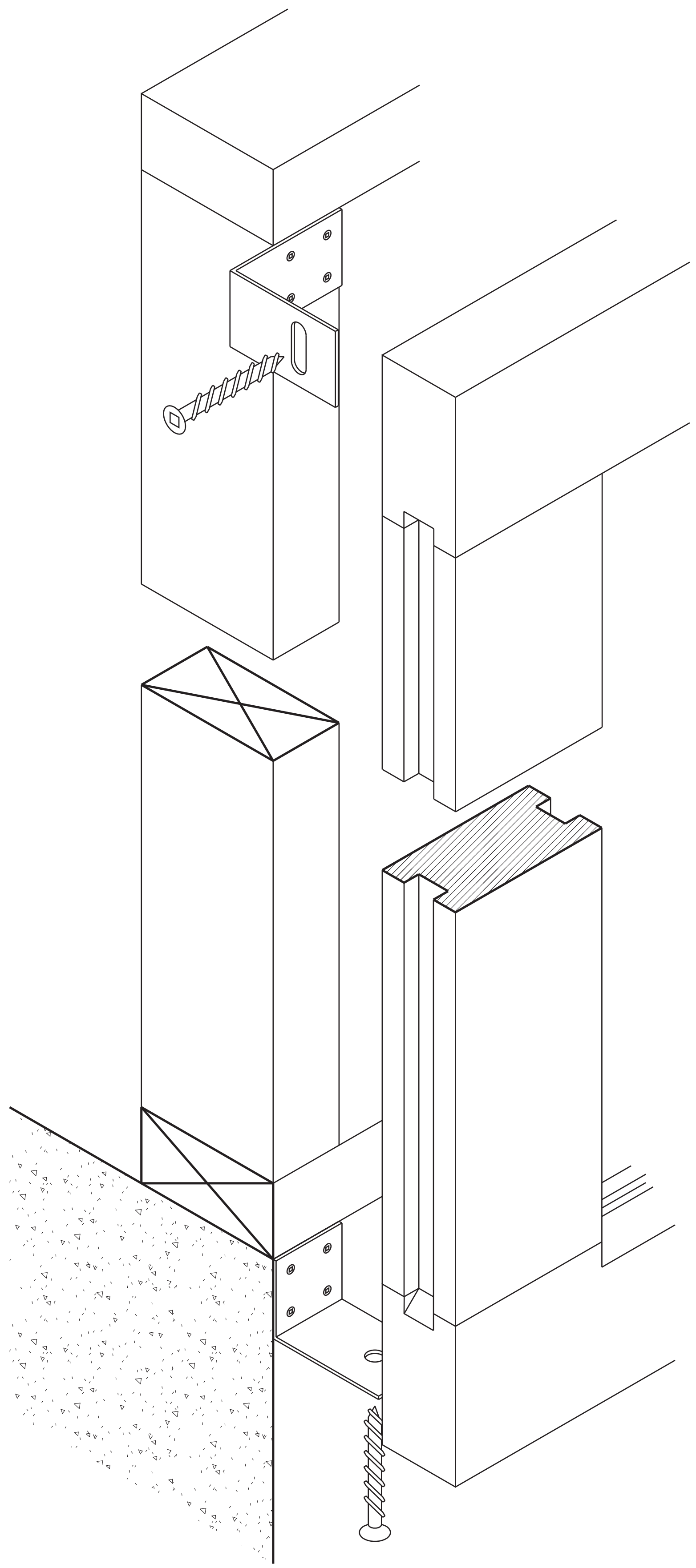


Fig 6.14 Bracket mounting on concrete slab exploded

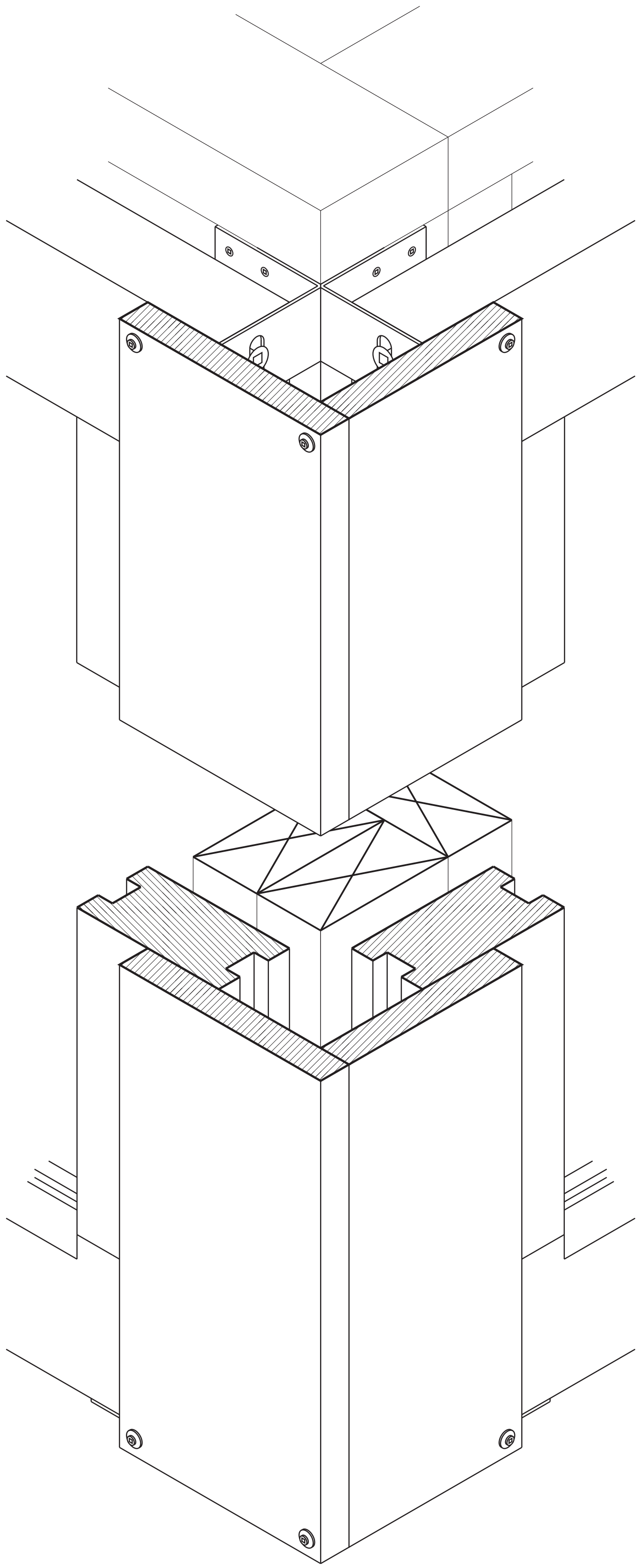


Fig 6.15 External timber corner board

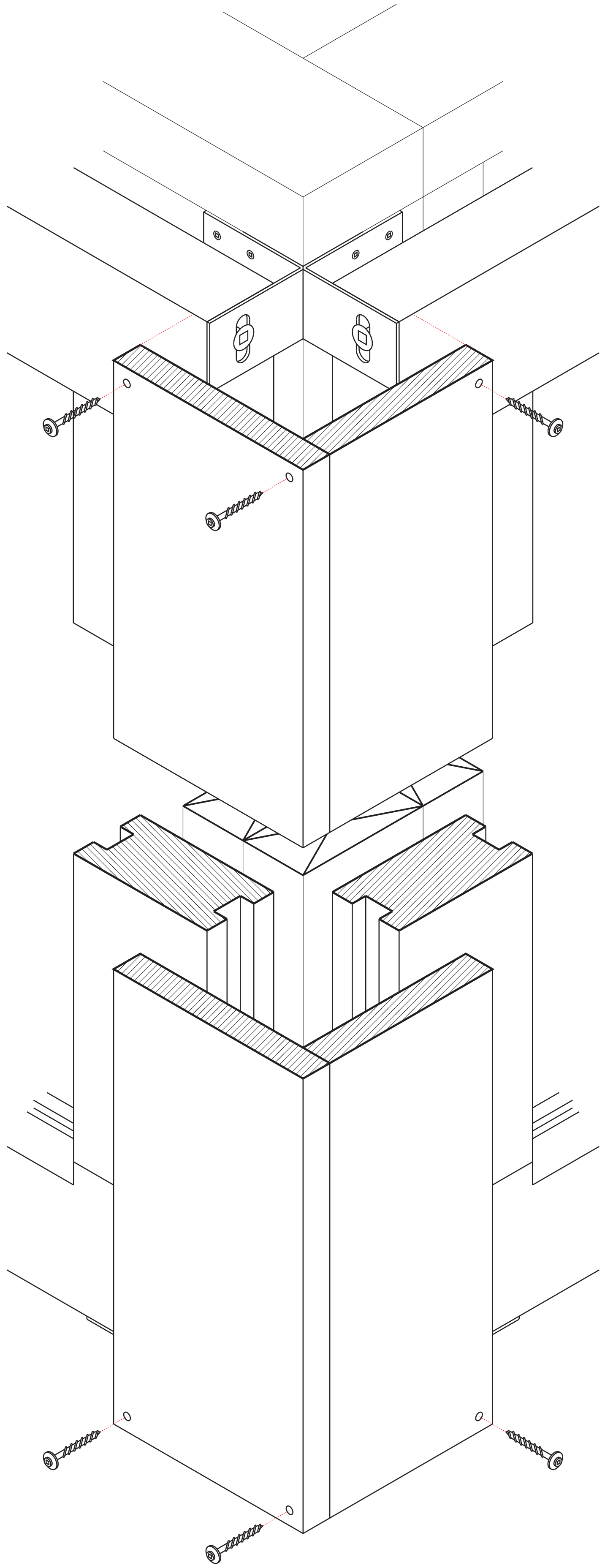


Fig 6.16 External timber corner board exploded

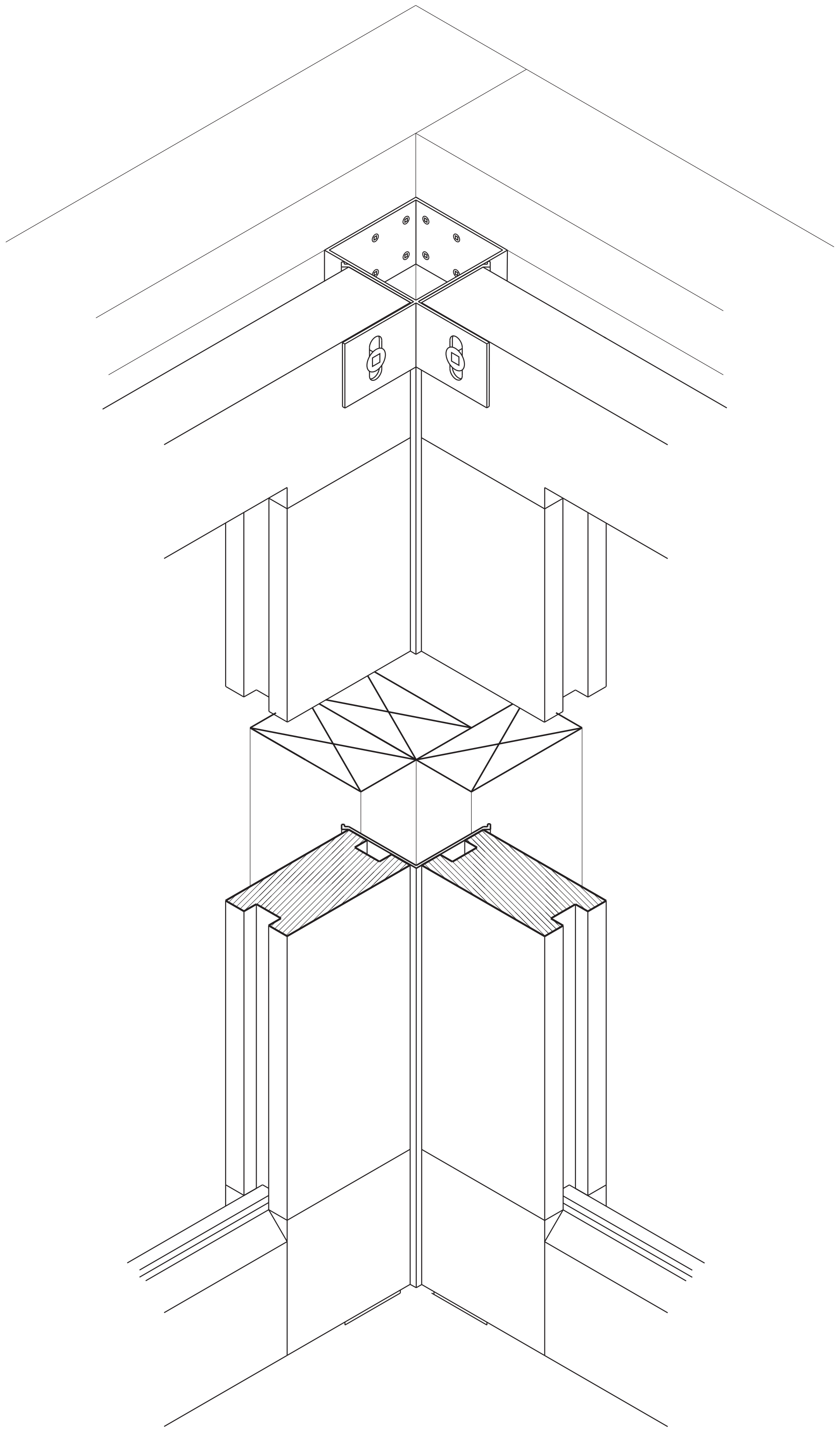


Fig 6.17 Internal flashed corner

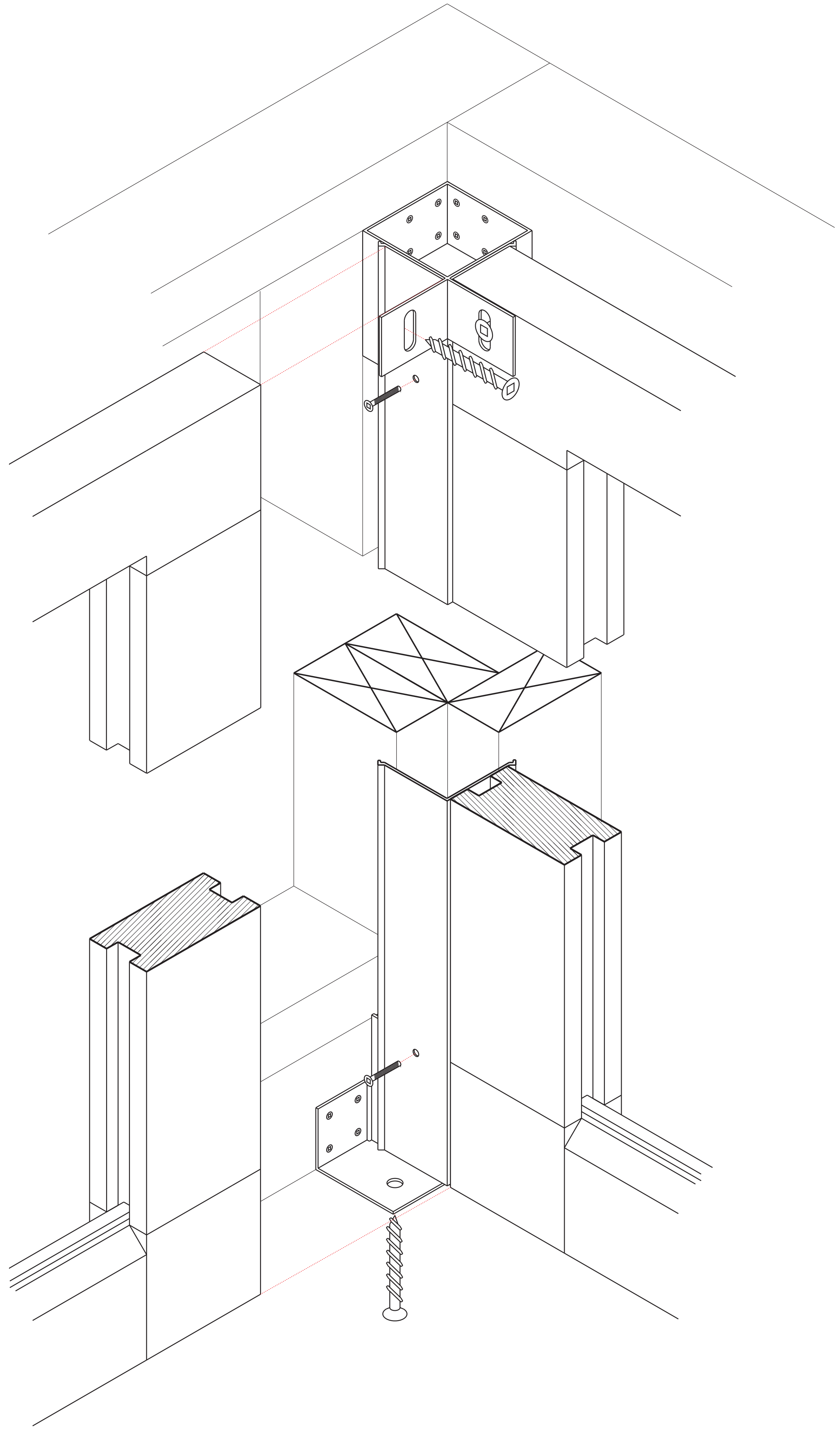


Fig 6.18 Internal flashed corner exploded

6.2.1 Brackets and Fixings - Findings

During the refined iterative process, it was suggested that cladding be fixed using dowels that are fixed into a building's bottom plate. This did not provide significant framing cover and would only be viable if a building was constructed on timber piles, allowing dowels to be fixed into perimeter joists. If dowels were fixed into a concrete slab, moisture transfer could risk the integrity of the system (Buchanan, p. 82, 2007). The potential shrinkages of different elements in a dowel system, particularly likely with reused timber, would make prefabrication difficult and the lack of tolerance in a dowel joint could cause splitting or distortion over time.

As an alternative, a series of brackets, screws, and bolts have been suggested (Fig 6.10-6.23). Slotted brackets have been used for connections at the top of the cladding (Fig 6.19,) to allow for potential variations in timber dimensions over time. While the use of specific or custom brackets limits the possibility of sourcing through reuse and requires penetrations into the timber, these brackets would likely increase the applicability and preservation of this cladding system. They could also be welded together in a variety of combinations to allow applications across wall junctions (Fig 6.15-6.18). The proposed internal corner brackets allow for the use of flashing that does not need to be fixed to the system, limiting the need for penetrations and facilitating a more effective assembly (Fig 6.18). Traditional corner boards have been used to cover external corners (Fig 6.15, 6.16). While this requires the use of additional screws and penetrations, it allows the use of native timber to cover an area that would otherwise require a large flashing profile.

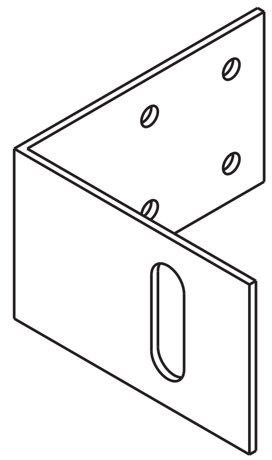


Fig 6.19 Top rail slotted bracket

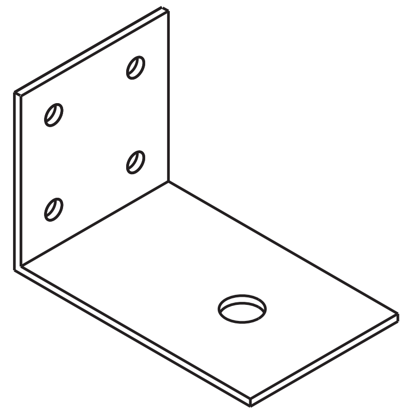


Fig 6.22 Bottom rail bracket

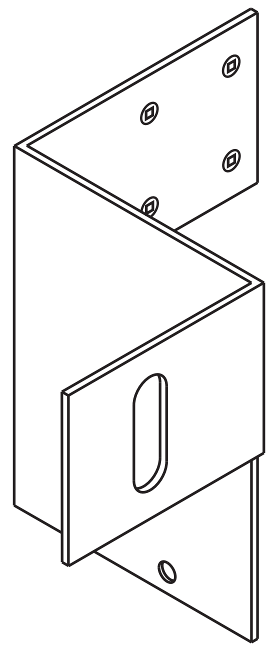


Fig 6.20 Top rail internal corner slotted bracket

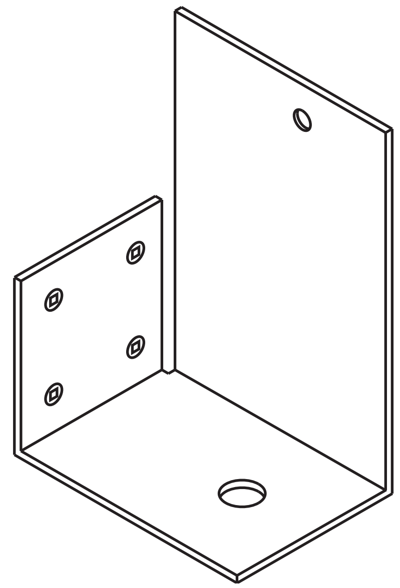


Fig 6.23 Bottom rail internal corner bracket

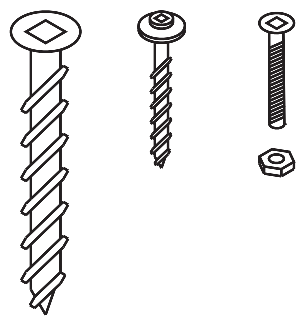


Fig 6.21 Assorted screws and bolts

6.3 Windows and Doors

6.3.1 Timber Windows

Windows, if this cladding system were to be applied, would need to be designed in a way that facilitated cladding penetrations fitting over a frame that has been previously installed. This meant cover from window frames would have to be either minimal or be improved using scribers or beads after the cladding has been applied. Investigations of the reuse of state house casement windows and the way they might interact with this system were limited. However, if combined with an additional box frame to mimic the window frame shown in Fig 6.24-6.29, this could be a valuable way to preserve the heritage qualities of state houses. As this would require a more thorough investigation into the profiles of state house joinery, the retrofitting of double glazing, and the removal of potentially hazardous paints, it has been excluded from this research.

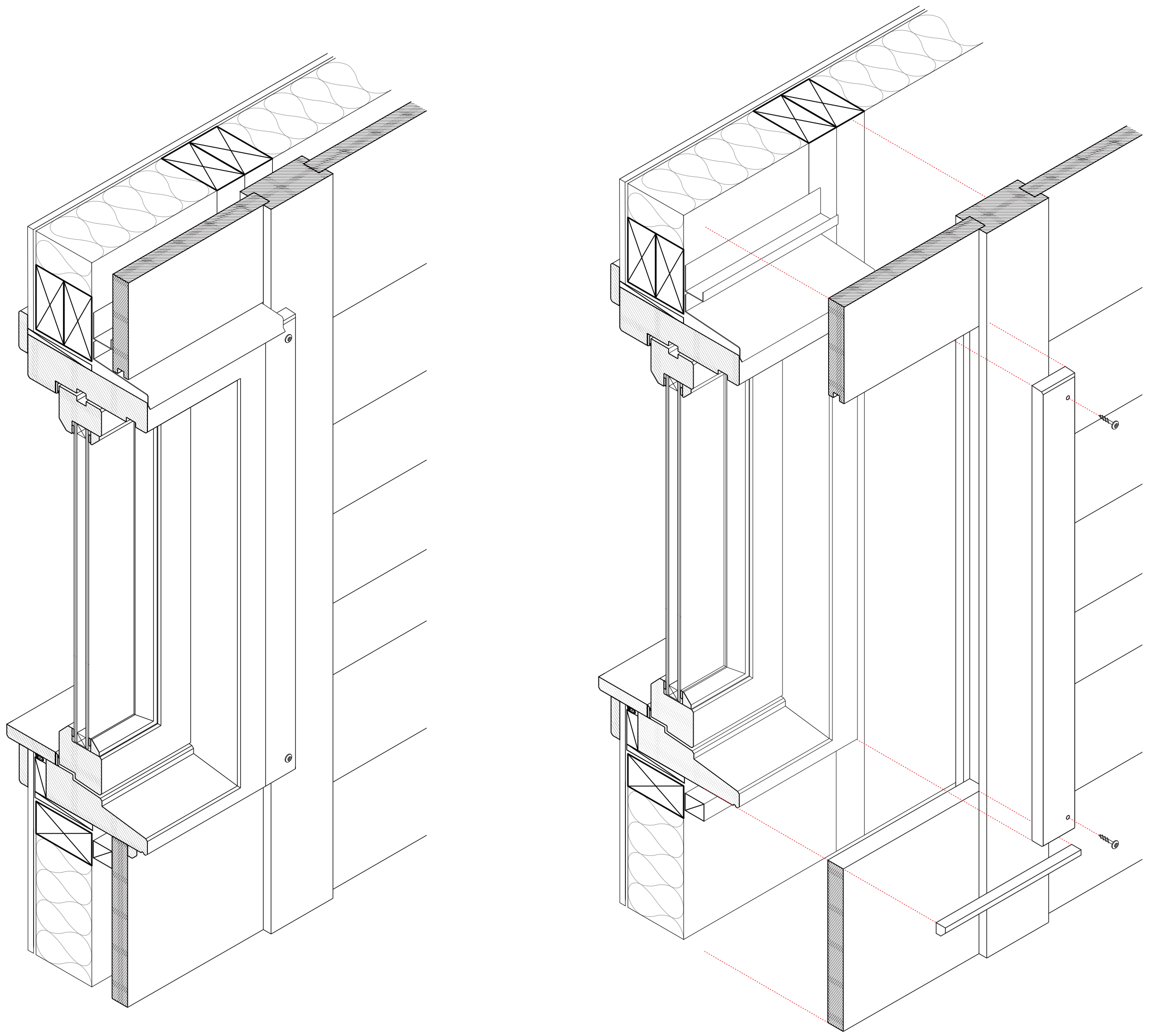


Fig 6.24 Assembly of timber window penetration - enlarged on page 135-136

Fig 6.26 Timber window head 1:5

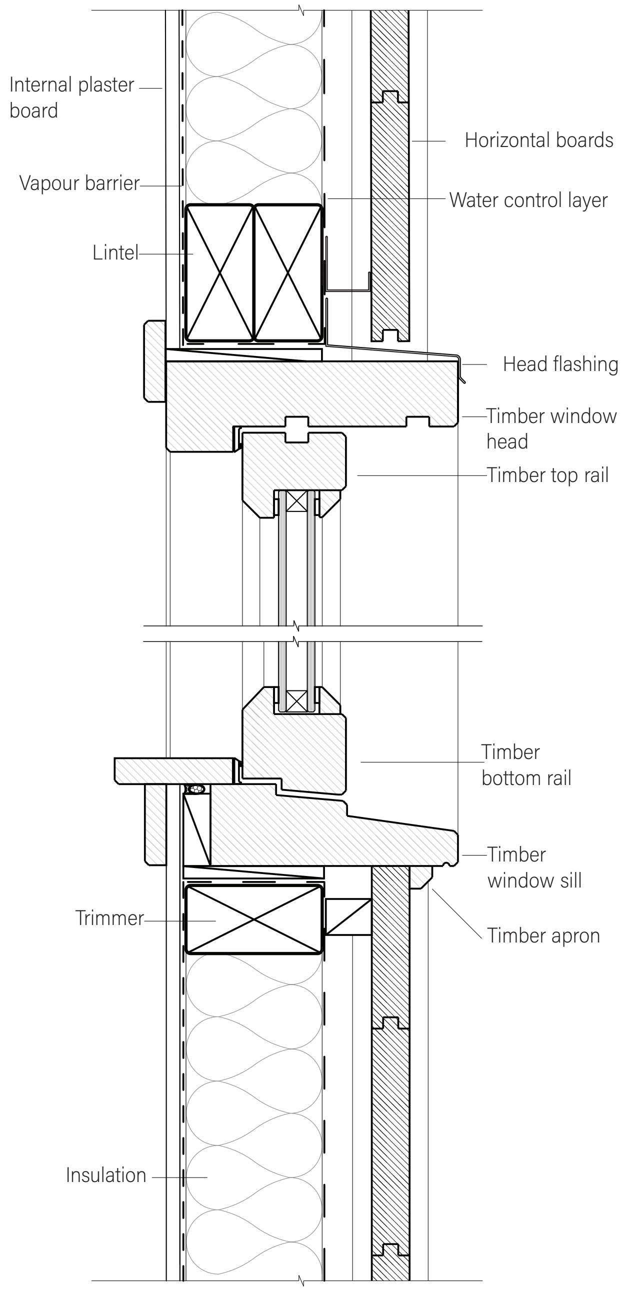


Fig 6.27 Timber window sill 1:5

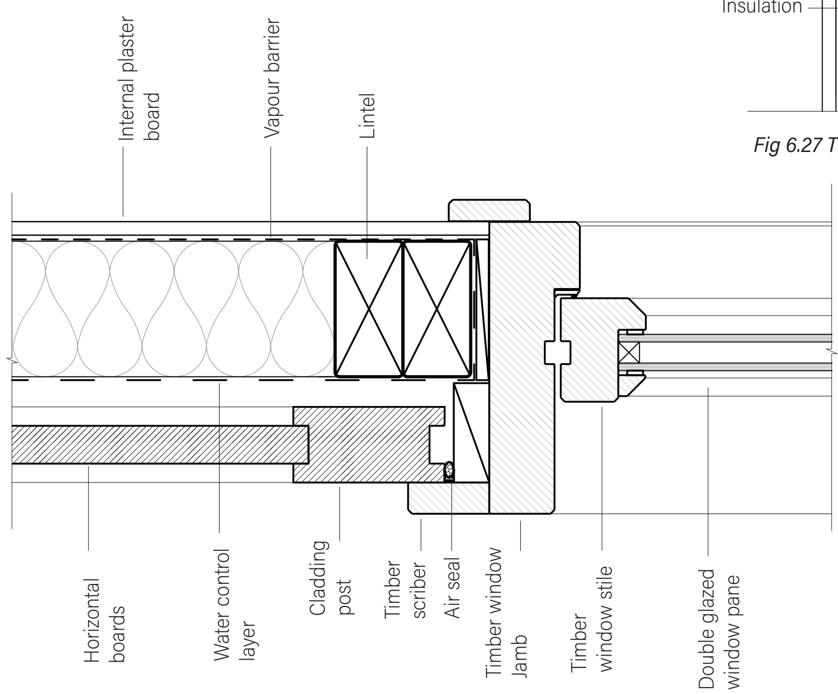


Fig 6.25 Timber window jamb 1:5

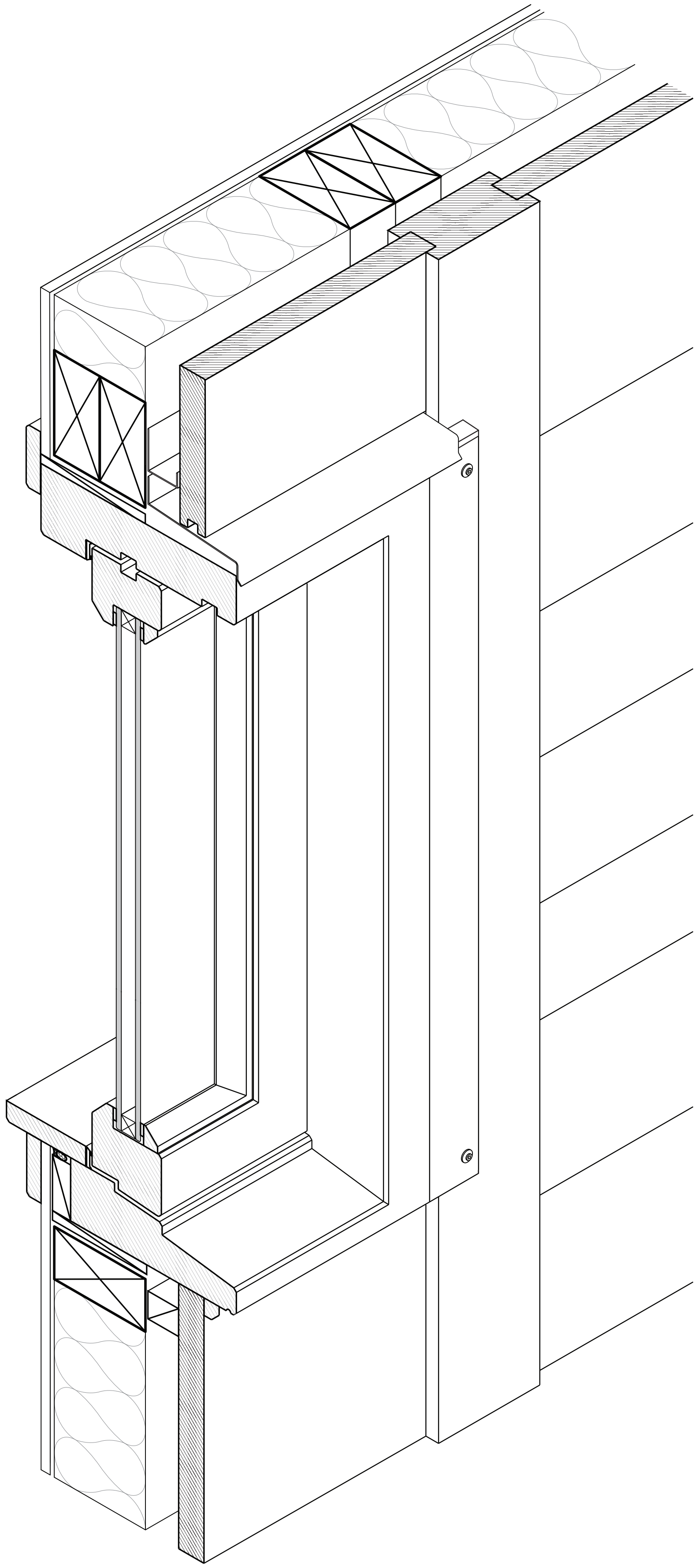


Fig 6.28 Assembly of timber window penetration

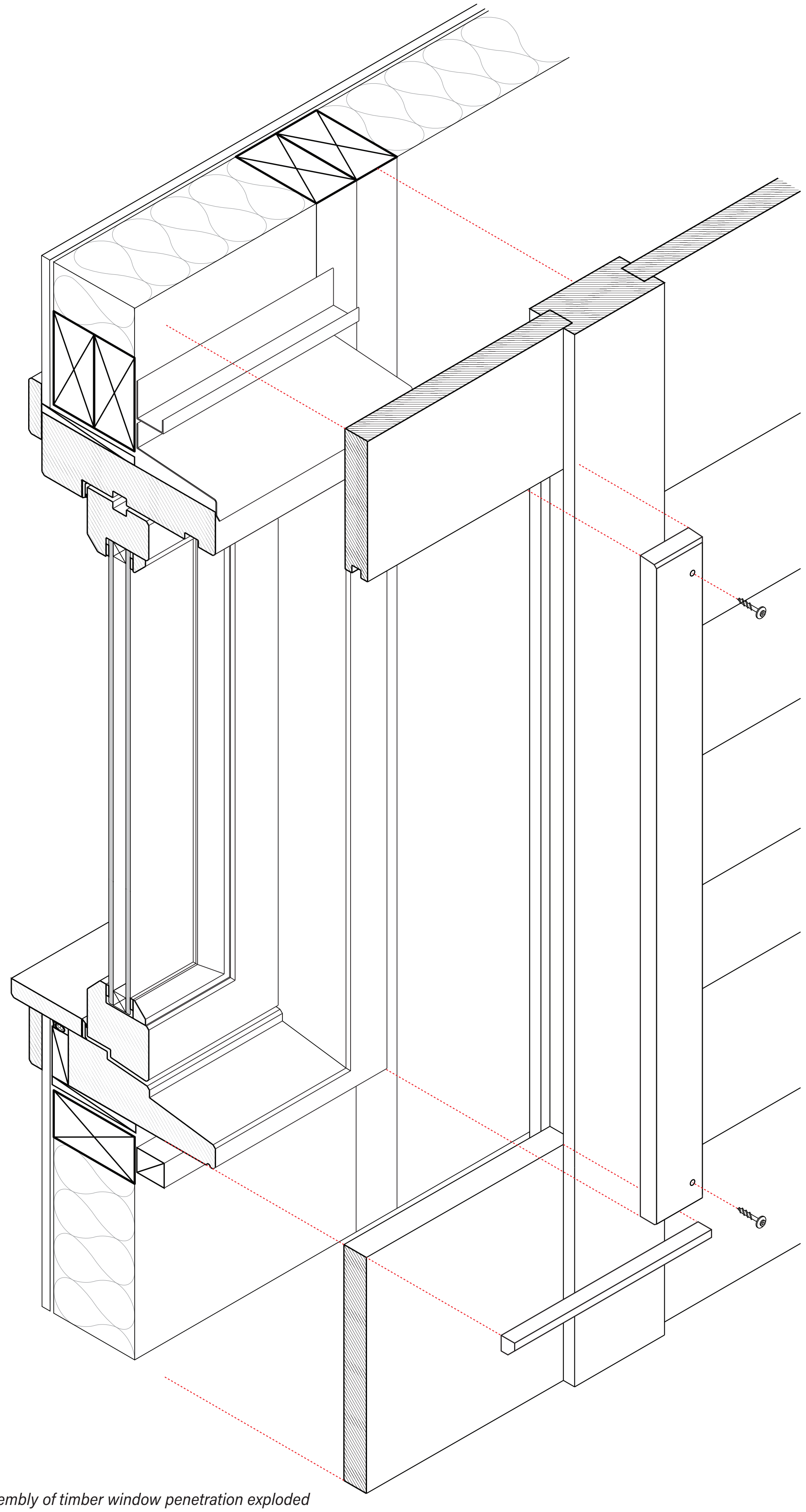
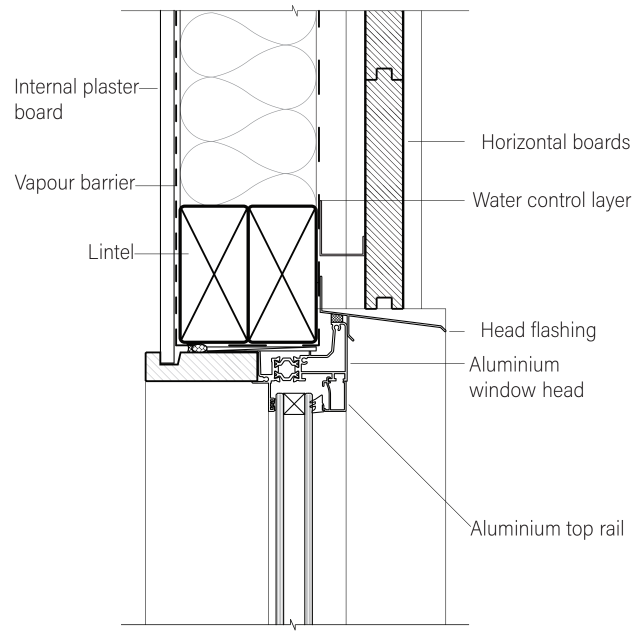


Fig 6.29 Assembly of timber window penetration exploded

6.3.2 Aluminium Windows

Aluminium windows have been considered due to their wide use in Aotearoa. Systems developed to facilitate the interaction between timber cladding and aluminium windows provided a valuable precedent in the application of this system. The suggested application uses a flashing box installed around the window frame. This system is modelled closely on the Flashclad extruded aluminium mechanical flashing with vertical cover reduced to allow cladding application (Fig 6.30-6.35). This is then finished with the use of timber scribers to provide cover (Fig 6.35).

Fig 6.32 Aluminium window head 1:5



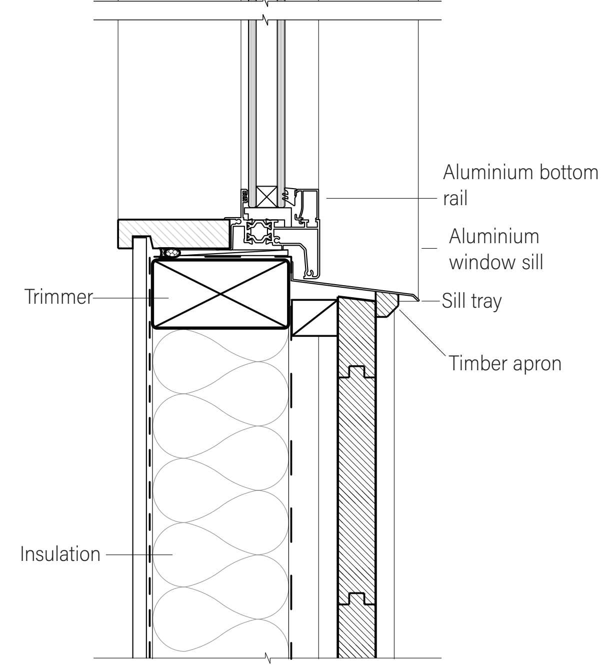


Fig 6.33 Aluminium window sill 1:5

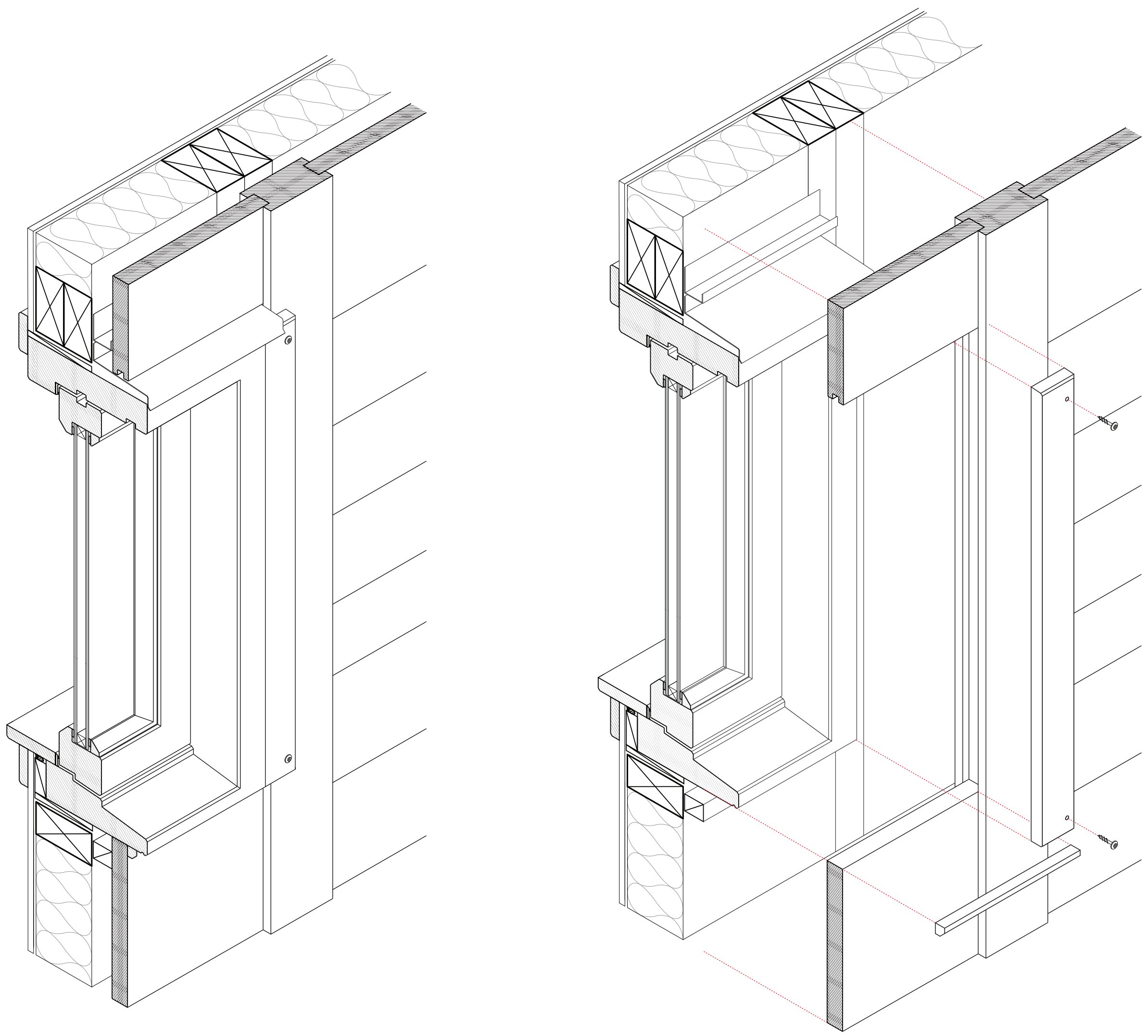


Fig 6.30 Assembly of aluminium window penetration - enlarged on page 139-140

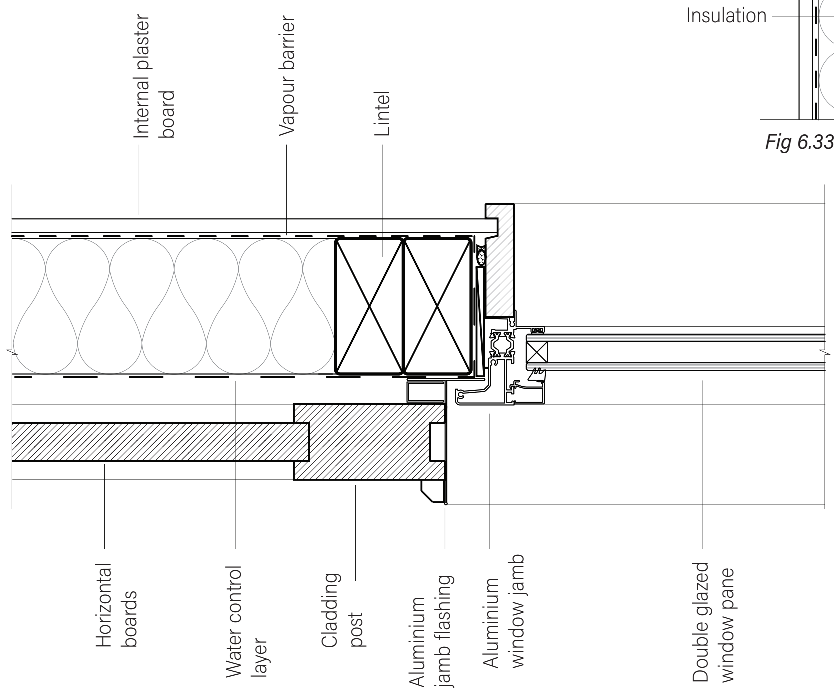


Fig 6.31 Aluminium window jamb 1:5

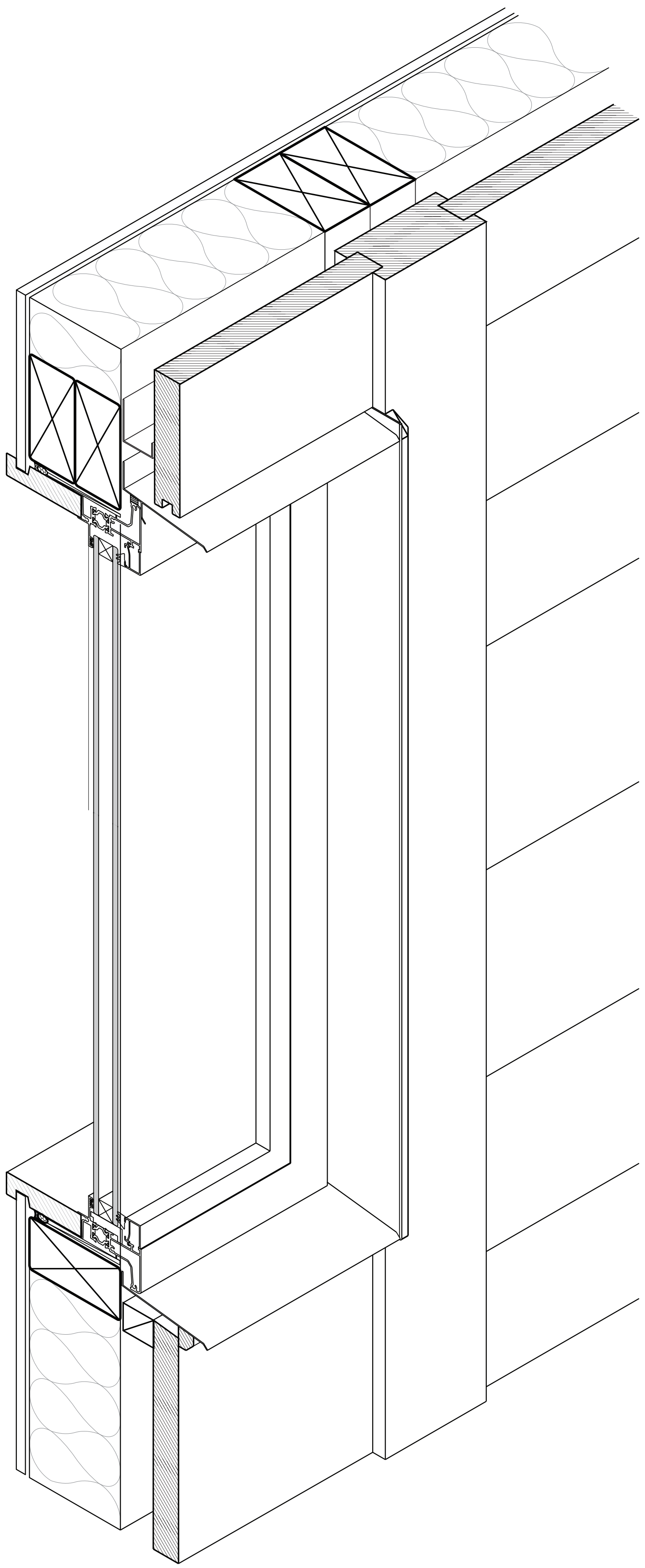


Fig 6.34 Assembly of aluminium window penetration

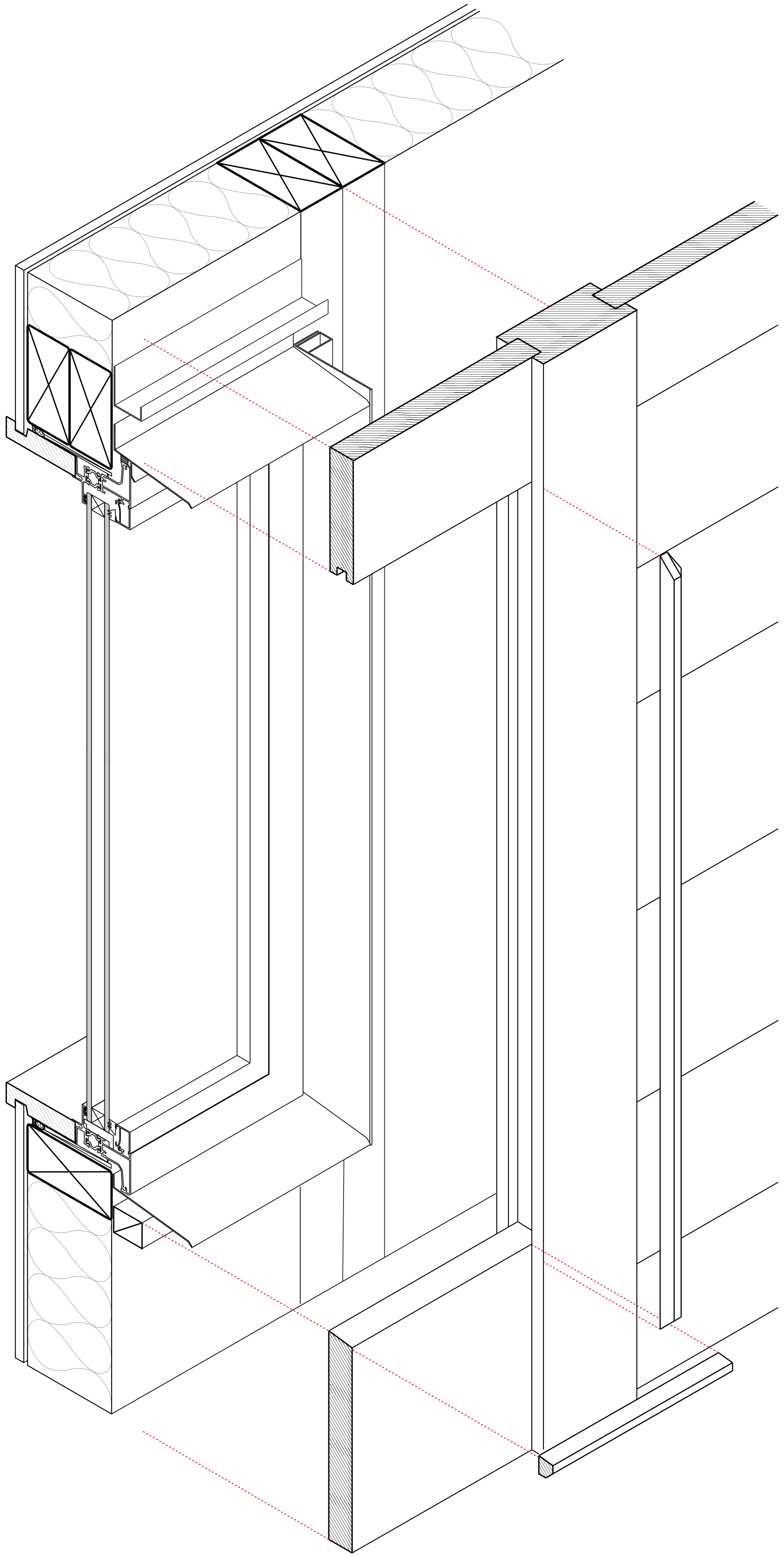


Fig 6.35 Assembly of aluminium window penetration exploded

6.3.3 Doors

Steps and ramps make it difficult to run a continuous bottom rail from this cladding system across doors. For this reason, the use of an alternative cladding panel to the system explored in this application is proposed for these sections as shown in Fig 6.36. This research generally focused on large-scale application of native timber and because this alternative panel would occupy a very small area of a building's exterior surface, the development of this panel has been excluded from the design scope.

The connection between posts and door jambs could be covered using similar methods to those suggested in the window application, with adjustments made according to the door system used (Fig 6.37).

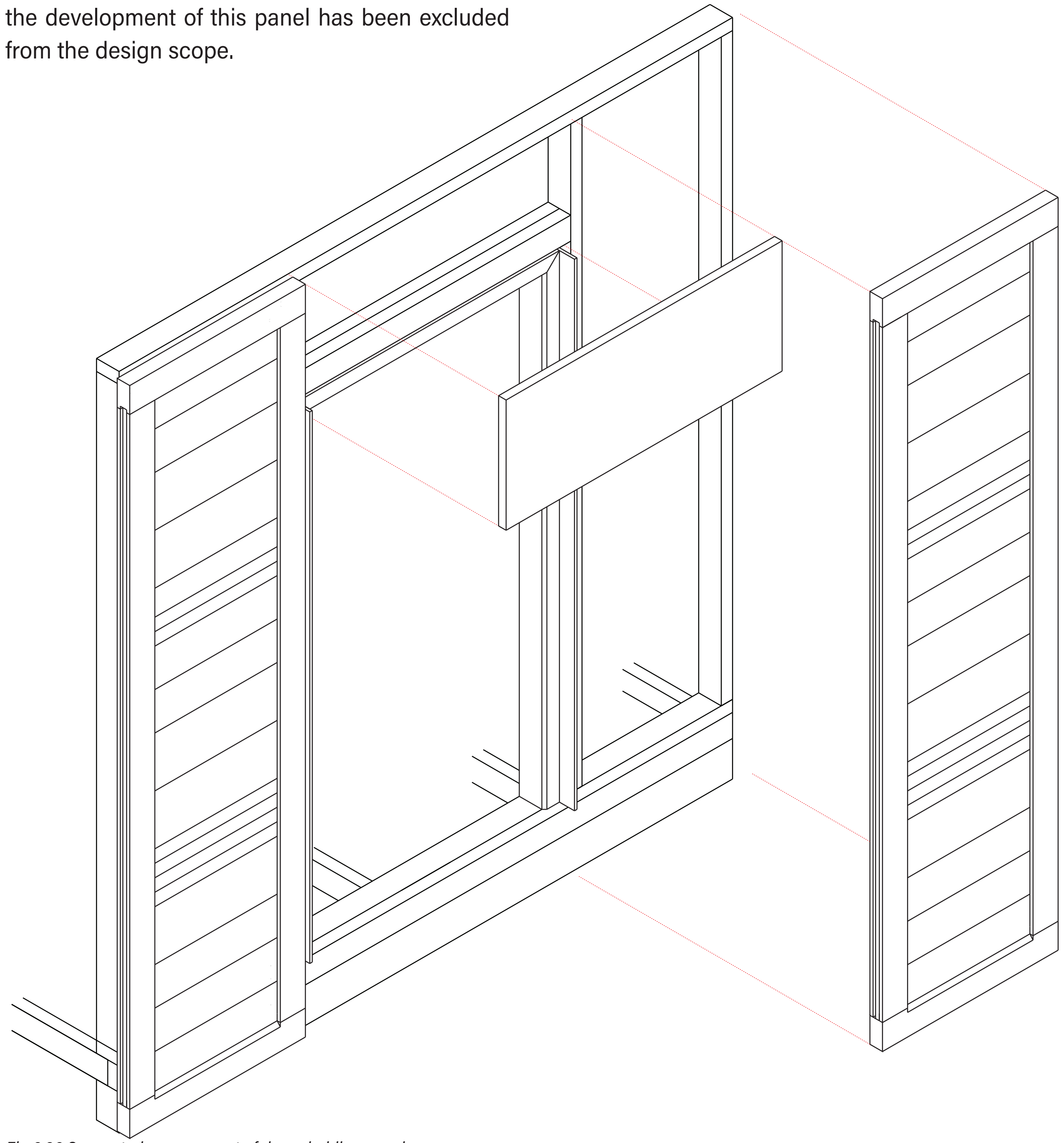


Fig 6.36 Suggested arrangement of door cladding panel

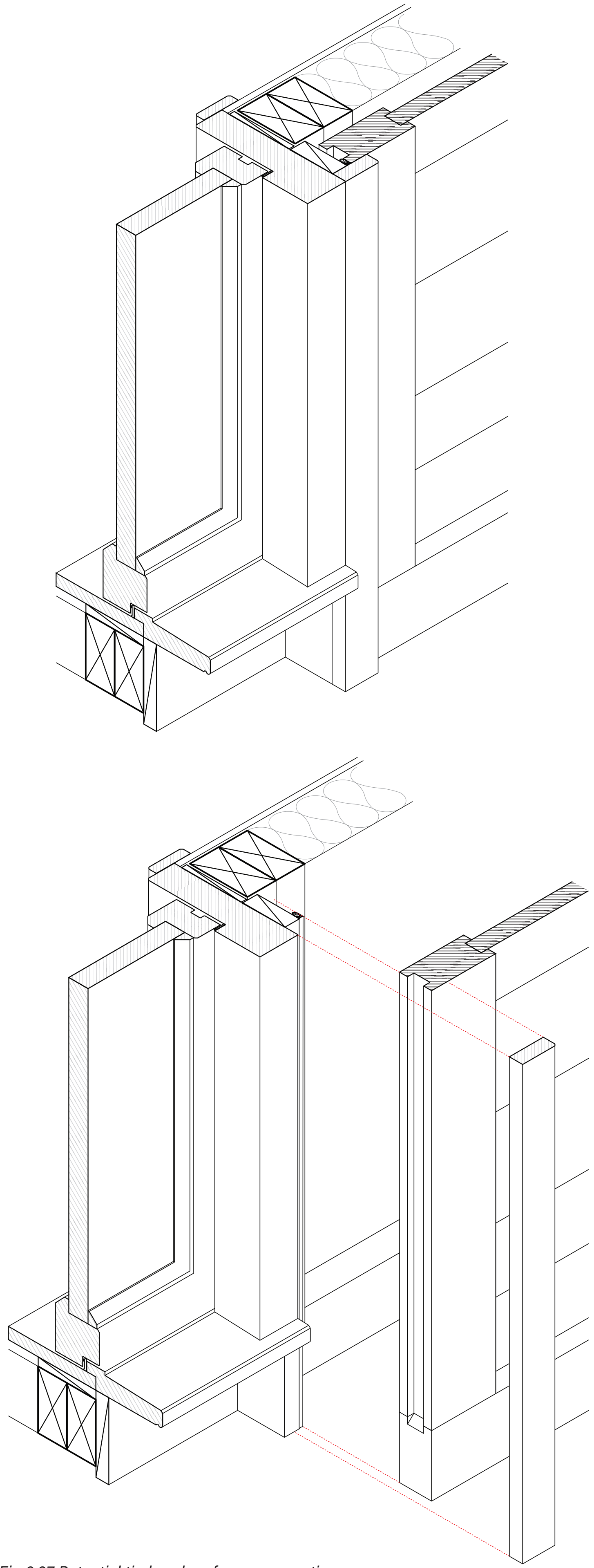


Fig 6.37 Potential timber door frame connection

6.4 Application in Context

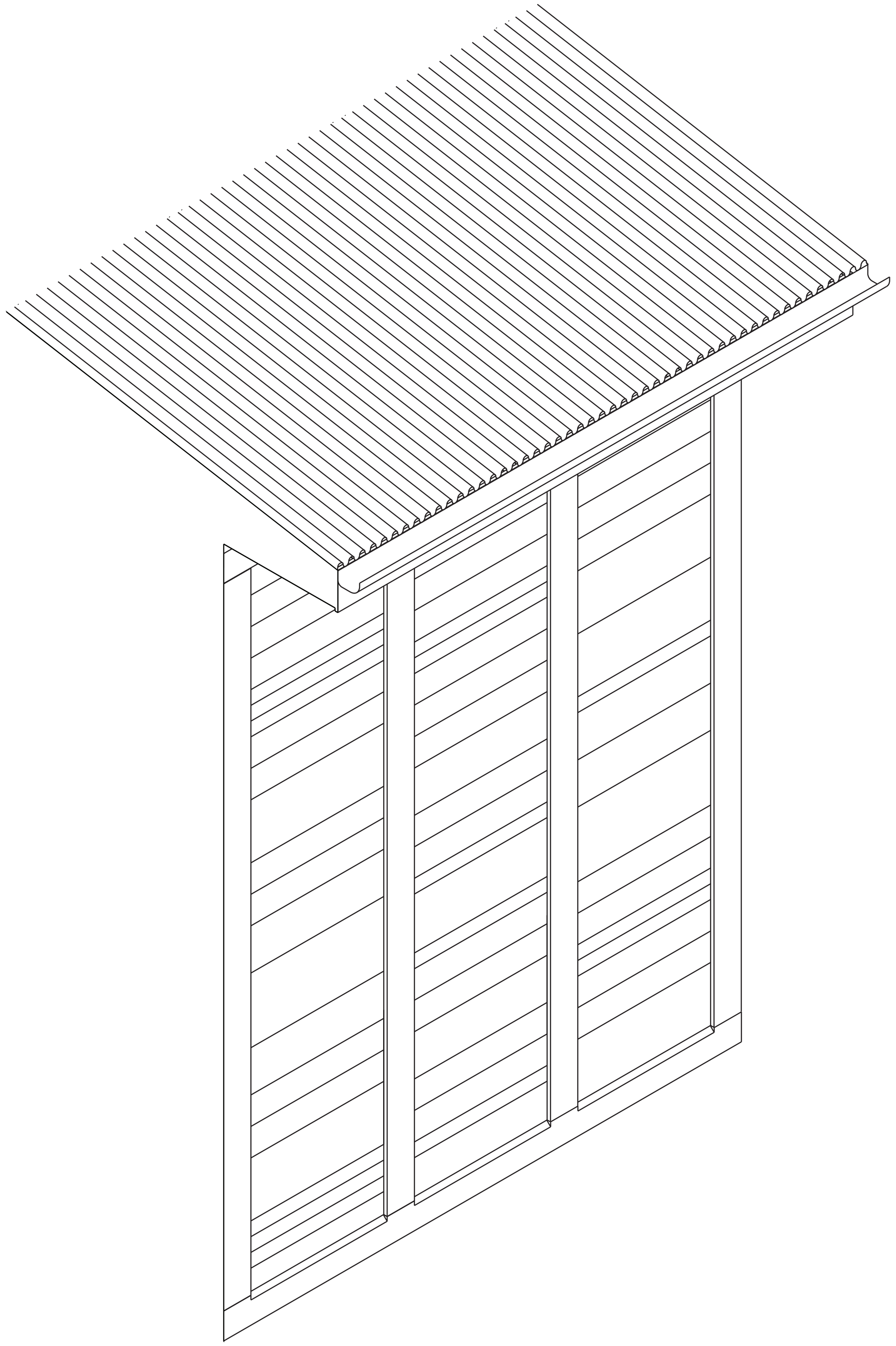
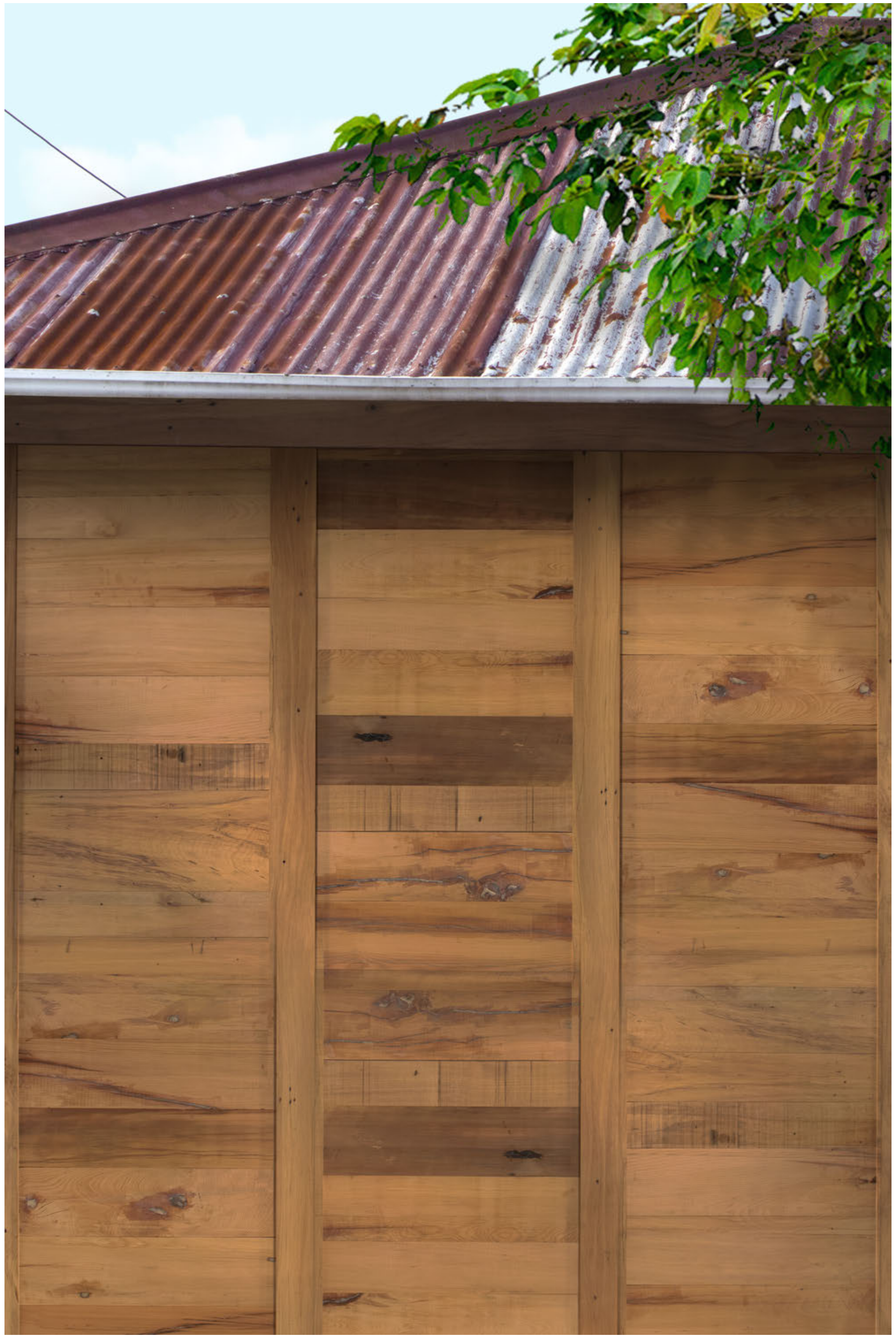


Fig 6.38 Continuous panel application context



Opposite page Fig 6.39 Continuous panel application

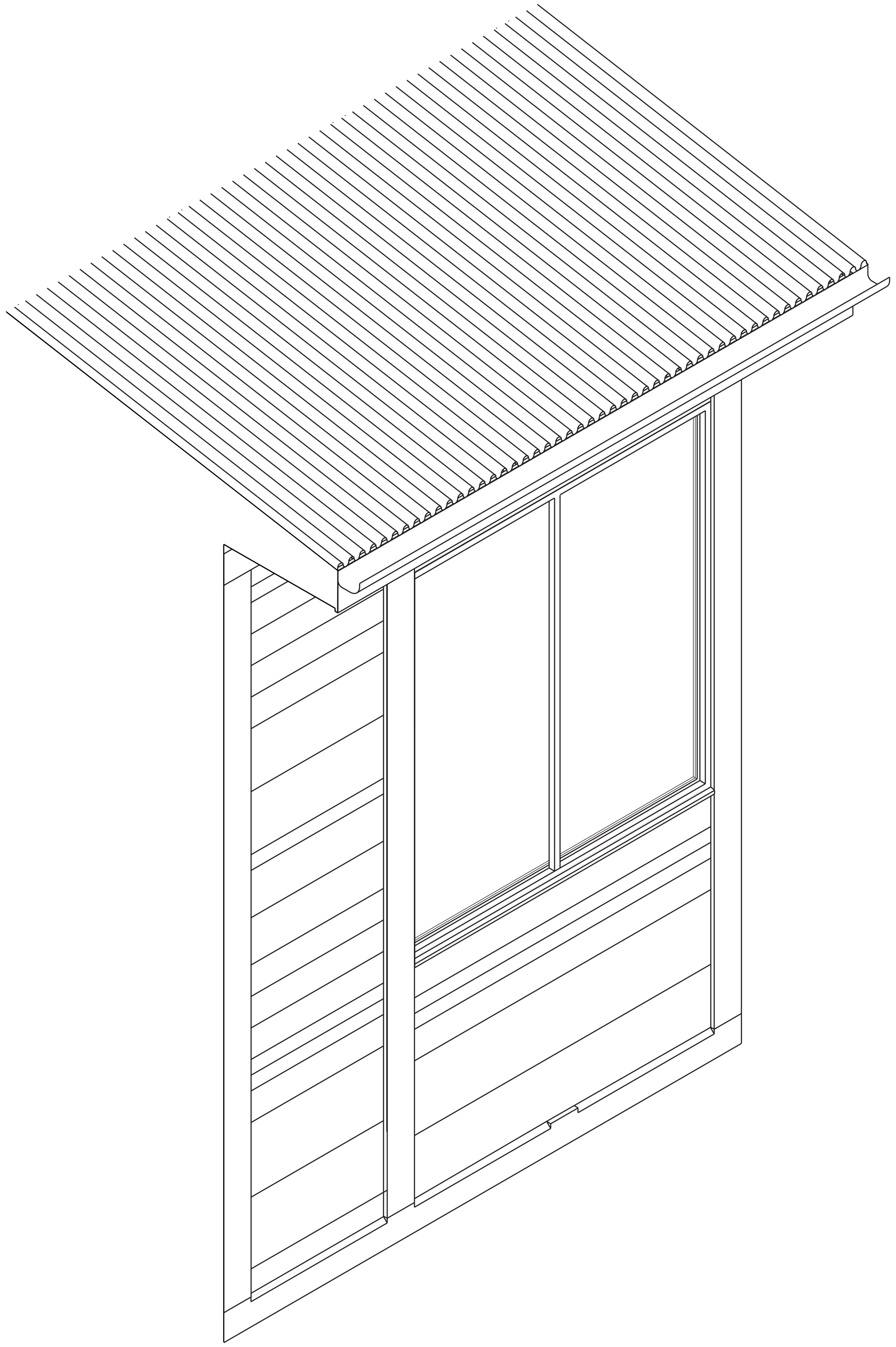


Fig 6.40 Timber window application context

Opposite page Fig 6.41 Timber window application

6.5 Application Suggestions

This exploration of speculative applications has informed several potential parameters for the installation of this current iteration. Outlining the implementation of this system against construction standards creates an understanding of the complete process of reuse and how a system of reuse may sit within the wider context of the built environment. It also highlights key limitations of the current iteration, providing additional issues to be approached in further design research.

Wide eaves are a commonly employed method used to facilitate alternative cladding, such as straw or earth walls (Smarter Homes, 2017) and would be a suitable means to reducing risk with this cladding system (Fig 5.42). If eaves are incorporated, they should be designed to facilitate application. The construction method for the current system involves flat assembly on the ground that is then tilted upward and pushed forwards onto brackets. Because of this, angled soffits would provide a barrier and limit manoeuvrability. For this reason, flat soffits will have to be employed rather than angled (Fig 5.43).

Fewer stories in a building generally mean that cladding is less exposed to the weather. It is suggested that the system is applied to one or two-story buildings to enable use in medium-density housing (Fig 5.45). This is also a factor affected by the method of on-ground assembly as lifting three-story panels would require a large span of ground and the transfer of a great deal of weight as found during prototyping.

Framing and foundations will also need to be sized accordingly. Foundations should have enough above-ground height to facilitate clearance from the base of the 50mm high bracket (Fig 5.44). This ensures that brackets can be fixed to the foundation and provide cover for framing.

These suggestions, while useful for the implementation of the system in its current phase, should be considered as limitations rather than design features. In further research, these limitations would inform areas in which the design would change to be more adaptable and widely applicable.

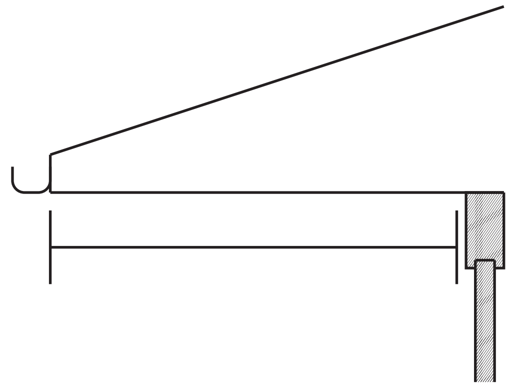


Fig 5.42 Wide eaves to minimise excess weather exposure

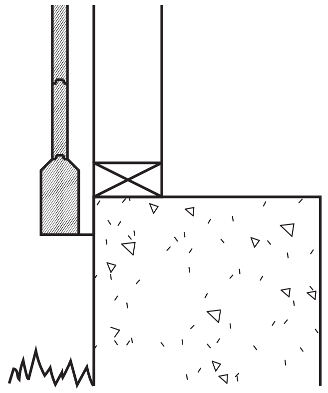


Fig 5.44 Appropriate clearance allowed by above-ground foundation height

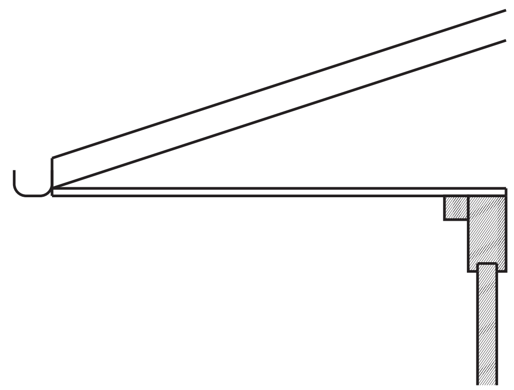


Fig 5.43 Flat soffits as opposed to angled

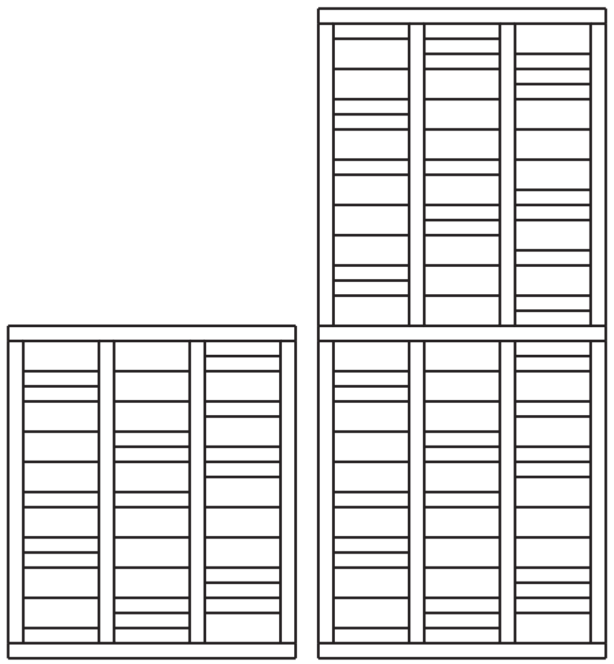


Fig 5.45 One to two stories are lower risk so medium density is preferable to high density

6.6 Consideration of Interior Application

There are several qualities of reused timber that require specific design solutions when it is used as exterior cladding. The variety across each piece of reused timber and the potential damage caused by previous use or removal create flaws that not only make machining the material difficult but create a risk of deterioration when in use. Splits, chips, nail holes, and borer all pose a risk when placed in an exterior context as they are places in which water will collect, leading to rot. The use of epoxy, oils, and other sealants are good ways to repair and mitigate these issues, however, these are less effective when a piece of timber has distorted in a way that has caused splitting throughout. This is an issue particularly in sap rimu, which tends to be more fragile along its grain.

One potential application for timber unsuitable for exterior use is to use it in an interior context. This provides a solution that will continue to maintain its qualities and keep it in the cycle of the built environment. Protection from the weather means that a great deal less has to be done to these timbers and their flaws become significantly less of a concern to the integrity of the building's envelope. This is a well-trodden path for the recycling of timber. Feature interior walls are a common use for reused timber. Occupants have more frequent opportunities to engage with the material and the unique nature of each piece of timber provides an appearance that cannot be obtained through new products.

Potential circular reuse is also a factor when considering interior cladding. On one hand, connections between elements do not have to withstand wind, so fewer fixings would likely be needed. This could allow fewer holes in timber elements or the incorporation of more gravity-based solutions. Where interior cladding becomes slightly more limiting is in the preservation of larger reused elements. Due to the reduced space through which interior cladding must move, smaller panels of cladding may be needed. This dictates the singular lengths of timber used for posts as well as top and bottom plates and therefore reduces lengths available during the system's second life, limiting the versatility of potential reuse.

In a continuation of this research, the development of a dual system of cladding would be explored. This would entail a categorisation of sourced timber into categories of condition. Timber containing flaws that would not inhibit its workability but would likely pose a risk if exposed to the elements would be designated for interior use. Any timber that could be brought to standards fit for exterior application without excessive effort would be designated for exterior use. Through this two-part system, more complete reuse could be achieved.

Opposite page Fig 4.46 Speculative interior application

7. Prototyping

The use of prototyping allowed a more in-depth exploration of the process needed to create and assemble the current design outcome. Detail models, while valuable for testing the machining process and the working qualities of native timber, do not form a full understanding of how various elements of the system operate as a whole. This exploration of full-scale prototyping examined the process of making from post-deconstruction timber elements to assembly. This prototype was made using 2x4s and sarking sourced from various timber recyclers and renovations and used a combination of rimu and matai.

Opposite page Fig 7.00 prototype boards

Fig 7.01 assembly of prototype

Fig 7.02 assembly of prototype


Fig 7.03 1:1 prototype


Fig 7.04 Front face


Fig 7.05 Back face

Fig 7.06 Post and bottom frame junction

Fig 7.07 Post and bottom frame junction

Fig 7.08 Doweled connection

Fig 7.09 Chamfered bottom rail end

Fig 7.10 Horizontal boards

Fig 7.11 Horizontal boards

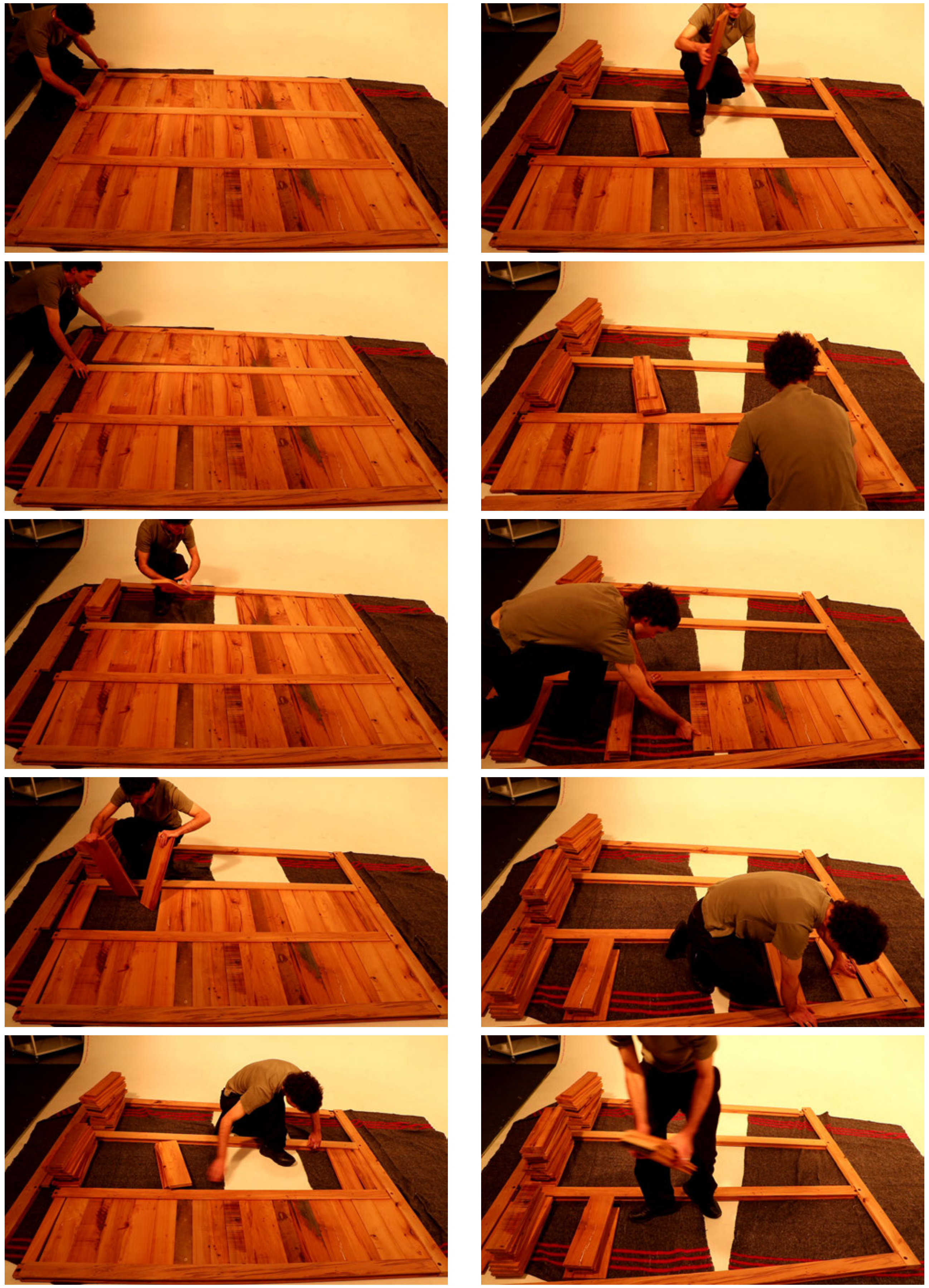


Fig 7.12 Disassembly of prototype

Fig 7.13 Prototype components

7.1 Findings from 1:1 prototype

The creation of a 1:1 prototype has highlighted a number of additional issues with the current iteration of this cladding system. The process of preparing the timber and machining the parts has revealed common issues with reused native timber that did not become apparent during contextual research. Assembling a full-scale model has helped to refine the speculative construction process and understand points at which the design could be improved to ensure efficiency on site.

7.2 Assembly

The process of assembling a 1:1 section of this cladding allowed a greater understanding of the physical interactions between native timber elements that could not be gained from drawings or detail models. While much of the assembly process occurred as expected, some key findings can be used to inform further design considerations.

7.2.1 Flexibility

The complete cladding system has a tendency to twist and flex when not fully supported, which was not accounted for during the design stages. This occurs as a result of the system's almost complete weight being placed on the mortise and tenon joints that are not completely flush (Fig 7.09). While this is not a serious issue, it does mean the cladding is difficult to lift for one person as it needs to be supported at two points. All three refined iteration models had little-to-no movement of posts once they were dowelled in place. More time was spent chiselling tenons due to detail models only having a singular one each, so allowing more time for the making of the top and bottom rails may be the key to this issue.

Another contributor to this flexibility was imperfect dowels. The timber batten that was used to create the dowels contained many small splits which, when placed in the lathe, caused chips and inconsistent thicknesses. Due to the limited amount of time in which floor space was available for assembly in the workshop, dowels were cut before holes were drilled. By reversing this process, dowels can be cut slightly larger than holes and sanded back to ensure a snug fit.

Flexibility also impacted the assembly and deconstruction of this model. As posts can pivot slightly to the side, pushing boards down the routed slots sometimes caused posts to kick out to the side. This caused boards to fall out of place and sometimes become stuck meaning the assembly of that specific bank of boards needed to be restarted (Fig 7.14). This could be resolved using clamps or stops to prevent posts from moving outwards. A benefit to this flexibility is the ease of deconstruction. Posts can be pulled out to let the boards fall, allowing them to be rapidly stacked (Fig 7.15).

Fig 7.14 Difficulties in assembly due to flexibility

Fig 7.15 Ease in disassembly due to flexibility

7.2.2 Friction

Boards offered more resistance than expected when being slotted between posts. This was due to the friction created by end grain faces which have a textured surface. This is because these boards were mostly cut to length using a drop saw, resulting in a rougher cut than the thicknessed faces (Fig 7.16). Sanding the slots in posts with fine-grit sandpaper helped to reduce this friction. Due to the fact that each board was cut 2mm shorter than the space between posts, friction did not prevent construction, only slowed the process slightly. Generally, allowing small tolerances within the prototype meant that while the final result did not assemble completely flush, components rarely had to be machined twice. This is a widely applicable finding when considering native timber reuse, as the tendency of the material to split, expand, or warp when cut means that measuring to the exact millimetre is usually not a viable option.

Fig 7.16 End grain textures

7.2.3 Joint Damage

The main risk to the structural integrity of the system is the connection between the posts and the bottom rail, as this is where the majority of stress is placed when the system is being lifted from a flat assembly. This connection was refined from a through-dowel to one that only extended through the internal face of the mortise to reduce the risk of moisture penetration. However, this increased the flexibility of the connection. While this flexibility will benefit the system as the timber expands and contracts, it also means that the stress is applied to a singular 10mm wall of the mortise, rather than two. This has caused splitting in one of the mortises during the assembly of the 1:1 model (Fig 7.17). To maintain water resistance an alteration to the assembly process rather than the design may provide a solution to this issue. The system should be lifted flat once assembled and lengths of timber should be placed parallel to the top and bottom plate at each end of the posts (Fig 7.18). This will allow the cladding to be tilted upwards while removing all stress from the wall of the mortise. Lifting the system will likely require at least four people, as opposed to the two required to tilt it from flat, but this process will ensure that the system can be reapplied to a different building without the need to replace any complex parts.

Fig 7.17 Damage From Assembly

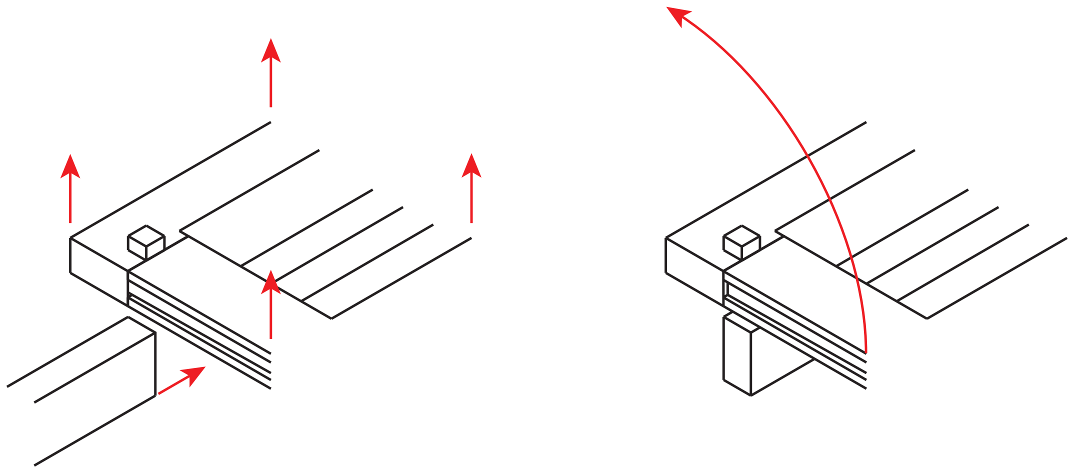


Fig 7.18 Reworked assembly process

7.3 Making Process

7.3.1 Issues with timber

During the sourcing and making process, several common issues across the majority of timber became apparent. While nail holes were largely expected, rebates were also present in much of the timber as many of the longer lengths of native timber sourced were used as rafters (Fig 7.19). Additionally, the issue of splitting was far more widespread than expected. The majority of timber used in this prototype was rimu, with matai making up the remainder. Due to the brittle nature of rimu, there was a tendency for builders to construct houses from the timber while it was still green (NZ timbers). As these timber elements have dried in place, they have shrunk and, in some cases, twisted, causing splits at nailed connections. Deformation has caused small fractures to occur across entire lengths of some posts.

Another effect of this deformation was the adjustment of the design according to the dimensions of each timber element after it was dressed. While some pieces had remained fairly straight, others had become warped. After planning and thicknessing these pieces, some lost as much as 20mm from the depth of their profile. As each post in this design was required to be the same dimensions to facilitate a standard board width, the most warped post defined the standard size for all the remaining posts to be thicknessed to. This means that designing exactly to the standards in practice when this timber was first milled is not particularly accurate as, in reality, very few pieces of timber will have remained straight enough to be used at these dimensions.

It was also apparent that a consistent guide on the size and frequency of nails would be difficult to obtain. Beyond structural connections, vast amounts of small nails and staples have been used to fix plasterboard, wiring, building paper, and sarking. However, the holes left by these fixings consistently run down the centre of the narrow face. In the current design iteration, this is where the slot for the boards is routed. This means that the majority of these holes are well-covered when the system is assembled. This was an unanticipated benefit of the use of a groove, rather than a tongue, to secure the sides of the boards.

Fig 7.19 Rebate repair using PVA

Fig 7.20 Damage repair using epoxy

7.3.2 Use of Adhesives

A key element of this design process was the avoidance of any adhesives, as their use in the built environment is a hindrance to the circular use of building materials. However, an important part of waterproofing this system was filling nail holes, repairing voids, and sealing splits. This required the use of both epoxy and a small amount of PVA to achieve. Along with these adhesives, masking tape was used to close off nail holes and rubber gloves were worn while handling adhesives. Polyvinyl Alcohol (PVA), while petroleum-derived, has low toxicity while in use and little ecological impact and for this reason was chosen as the most appropriate wood glue for this system (Saxena et al, 2021). PVA was used to fill rebates and to combine multiple sheets of 10-12mm sarking to create boards of the same thickness as those machined from standard 25mm sarking (Fig 7.27). This totalled 200ml of PVA. Epoxy, however, was used far more frequently (Fig 7.23, 7.24, 7.26, 7.28). For approximately 4m^2 of cladding, around 600ml of epoxy was used. This was a combination of a builder's glue with a high filler content in its hardening element and a more fluid epoxy with a high resin ratio. While the use of these adhesives facilitates the continued reuse of timber, there are still issues that arise from the use of epoxy. The process of creating epoxy is largely petroleum-based and is a process that emits a large number of greenhouse gases (Maxineasa et al, p. 370, 2015). This is a major drawback in the sustainability of this prototype.

One method of minimising the environmental impact of this cladding system is to find a green alternative to traditional epoxy. Before beginning the 1:1 prototype, pine rosin was processed into pitch glue using an ash mixture (Fig 7.21). This was a largely unsuccessful experiment, particularly in regards to use as an adhesive rather than a filler. This may have been, however, an issue with the equipment used as the only immediately available method of heating the rosin was using a double boiler that produced a relatively low heat. This meant the pitch glue became unworkable extremely quickly. Its consistency and adhesion were also inefficient for filling nail holes right through a timber element. The pitch glue was, however, reasonably effective at covering the entry and exit points of a nail hole. It is likely that if the process was carried out in a facility where the glue could be maintained at high heat for extended periods, it would serve as an adequate replacement for epoxy regarding nail holes and shallow splits. This still does not account for the repairing of major splitting as pitch glue lacks the adhesive qualities required to hold two faces of timber together. To fill splits with a low environmental impact, a bio-based resin is a viable option. Currently, these are not widely available and subject to debate regarding the environmental benefits of the production process (Terry, 2021). However, the use of vegetable oils has yielded positive results as a base for traditional epoxy alternatives and, although it is still a product that is yet to become readily commercially available, could provide an appropriate solution to the problem posed by large splits in timber (Baronciniet al, 2016).


Fig 7.21 Pine rosin used for nail holes


Fig 7.23 Epoxy used for nail holes


Fig 7.22 Split 2x4 end


Fig 7.24 Epoxy used for split repair


Fig 7.25 PVA used for repairing rebates


Fig 7.27 PVA used for combining 10-12mm sarking


Fig 7.26 Machining of epoxy


Fig 7.28 Machining of epoxy repair

7.3.3 Order of Process

As the creation of this prototype enabled the experimentation needed to further refine the design process, it is difficult to gauge the total time required to dress the timber, repair flaws, and cut elements to size. What can be gauged from this process is an ideal order in which each task could be carried out. When nail holes were initially filled, before the timber had been dressed, many were filled with wood chips or sawdust. As a result, when the timber was dressed much of this epoxy was removed, reopening holes. The ideal process, in this case, would have been a quick plane of the timber's surface to establish a cleaner workspace, place epoxy in, and then redress the timber more carefully to remove any build-ups on the surface.

Another issue was that many flaws and voids were filled, only to then be removed as the timber was cut more accurately to size. Ideally, in this case, the timber should be cut to length with a smaller allowance so that unnecessary adhesive is not used and unnecessary time is not spent during these early stages of processing. The following is the suggested order of processing native timber for this system, according to the findings of this prototype:

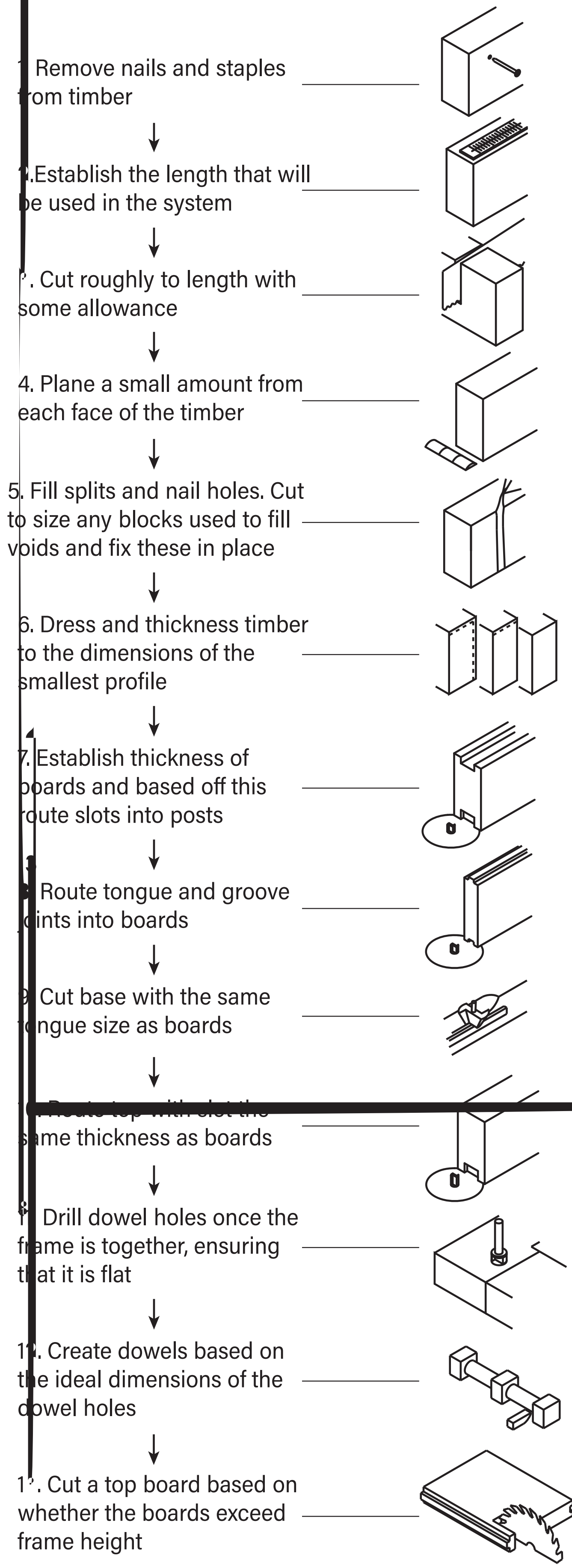


Fig 7.29 Suggested order of process

7.3.4 Offcuts

The majority of offcuts produced during the creation of this prototype were wood chips and sawdust (Fig 7.29). This was collected and amounted to approximately 30l in total. These chips could serve several purposes within the project. If burnt, the ash produced could form the base for producing pitch glue. Alternatively, finer sawdust could be filtered out of the larger wood chips and used as a filler to be paired with adhesives. Outside of use in this project, these smaller offcuts could be used in gardening, as they are untreated timber. Ideally, the collected waste would be separated between what has come from timber containing epoxy and untouched timber, although epoxy use in areas that were routed or sawn was minimal.

The other major source of waste, as expected, was offcuts. These came to around 2000mm in total (Fig 7.30). However, with more careful planning this could be minimised. Due to the relatively short length of the horizontal boards (528mm), many pieces of timber could be cut in a way where they on produced a few mm of wastage. Some posts were cut roughly to length and then carefully cut once they had been dressed. If these were cut more carefully, they would have produced several usable boards. These offcuts did provide useful test pieces, as they were identical dimensions to the pieces used in the prototype. This allowed many test cuts to be trialled before taking tools to the primary elements, ensuring minimal mistakes were made. A benefit of a material such as native timber is that even smaller lengths can be utilised outside of an architectural context for their use in woodworking and crafts, so there is a potential for total reuse of offcuts (Fig 7.31).

Fig 7.29 Wood chips and sawdust

Fig 7.30 Offcuts from prototype

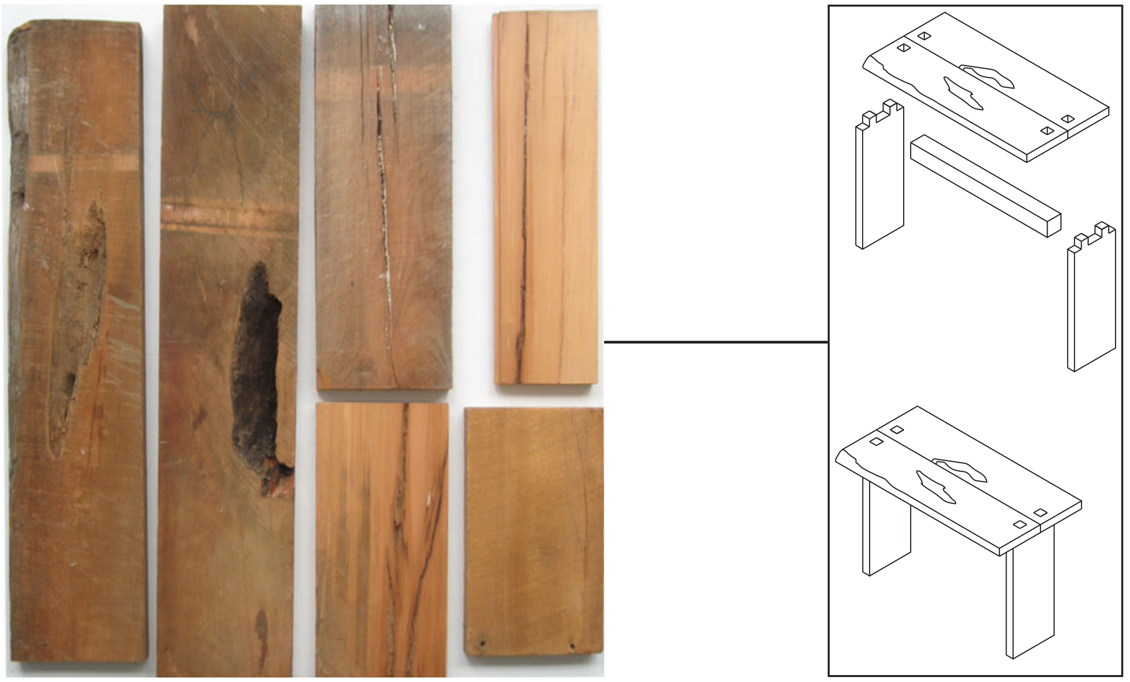
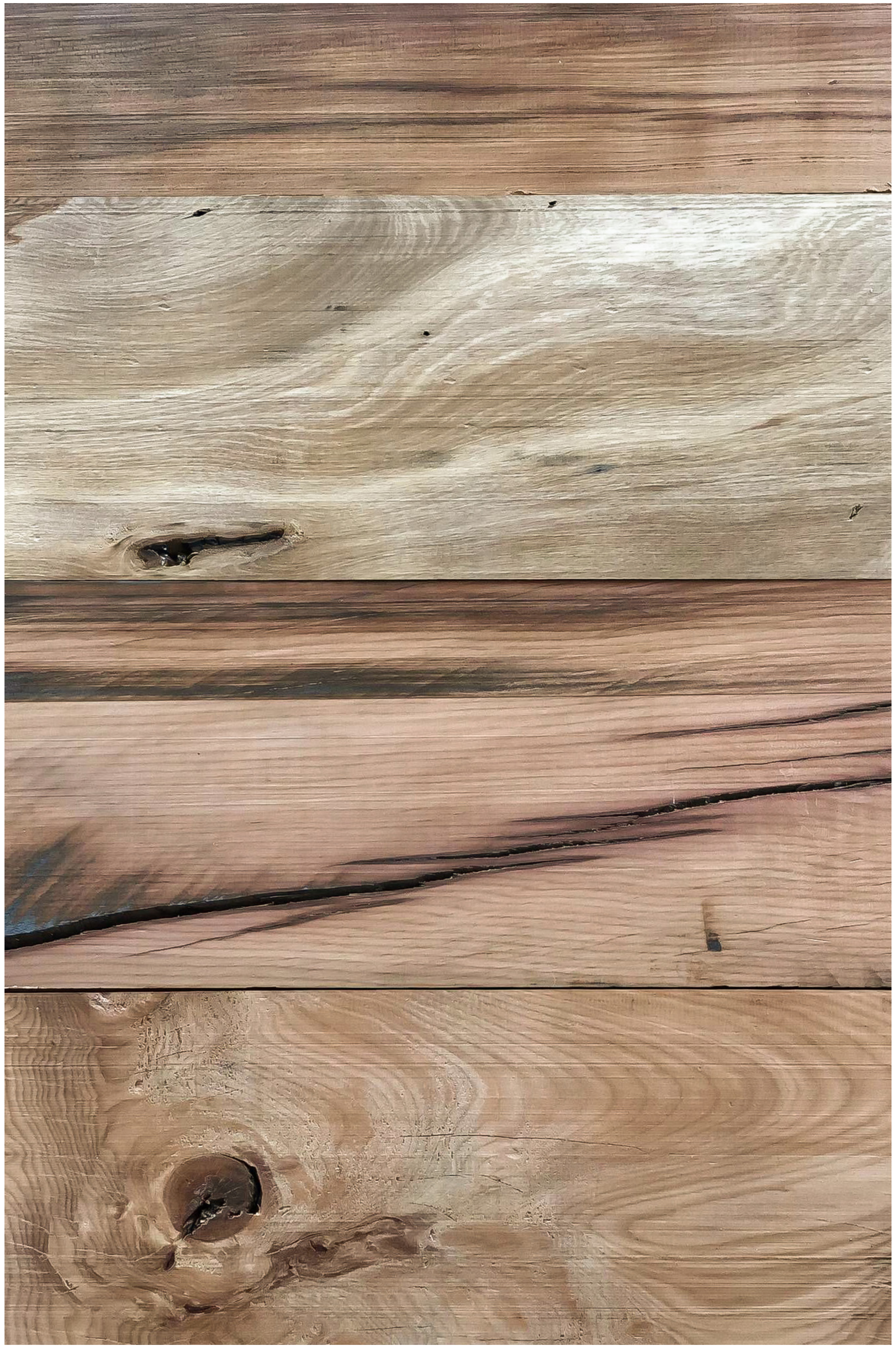


Fig 7.31 Draft of Circular Offcut Bench

8. Conclusion

Opposite page Fig 8.00 Horizontal board variation



8.1 Critical Reflection

This design iteration can be examined according to two overarching criteria. These are its ability to accommodate reused materials from the built environment and its ability to facilitate the continued reuse of these materials. The overall sustainable impact of this system can also be critiqued to help refine further design research. Additionally, the process of reuse followed in this research can be assessed, not only for the reuse of native timber but in the wider context of reuse in architecture.

8.1.1 Environmental Impact

This system can be assessed in two main categories for its environmental impact. The first is the overall life cycle of the native timber and the second is the environmental impact of the additional materials used to facilitate reuse.

One immediate benefit of native timber reuse is the prevention of material entering landfill. Based on data retrieved from NZSS 95, framing and floorboards from state house demolition alone amounted to 26,650m^3 of demolition waste. While it is unlikely that all of this material went to landfill, reducing this number to zero through systematic reuse is an important step in waste minimisation. Waste minimisation is a more prominent benefit in this research than carbon reduction as the use of new timber sequesters carbon during its lifespan (Payn, 2020). It does, however, provide an opportunity to source timber immediately within urban environments, minimising transportation emissions from rural radiata plantations.

The most notable environmental impact is from this system's incorporation of non-recycled materials. To construct the 1:1 prototype, approximately 600ml of epoxy was used. This served as an experiment to test the physical interaction between epoxy and native timber. For this reason, the second batch of timber sourced for the model was not treated with epoxy to avoid unnecessary adhesive use. For the total treatment of the model, it is estimated that 800ml would be the total volume of epoxy needed. This would amount to 200ml, or 0.21Kg of epoxy per m^2 of cladding which would emit approximately 1.4Kg CO2 (Chard et al, 2019) (Venkatesh et al, 2009). The volume of PVA amounted to 200ml. The majority of this was applied to 10mm sarking from a renovated bungalow that was used due to time limitations. As this would not be necessary if standard 25mm sarking from state housing was used, the use of this adhesive has been considered negligible in this research

Steel brackets, included in the speculative application of this design, would be unlikely to be sourced from demolition. These brackets replaced timber dowels in earlier systems, as dowels would both limit the range of application and potentially lead to accelerated degradation of the material. A standard heavy-duty bracket of approximately the same dimensions as those specified in the system would produce 0.17Kg of carbon emissions, based on 1.89-tonne emission per ton of steel produced (World Steel Association, 2021). The current iteration of the system requires custom brackets to be used, meaning that reused brackets from demolition waste would be unlikely. However, if further design iterations worked to incorporate brackets that are commonly found in demolition waste, the impact of this system could be reduced.

8.1.2 Accommodation of Reuse

A leading design drive for all iterations during this research was a system that could accommodate a range of profiles, lengths, and conditions of native timber. The method of achieving this in the slotted board and batten system was to reduce all pieces to the same thickness while allowing for variation in height and standardised lengths. Where this has been most effective is in accommodating height variation. The system design means that only the top board in each bank must be cut to a specific height, a simple task which could be done on-site. This would allow boards to be assembled in a variety of combinations regardless of vertical dimensions.

More limitation is placed on the width of the boards. Boards must be cut to fit between posts and while a wider variation in these spaces could be achieved at the scale of a full building, there is still a finite number of width variations. This means that there will consistently be offcuts when native timber is reused in this system. This can be minimised if timber is sourced before the design is finalised for the building to which the cladding is being applied. If general board lengths are known, studs and penetrations can be arranged accordingly to facilitate these.

The most limiting aspect of this system is the lack of variation accommodated in board thickness (Fig 8.01). As all boards must be the same thickness, battens, 2x4s, and joists must be cut into halves or thirds if they are to be incorporated outside of their use as posts or rails. This means that not only are these larger profiles not preserved but a greater number of alterations must be made to these pieces of timber, slowing the process of fabrication. This is particularly an issue for battens, as the time used to cut a batten down only produces two 50mm high boards. This is one of the shortcomings of a cladding system as a medium of reuse, as achieving a flat profile makes unaltered framing elements generally unideal.

Fig 8.01 Standardised board thickness

8.1.3 Facilitation of Reuse

One key aim of later iterations in this research, as influenced by Zumthor's Swiss Sound Pavilion, was to design a system that produced material at the end of its life cycle that was not limited only to that particular system. This was explored using a selection of specific machined elements that facilitated the wider use of simple boards free from penetrations. These can then be removed from the cladding without damage and used for a range of applications (Fig 8.02-8.05). Additionally, if they have been utilised as cladding, they will have been treated for weather and had splits and nail holes repaired. This means that in their next life cycle they can be used in a context where weatherproofing is necessary.

The reuse of timber from this system in food areas such as kitchens or as items with which children interact would be dependent on the use of non-toxic or inert adhesives to repair flaws in the timber for use in the cladding system.

The main limitation in the continuing reuse of this system is the frequent tenons in the top and bottom rails. The tenons in this design iteration penetrate halfway through each rail, limiting the maximum length of continuous timber in the rails to the same length as the boards in that particular section of cladding. The use of brackets or bolts could minimise the size of penetrations in these elements, increasing the length of largely usable native timber elements. This would, however, mean the introduction of more steel elements, increasing the potential carbon footprint of the system. All elements in this system overall are limited by the standardised lengths with which cladding must be constructed.

It is currently unknown the degree to which the usability of recycled native timber, if thermally modified, would deteriorate if used for long periods in an exterior context. It is therefore unclear the effect that use as exterior cladding would have on this material's circular use. Testing this in further research would inform whether an exterior application would continue to be explored.

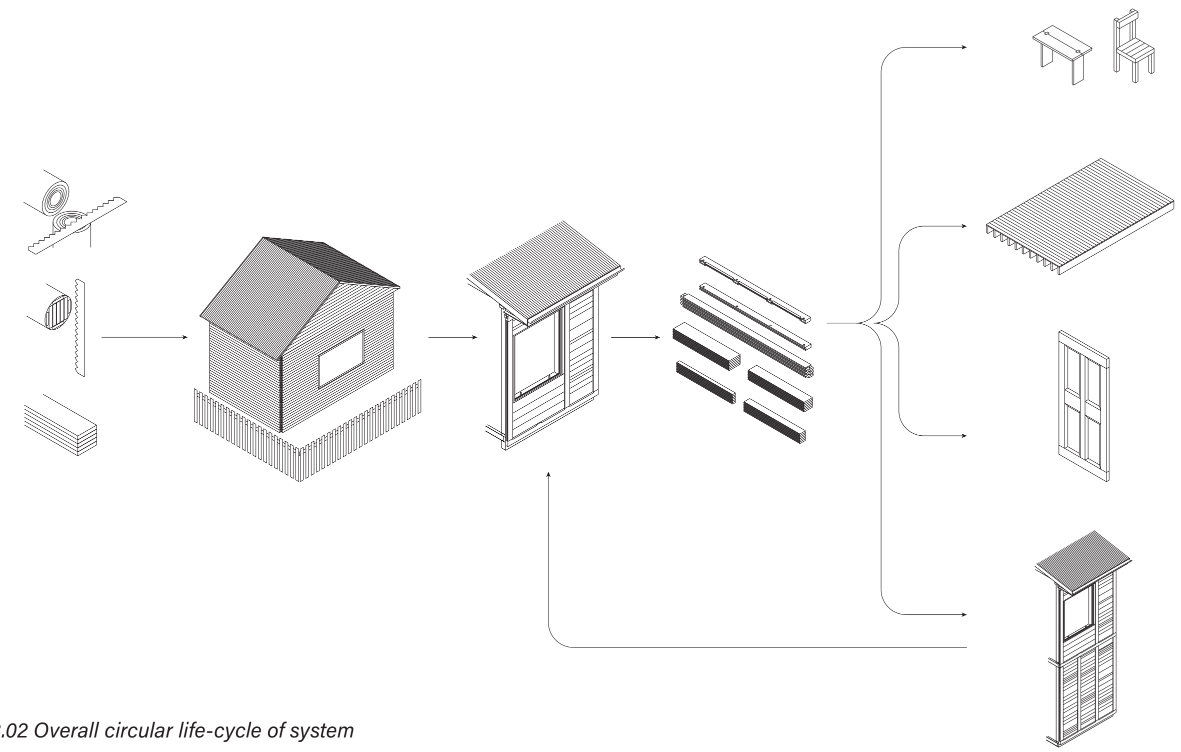


Fig 8.02 Overall circular life-cycle of system

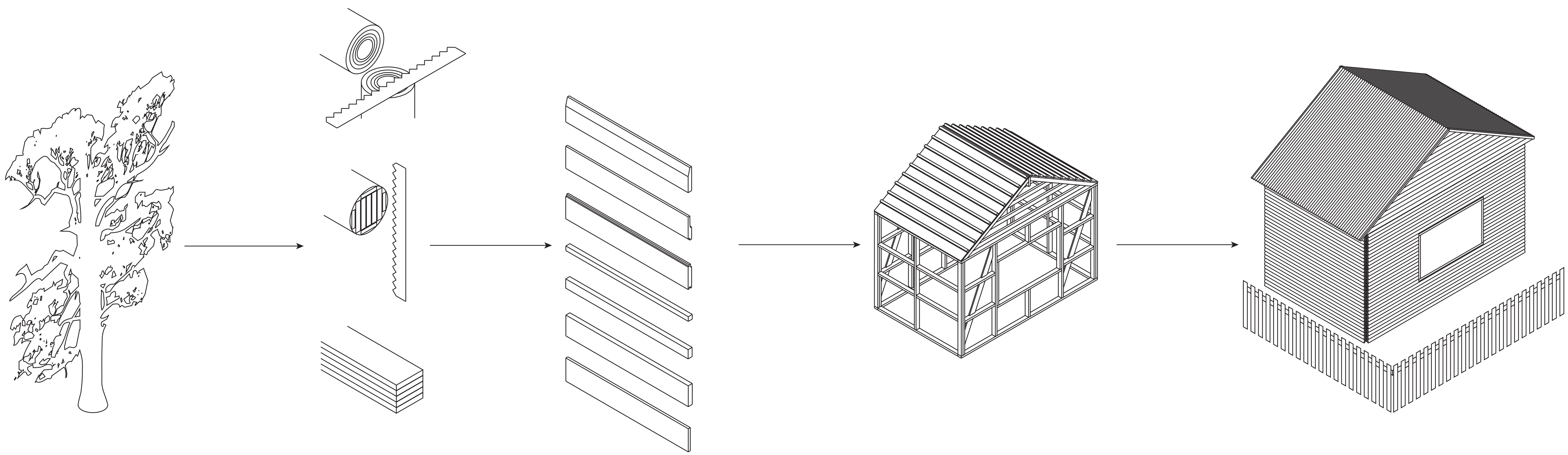


Fig 8.03 First life-cycle

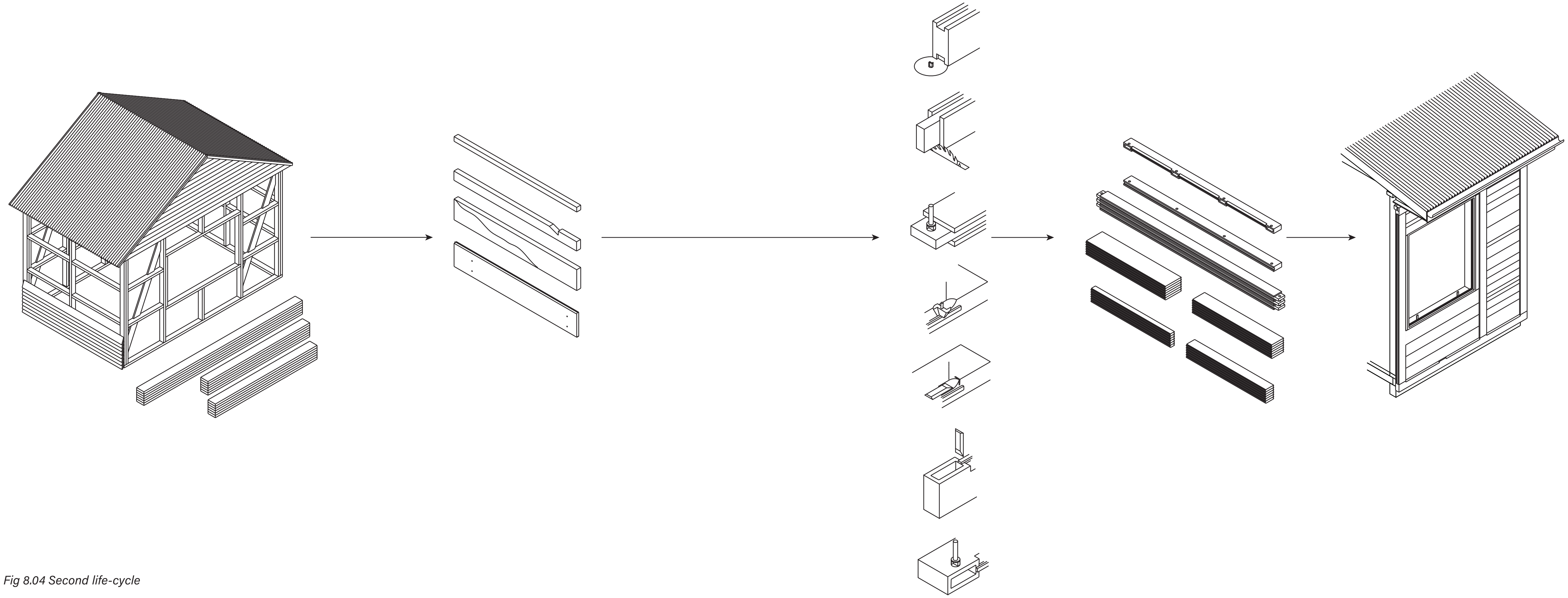


Fig 8.04 Second life-cycle

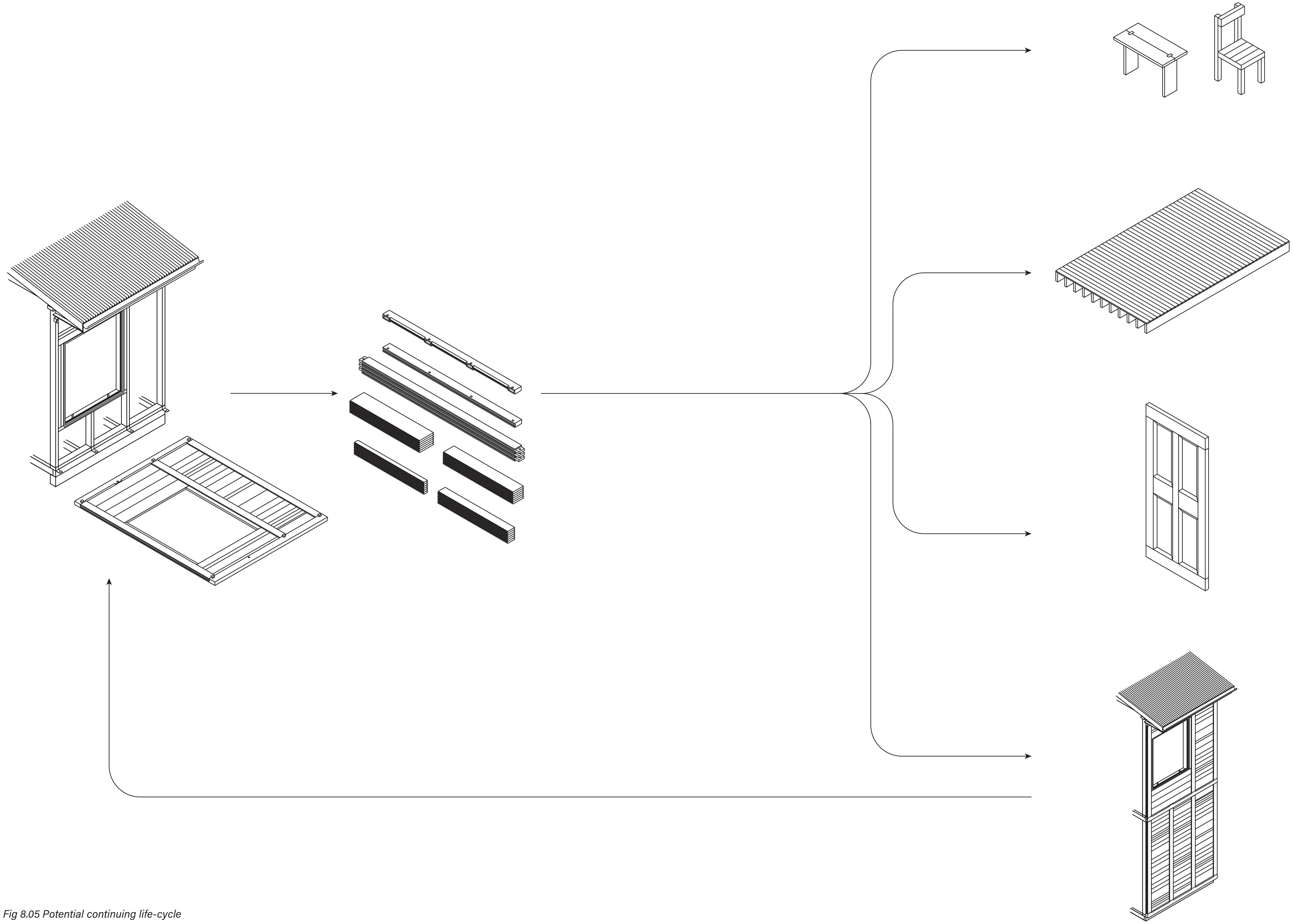


Fig 8.05 Potential continuing life-cycle

8.1.4 Overall Reuse Process

This research has provided valuable insight into the process of reuse in an architectural context. There were several limitations to the extent to which this process was carried out. This can be used to inform a more effective outline for reuse and contribute additional steps to be introduced into the process for a more comprehensive system design.

The main limitation of this research is a lack of methodical testing to understand both the properties of native timber and the performance of the overall system. Experimentations with thermal modification would ideally be carried out during the "material context" phase of the research. The success of this could then inform whether a cladding system is truly a practical application for this material. Additionally, weather testing in a controlled environment could inform design decisions as the interaction of moisture with the system could be recorded. These tests should be carried out both during "material context" and during "refined design iterations".

Physical experimentation was a key stage of this research that would have benefited the process if it was carried out earlier. An understanding of the workability of the timber was not fully formed until the "refined iteration" stage of the research. This would have helped refine the design scope as physical factors such as brittleness became a primary driver of profile design. For this reason, it is the finding of the research that some amount of material should be sourced and used in physical design experiments before refined iteration to limit unnecessary iteration and streamline the process.

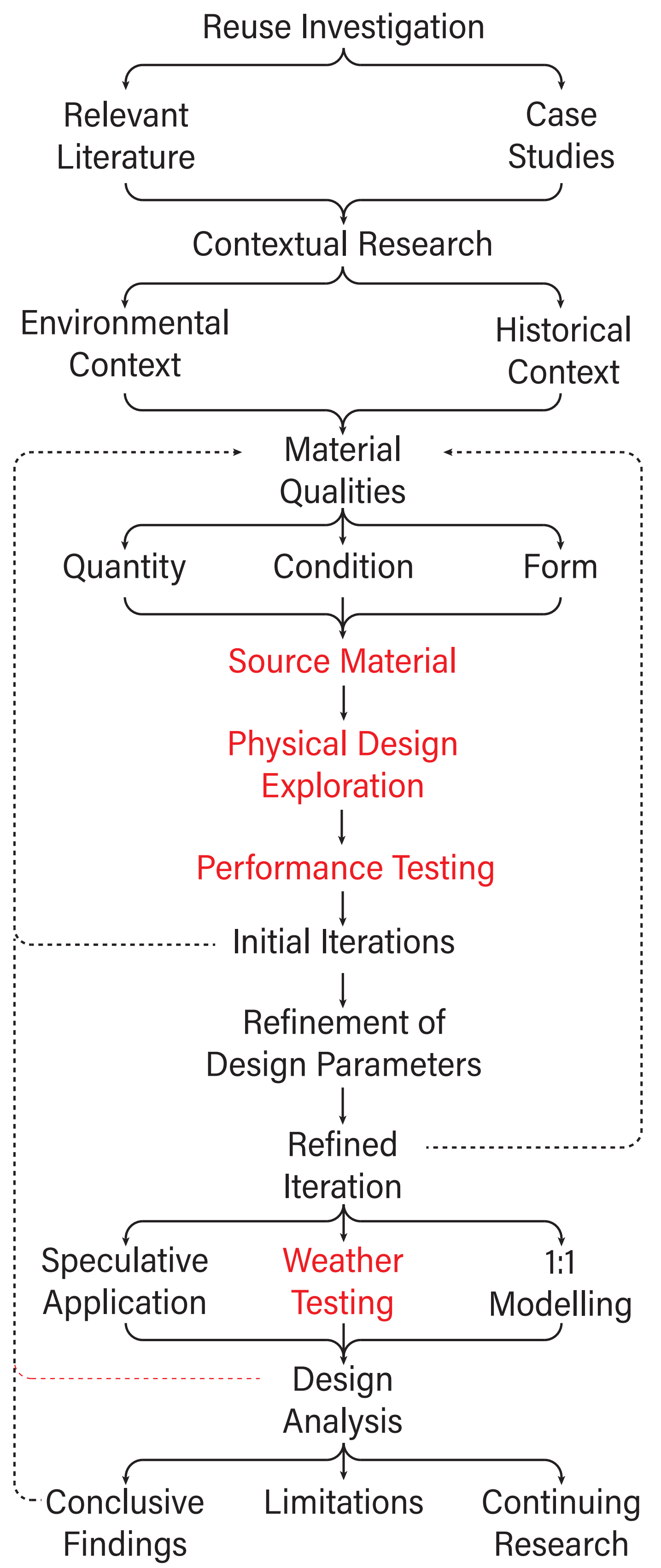


Fig 8.06 Reconsidered reuse process - Red text and finding contributions representative of additional research

8.2 Conclusive Findings

This research aimed to investigate how architectural design solutions can facilitate the reuse of native timber. This resulted in a series of explorations of sustainable architectural alternatives through material preservation in the built environment.

An understanding of general material reuse was formed through the investigation of relevant literature and case studies concerning the application of circular principles in architecture. This highlighted the significance of heritage preservation material reuse. These investigations also informed a deeper understanding of the wider life-cycle of circular systems and how design solutions can contribute to this process.

The design outcomes of this research have been led by an understanding of both the physical and contextual qualities of native timber. Research into the historical and present-day context of native timber in the built environment informed refined design solutions that facilitated a more considered cycle of reuse. An exploration of state housing in Aotearoa as a scope for the reuse of native timber allowed a more specific investigation of the material's presence in the built environment. Rather than consider the entirety of native timber use in Aotearoa's built environment, the consideration of state housing as a material source allowed design iterations to draw on a standardised set of timber elements. Additionally, using timber from state houses as a design basis facilitated the investigation of a closed-cycle system through which reuse could potentially occur.

The introduction of 1:1 modelling using reused native timber elements allowed a more comprehensive understanding of how design can respond to the qualities of reused native timber. Additionally, the use of models as a means of iterative testing informed the use of vernacular craft to effectively design with native timber and facilitate circularity. The iterative reuse process through making suggests the advantages of simultaneous physical and contextual-based investigations as a means of refining the design scope. The creation of a prototype allowed further refinement of the design and developed a more comprehensive understanding of the assembly process.

This research has formed conclusions on the implementation of reuse-based design through a speculative application. This involved investigations of how the proposed cladding system may be applied in the construction process and how it would interact with the building envelope. Initial iterations used only native timber without the incorporation of any introduced components as a means of designing using only reused material, which risked reducing the continued preservation of the material. Several compromises were introduced to create a system that allows greater overall reuse. The introduction of metal brackets and flashing has facilitated the design of a system with greater potential for overall material longevity. Additionally, the introduction of a selection of machined parts allowed larger overall elements that were less specific to the cladding system. This reduction of potential reuse for some specific elements to increase the variation of the potential reuse of a majority of others is an important compromise in the design of reuse-based architectural systems.

8.2.1 Limitations and Opportunities

Design investigations in this research were primarily concerned with the qualities of native timber post-deconstruction and provided conclusions on the effect these qualities have on the design process. If these investigations were to be carried out with physical explorations of the deconstruction process, a more comprehensive understanding of the total life-cycle of native timber could have been obtained. The timber used in this project was sourced from the Wellington Tip Shop, various timber recyclers, and several renovations. While all profiles of timber sourced were consistent with that standard in state housing, an in-depth investigation of the deconstruction process would likely have brought to light significant additional factors in the reuse process that could have informed design outcomes. Investigation of the reuse of native timber from state housing from deconstruction to reapplication could create a more refined understanding of the process of circularity in the built environment.

This investigation of the wider life cycle of circular design could also encompass potential applications of design outcomes post-use as a cladding system. The reapplication of elements of timber used in physical prototypes in a variety of contexts could provide a better understanding of the extent of design circularity. As potential reuse for the current system encompasses a wide range of design possibilities, a focused investigation into specific applications would likely achieve the most conclusive outcomes.

While solely exterior cladding was explored as a means of limiting design scope and undertaking an in-depth iterative process, the interior application of reused native timber as a means of creating a two-part architectural system could potentially facilitate more complete reuse. A dual system could allow timber to be divided and allocated to where it would be most suitably applied. The simultaneous design iteration of both exterior cladding and interior lining systems would allow the development of a design that most efficiently uses native timber, ensuring that wastage is minimised.

A focus on contextual research and iterative design through the making process meant that while treatment and performance were considered as part of the broader material context, performance testing was not factored into the scope of this research. Continued prototyping of design iterations could allow for weather testing and an investigation into the ways exterior application affects native timbers over time. This process could also involve the assembly of the system against a mock building envelope to further test the application. Additionally, thermal modification has presented itself as a potentially viable solution for native timber treatment. Access to a kiln or a small-scale replication method could facilitate testing the effects of thermal modification on reused native timber. If future research were to undertake this testing, the potential findings could support the resolution and implementation of cladding systems that facilitate the reuse of native timber.

8.3 Bibiliography:

A.J. Vieira, F.P. Beserra, M.C. Souza, B.M. Totti, A.L. Rozza. *Limonene: Aroma of innovation in health and disease*. Chemico-Biological Interactions, Volume 283, 2018, Pages 97-106, ISSN 0009-2797. Ireland: Elsevier B.V. https://doi.org/10.1016/j.cbi.2018.02.007

Abodo. (2018). *Vulcan Panelling*. Technical data sheet; no. 43. NZ: Abodo Wood. https://productspec.co.nz/media/rk1mmsuh/technical-data-sheet-vulcan-panelling.pdf

Abodo. (2022). *Timber: What is Thermally Modified Wood*. NZ: Abodo Wood. https://www.abodo.co.nz/resources/articles/what-is-thermally-modified-wood

Addis, B. (2006). *Building with reclaimed components and materials: A design handbook for reuse and recycling*. Bodmin: Mpg Books Ltd.

Arnott, J., McIntyre, K., Galloway, M., & Frederick, G. W. (2014). *Whole house reuse: deconstruction*. 1st ed. Christchurch: Rekindle.

Arquitectura Viva. (2018). *History Museum in Ningbo - Amateur Architecture Studio*. Arquitectura Viva. https://arquitecturaviva.com/works/history-museum-in-ningbo

Baroncini, E. A, Kumar Yadav, S., Palmese, G. R., Stanzione, J. F. (2016). *Recent advances in bio-based epoxy resins and bio-based epoxy curing agents*. J. Appl. Polym. Sci., 133, 44103. https://doi.org/10.1002/app.44103

Black, R., McDonald, H., Ten Broeke, J., Hardie, G. (2006). *Timber cladding: good practice guide*. 2nd ed. Porirua: BRANZ.

Boyce, S. A., Simon, A. (2010). *Only the houses remain: the demise of the state housing scheme in New Zealand*. Paraparaumu Beach: Wayside Press.

BRANZ. (2013). *Guideline: September 2013*. BRANZ. https://d39d3mj7qio96p.cloudfront.net/media/documents/BRANZ_Guideline_Sep_2013.pdf

Brischke, C. (2019). *5: Timber in Woodhead Publishing Series in Civil and Structural Engineering, Long-term Performance and Durability of Masonry Structures*. Pages 129-168. Woodhead Publishing. https://www.sciencedirect.com/science/article/pii/B9780081021101000054

Brown, D. (Deidre S. (2009). *Maori Architecture: from fale to wharenui and beyond*. Auckland: Raupo.

Buchanan, A. H. (2007). *Timber design guide*. Wellington: New Zealand Timber Industry Federation.

Chard, J., Basson, L., Creech, G., Jesson, D., Smith, P. (2019). *Shades of Green: Life Cycle Assessment of a Urethane Methacrylate/Unsaturated Polyester Resin System for Composite Materials*. 11(4), 1001. Basel: MDPI AG. https://doi.org/10.3390/su11041001

Chau, H. (2015). *The Aesthetics of Reuse: The Materiality and Vernacular Traditions of Wang Shu's Architecture*. Unmaking Waste 2015 conference proceedings. Adelaide, SA: Zero Waste SA Research Centre for Sustainable Design and Behaviour. https://www.researchgate.net/publication/325280543_The_Aesthetics_of_Reuse_The_Materiality_and_Vernacular_Traditions_of_Wang_Shu%27s_Architecture

Clifton, N. C. (1990). *New Zealand timbers*. Wellington: GP Books.

Cooney, R. (2010). *Leaky Building Challenges in Build 119: Weathertightness*. BRANZ. https://www.buildmagazine.org.nz/assets/PDF/BUILD119-42-Leaky-Building-Challenges.pdf

Dirksen, K. (2017). *Dan Phillips turns backyard scraps into whimsical Texan houses*. (Video). YouTube. https://www.youtube.com/watch?v=hNII1K0SZdw

Elkink, A. (2011). *Renovate: 1940-1960s*. BRANZ. https://www.renovate.org.nz/1940-60s/

Estudio Belderrain. (2006). *Aizkibel Library Extension*. Arch Daily. https://www.archdaily.com/773726/enlargement-of-aizkibel-library-estudio-beldarrain -

Finch, G. (2018) *Defab: Architecture for a Circular Economy*. (Master's Thesis). Victoria University, Wellington. https://doi.org/10.26686/wgtn.17135558.v1

Forbes, N. (2018). *The structural reuse of Pinus Radiata in New Zealand*. (Master's thesis). Wellington: Victoria University. https://doi.org/10.26686/wgtn.17131817.v1

Gately, J. (2014). *Domestic Architecture*. Te Ara - the Encyclopaedia of New Zealand. https://teara.govt.nz/en/domestic-architecture

Gorgolewski, M. (2017). *Resource salvation: the architecture of reuse*. 1st ed. Newark: Wiley-Blackwell.
Hadrup, N., Frederiksen, M., Sharma, A. K. (2021). Toxicity of boric acid, borax and other boron containing compounds: A review. Regulatory Toxicology and Pharmacology, 121, 104873. Netherlands: Elsevier Inc. https://doi.org/10.1016/j.yrtph.2021.104873

Hill, C., Kymäläinen, M., Rautkari, L. (2022). *Review of the use of solid wood as an external cladding material in the built environment*. Journal of Materials Science, 57(20), 9031–9076. https://doi.org/10.1007/s10853-022-07211-x

Hinte, E. van, Peeren, C., Jongert, J. (2007). *Superuse: constructing new architecture by shortcutting material flows*. Rotterdam: 010 Publishers.

Hosking, G. (1978). *Anobium punctatum (De Geer), (Coleoptera: Anobiidae): House borer.* Forest and timber insects in New Zealand; no. 32. Rotorua: Forest Research Institute, New Zealand Forest Service. https://www.nzffa.org.nz/farm-forestry-model/the-essentials/forest-health-pests-and-diseases/Pests/Anobium-punctatum/household-borer-anobium-punctatum/

Howlett, S. (2019). *Wasted Opportunities: A Model for the Sustainable Recalibration of Suburbia*. (Master's Thesis). University of Auckland. http://hdl.handle.net/2292/52666

Isaacs, N. (2015). *Making the New Zealand House 1792 – 1982*. (PHD). Victoria University, Wellington. http://hdl.handle.net/10063/4804

Jacobs, J. (1969). *The economy of cities*. New York: Random House.

Janesch, J., Arminger, B., Gindl-Altmutter, W., Hansmann, C. (2020). *Superhydrophobic coatings on wood made of plant oil and natural wax*. Progress in Organic Coatings, 148, 105891. https://doi.org/10.1016/j.porgcoat.2020.105891

Jones, D., Brischke, C. (2017). *Performance of bio-based building materials*. Duxford: Woodhead Publishing, an imprint of Elsevier. https://doi.org/10.1016/C2015-0-04364-7

JSC Timber. (2020). *Thermally Modified Timber: An Innovative and Exceptional Quality Timber Solution*. JSC Timber. https://www.jsctimber.co.nz/thermally-modified-timber/x_sku/01495.html

Kainga Ora. (2021). *Reduce emissions and change and industry at the same time: Kainga Ora shows what's possible*. Wellington: Kainga Ora. https://environment.govt.nz/what-you-can-do/stories/reduce-emissions-and-change-an-industry-at-the-same-time-kainga-ora-shows-whats-possible/

Kainga Ora. (2022). *What we're building*. Wellington: Kainga Ora. https://kaingaora.govt.nz/developments-and-programmes/what-were-building/

Kaingaroa Timberlands. (2022). *Kaingaroa is a Major Supplier of Logs*. Rotorua: Kaingaroa Timberlands. https://www.kaingaroatimberlands.co.nz/kaingaroa_forest

Kelly, R. (2021). *Number of state houses sold or demolished*. Wellington: Kainga Ora. https://kaingaora.govt.nz/assets/Publications/OIAs-Official-Information-Requests/July-2021/6-July-2021-Number-of-state-houses-sold-and-demolished.pdf

Krieger, J, Rooyen, K, Dirkx, L, Feder, F. (2021). *Harvest! Collect! Reuse!: The New Building Site*. Superuse Studios. https://www.superuse-studios.com/publication/harvest-collect-re-use/

Kubojima, Y. (2000). *Bending strength and toughness of heat-treated wood*. Journal of Wood Science, 46(1), 8–15. https://doi.org/10.1007/BF00779547

Lee, P. M, Matta-Clark, G. (1999). *Object to be destroyed: the work of Gordon Matta-Clark*. Cambridge: MIT Press.

Maxineasa, S. G., Taranu, N., Lupasteanu, V., Dupir, I. (2015). *Environmental Impact Of Fibre Reinforced Polymers' Constituent Materials*. 15th International Scientific Conference Vsu'2015. Iasi: Technical University of Iasi. https://doi.org/10.3390/ma14081885

MBIE (2021). *Building and construction sector trends annual report 2021*. Wellington: MBIE. https://www.mbie.govt.nz/dmsdocument/16973-building-and-construction-sector-trends-annual-report-2021-pdf

McDonough, W, Braungart, M. (2002). *Cradle to Cradle: Remaking the Way We Make Things*. 1st ed. New York: North Point Press.

McGlone, M, Bellingham, P, Richardson, S. J. (2022). *Science, policy, and sustainable indigenous forestry in New Zealand*. New Zealand Journal of Forestry Science, 52(8). Rotorua: SCION. https://doi.org/10.33494/nzjfs522022x182x

Morais, S., Fonseca, H. M. A. C., Oliveira, S. M. R., Oliveira, H., Gupta, V. K., Sharma, B., de Lourdes Pereira, M. (2021). *Environmental and Health Hazards of Chromated Copper Arsenate-Treated Wood: A Review*. International Journal of Environmental Research and Public Health, 18(11), 5518. Basel: MDPI AG. https://doi.org/10.3390/ijerph18115518

Nathan, S. (2007). *Conservation: A History*. Te Ara - the Encyclopaedia of New Zealand. http://www.TeAra.govt.nz/en/conservation-a-history/page-8

O'Donnell, C., & Pranger, D. (2020). *The Architecture of Waste: Design for a Circular Economy*. Milton: Taylor and Francis. https://doi.org/10.4324/9780367247478

Olley, S. (2022). *Material shortage creating 'perfect storm' for building company failure*. New Zealand: RNZ. https://www.rnz.co.nz/news/national/469617/material-shortage-creating-perfect-storm-for-building-company-failure

Payn, T. (2020) *Planted forests and carbon*. Brochure. New Zealand: SCION. https://www.nzfoa.org.nz/resources/file-libraries-resources/environment/factsheets/847-planted-forests-and-carbon/file

Petrovic, E. K., Vale, B., Zari, M. P. (2017). *Materials for a Healthy, Ecological and Sustainable Built Environment: Principles for Evaluation*. Cambridge: Elsevier Science & Technology. https://ebookcentral.proquest.com/lib/vuw/detail.action?docID=4829904

Phillips, D. (2010). *Creative houses from reclaimed stuff* (video). TED Conferences. https://www.ted.com/talks/dan_phillips_creative_houses_from_reclaimed_stuff?language=en

Pinniger, D. (2003). *Saving our treasures - controlling museum pests with temperature extremes*. Pesticide Outlook, 14(1), 10-11. https://doi.org/10.1039/b300660m

Pringle, T. (2011). *Building Basic: Weathertightness*. BRANZ. https://www.weathertight.org.nz/new-buildings/timber-treatment/

Pye, G., Schroth, S. (2010). *Trash culture objects and obsolescence in cultural perspective*. Oxford, New York: Peter Lang.

Red Stag Timber. (2022). *Timber Brief 2: The Effects of Moisture in Timber*. Rotorua: Red Stag https://www.redstagtimber.co.nz/files/2315/3989/8642/Timber_Brief_2_Moisture_in_Timber.pdf

Reinprecht, L. (2016). *Wood Deterioration, Protection and Maintenance*. Hoboken: John Wiley & Sons, Incorporated. https://ebookcentral.proquest.com/lib/vuw/reader.action?docID=4615151&ppg=1

Ridout, B. (1999). *Timber decay in buildings: the conservation approach to treatment*. London: E & FN Spon. https://www.building.govt.nz/assets/Uploads/building-code-compliance/e-moisture/e2-external-moisture/guide-timber-in-leaky-buildings.pdf

Rowe, P. G. (1987). *Design thinking*. Camebridge: MIT Press.

Sandberg, D., Kutnar, A., Karlsson, O., Jones, D. (2021). *Wood Modification Technologies: Principles, Sustainability, and the Need for Innovation*. Milton: Taylor & Francis Group. https://ebookcentral.proquest.com/lib/vuw/reader.action?docID=6541272&ppg=207

Saxena, G., Kumar, V., Shah, M. P. (2021). *Bioremediation for environmental sustainability: toxicity, mechanisms of contaminants degradation, detoxification and challenges*. Amsterdam: Elsevier. https://doi.org/10.1016/C2019-0-01053-9

Schrader, B., Birkinshaw, V. (2005). *We call it home: a history of state housing in New Zealand*. Auckland: Reed Pub.

Smarter Homes. (2017). *Smart Guide: Other Types of Construction*. Wellington: Ministry of Business, Innovation, and Employment. https://www.smarterhomes.org.nz/smart-guides/construction-and-materials/other-types-of-construction/

Standards New Zealand. (2012). *Dealing with Timber in leaky Buildings: A guide for Builders and Building Professionals*. Wellington: Department of Building and Housing.

Standards New Zealand. (2020). *E2 External Moisture*. 3rd ed. Wellington: Ministry of Business, Innovation, and Employment.

Statistics New Zealand. *A century of censuses: dwellings and households*. Wellington: Statistics New Zealand. https://www.stats.govt.nz/reports/a-century-of-censuses-dwellings-and-households/

Swarbrick, N. (2007). *Logging Native Forests*. Te Ara - the Encyclopaedia of New Zealand. http://www.TeAra.govt.nz/en/logging-native-forests

Teaca, C.-A., Rosu, D., Mustata, F., Rusu, T., Rosu, L., Rosca, I., Varganici, C.D. (2019). *Natural bio-based products for wood coating and protection against degradation: A Review*. Bioresources, 14(2), 4873–4901. https://doi.org/10.15376/biores.14.2.Teaca

Terry, J. S., Taylor, A. C. (2021). *The properties and suitability of commercial bio-based epoxies for use in fiber-reinforced composites*. Journal of Applied Polymer Science, 138(20), 50417. Hoboken: John Wiley & Sons, Inc. https://doi.org/10.1002/app.50417

The Forests Act 1949. (2021). *Indigenous Forests on Private Land*. Ministry for Primary Industries. https://www.mpi.govt.nz/dmsdocument/46-Indigenous-Forestry-on-Private-Land-Sustainable-indigenous-forest-management-in-accordance-with-Part-3A-of-the-Forests-Act-1949

Tunnicliffe Timber. (2018). *Thermally Modified Timber (TMT)*. Tunnicliffe Timber Solutions Ltd. https://www.tunnicliffes.co.nz/our-solutions/thermally-modified-timber

Vandkunsten Architects. (2017). *Rebeauty: Nordic Built Component Reuse*. Vallensbæk: Knudtzon Graphic. https://vandkunsten.com/en/news/rebeauty-new-report

Venkatesh, G., Hammervold, J., Brattebø, H. (2009). *Combined MFA-LCA for Analysis of Wastewater Pipeline Networks: Case Study of Oslo, Norway*. Journal of Industrial Ecology, 13(4), 532–550. New Haven: Wiley Subscription Services, inc. https://doi.org/10.1111/j.1530-9290.2009.00143.x

Visser, S. (2016). *Timber Harvesting in New Zealand: A guide for Small Scale Forest Landowners*. New Zealand: NZFFA. https://www.nzffa.org.nz/farm-forestry-model/the-essentials/roads-earthworks-and-harvesting/reports/timber-harvesting-in-new-zealand/

Welzbacher, C.R., Brischke, C., Rapp, A.O., Koch, S., Hofer, S. (2009). *Performance of thermally modified timber (TMT) in outdoor application – durability, abrasion and optical appearance*. Zagreb: Drvna Industrija, 60(2), 75–82. https://tewaharoa.victoria.ac.nz/permalink/64VUW_INST/1m9iv9v/cdi_doaj_primary_oai_doaj_org_article_9e335b8c8d4a40bebce2ed2cdb5e8cb8

Wöhler, T. (2010). *NINGBO MUSEUM*. London: The Architectural Review, 227(1357), 56-63. https://go.openathens.net/redirector/wgtn.ac.nz?url=https://www.proquest.com/trade-journals/ningbo-museum/docview/201216033/se-2

World Steel Association. (2021). *Climate Change and the Production of iron and Steel*. Public policy paper. Brussels: World Steel Association. https://worldsteel.org/wp-content/uploads/Climate-policy-paper-2021.pdf

Wypych, G. (2019). *Handbook of solvents: Volume 2*, Use, health, and environment. 3rd Ed. Toronto: ChemTec Publishing. https://tewaharoa.victoria.ac.nz/permalink/64VUW_INST/1ol91ac/alma99179573296202386

Zumthor, P., Bachmann, P., Hönig, R. (2000). *Swiss Sound Box: a handbook for the pavilion of the Swiss Confederation at Expo 2000 in Hanover*. Basel: Birkhäuser.

8.4 Figure List:

Unless stated below, all images are the author's own. Images that have been reproduced by the author have been stated.

Fig 1.00 – Ministry for the Environment. (2020). *Waste Composition Data of Class 1 Landfills*. [Graph]. Data: Eunomia (2020) Improvements to estimates of greenhouse gas emissions from Landfills. (Author's reproduction). https://environment.govt.nz/facts-and-science/waste/estimates-of-waste-generated/

Fig 1.01 – Stats NZ. (2020). *New Homes Consented, Selected Regions, Rolling Annual, March 1991-November 2019*. [Graph]. Statistics New Zealand. https://www.stats.govt.nz/news/45-year-high-for-new-home-consents

Fig 2.02 – Vandkunsten Architects. (2017). *Steel prototype from Rebeauty: Nordic Built Component Reuse*. [Photo]. Vallensbæk: Knudtzon Graphic. https://vandkunsten.com/en/news/rebeauty-new-report.

Fig 2.03 – Vandkunsten Architects. (2017). P*antile façade prototype from Rebeauty: Nordic Built Component Reuse*. [Photo]. Vallensbæk: Knudtzon Graphic. https://vandkunsten.com/en/news/rebeauty-new-report.

Fig 2.04 – Vandkunsten Architects. (2017). *Folded Metal Shingle. from Rebeauty: Nordic Built Component Reuse*. [Photo]. Vallensbæk: Knudtzon Graphic. https://vandkunsten.com/en/news/rebeauty-new-report.

Fig 2.05 – Vandkunsten Architects. (2017). *New Nordic wall from Rebeauty: Nordic Built Component Reuse*. [Photo]. Vallensbæk: Knudtzon Graphic. https://vandkunsten.com/en/news/rebeauty-new-report.

Fig 2.06 - Vandkunsten Architects. (2017). *Steel prototype from Rebeauty: Nordic Built Component Reuse*. (Author's reproduction). https://vandkunsten.com/en/news/rebeauty-new-report.

Fig 2.07 – Cazenave, J. (2006). *Aizkibel Library Extension: Estudio Belderrain*. [Photo]. https://www.archdaily.com/773726/enlargement-of-aizkibel-library-estudio-beldarrain

Fig 2.08 – Cazenave, J. (2006). *Aizkibel Library Extension: Estudio Belderrain*. [Photo]. https://www.archdaily.com/773726/enlargement-of-aizkibel-library-estudio-beldarrain

Fig 2.09 – Estudio Belderrain. (2006). [Section of Aizkibel Library extension façade]. https://www.archdaily.com/773726/enlargement-of-aizkibel-library-estudio-beldarrain

Fig 2.10 – Phoenix Commotion. (n.d.). [Photo of Tree House exterior]. http://www.phoenixcommotion.com/portfolio-item/tree-house/

Fig 2.11 – Stravato, M. (2009). *Whimsy.* [Photo]. https://www.nytimes.com/2009/09/03/garden/03recycle.html

Fig 2.12 – Stravato, M. (2009). *Cycles*. [Photo]. https://www.nytimes.com/2009/09/03/garden/03recycle.html

Fig 2.13 – Baan, I. (2009) *Ningbo Historic Museum 4278*. [Photo]. https://iwan.com/portfolio/wang-shu-ningbo-historic-museum/

Fig 2.14 – Baan, I. (2009) *Ningbo Historic Museum 4405*. [Photo]. https://iwan.com/portfolio/wang-shu-ningbo-historic-museum/

Fig 2.15 – Baan, I. (2009) *Ningbo Historic Museum 4200*. [Photo]. https://iwan.com/portfolio/wang-shu-ningbo-historic-museum/

Fig 2.16 – Shu, W. [Ningbo Historic Museum Façade composition]. (Author's reproduction). https://www.proquest.com/docview/201216033?parentSessionId=ea%2FmGnOudo1Ax1llSMiIHq0R7babwbkcic%2BTrjtw5DI%3D

Fig 3.01 – McGlone, M, Bellingham, P, Richardson, S. J. (2022) *Volumes of rough sawn timber extracted from indigenous forests in New Zealand, 1928-2000*. [Graph]. https://doi.org/10.33494/nzjfs522022x182x

Fig 3.02 – Te Ara. (2007). *Protesters from the Ecology Action Group 1972*. [Photo]. http://www.TeAra.govt.nz/en/conservation-a-history/page-8

Fig 3.03 – Te Ara. (2007). *Delivering the Maruia Declaration*. [Photo]. https://teara.govt.nz/en/photograph/12763/delivering-the-maruia-declaration

Fig 3.04 – Kelly, R. (2021). [Number of state houses demolished]. (Author's reproduction). https://kaingaora.govt.nz/assets/Publications/OIAs-Official-Information-Requests/July-2021/6-July-2021-Number-of-state-houses-sold-and-demolished.pdf

Fig 3.05 – Google. (2019). *Canal Road, Avondale.* [Photo]. https://www.google.com/maps

Fig 3.06 – Kainga Ora. (2021). *Canal Road: View after development completed*. [Photo]. https://kaingaora.govt.nz/developments-and-programmes/what-were-building/public-housing-developments/auckland-region/canal-road/

Fig 3.07 – Google. (2017). *Segar Avenue, Mount Albert*. [Photo]. https://www.google.com/maps

Fig 3.08 – Kainga Ora. (2019). *Segar Avenue: View after development completed*. [Photo]. https://kaingaora.govt.nz/developments-and-programmes/what-were-building/public-housing-developments/auckland-region/segar-avenue/

Fig 3.10 – Archives New Zealand. (1940). *State house prefabrication*. [Photo]. ABVF 7484 W4925.

Fig 3.11 – Archives New Zealand. (1940). *State house construction*. [Photo]. ABVF 7484 W4925.

Fig 3.12 – Archives New Zealand. (1940). *State house construction*. [Photo]. ABVF 7484 W4925.

Fig 3.13 – Archives New Zealand. (1940). *State house prefabrication*. [Photo]. ABVF 7484 W4925.

Fig 3.26 – Abodo. (2022). *What is thermally modified wood*. [Diagram]. (Author's reproduction). https://www.abodo.co.nz/resources/articles/what-is-thermally-modified-wood

Fig 4.15 – Zumthor, P., Bachmann, P., Hönig, R. (2000). *Swiss Sound Box: a handbook for the pavilion of the Swiss Confederation at Expo 2000 in Hanover*. Basel: Birkhäuser.

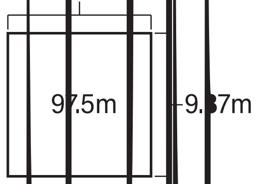
Fig 4.16 – Zumthor, P., Bachmann, P., Hönig, R. (2000). *Swiss Sound Box: a handbook for the pavilion of the Swiss Confederation at Expo 2000 in Hanover*. Basel: Birkhäuser.

8.5 Appendix

Working for timber quantities based on NZSS 95:

Floor plans of state houses of state houses between 9[illegible]-1[illegible]
Average of aproximately 4[illegible] of external walls if a roughly s[illegible] floorplan is assumed

$\sqrt{\frac{9[illegible]-1[illegible]}{2}}$ = 9.[illegible]7m

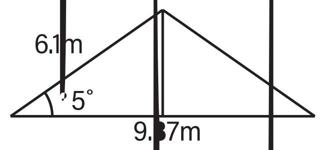


9.[illegible]7 x 4 = [illegible]9.4[illegible]

Studs spaced at 4[illegible]
[illegible]

Dwangs spaced at [illegible] dwangs per structural bank
[illegible] x 4[illegible]

Rafters spaced at 4[illegible] rafters per house
Average roof pitch [illegible]5˚



(6.1x2) x 2[illegible]

Ceiling and floor joists spaced at 5[illegible]
joists per house
2[illegible]

Floorboards assumed at 15[illegible]
9.[illegible]7 / [illegible] board across width of house
65.[illegible] x 9.[illegible]7 = 649.5m

Lengths rounded to nearest 1[illegible]

Timber Element	Dimensions of Profile	Estimated Length per House	Estimated Total from Demolition 2015-2021
Studs	100x50mm	270m	80,9730m
Dwangs	100x50mm	120m	35,9880m
Rafters	100x50mm	240m	719,760m
Ceiling Joists	100x50mm	200m	599,800m
Floor Joists	230x50mm	200m	599,800m
T&G Floor Boards	150x25mm	650m	1,949,350m

VICTORIA UNIVERSITY OF
WELLINGTON
TE HERENGA WAKA

Statement of Authorship
for MArch (Prof), MIA, MLA
Thesis 591 / Research Portfolio Document 593
(from 2020)

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