Shelter to Gather:
A Primitive Future for Resilient Cities in Post-earthquake Urban Environments

by

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CONTENTS

ABSTRACT

This thesis focuses on creating a strategic process for addressing the devastation of communities in the aftermath of earthquakes. In Christchurch, New Zealand the site of this thesis, buildings and infrastructure were destroyed, leaving people without homes, protection, or a sense of safety that are typically anchors of our communities. It investigates conditions of soil liquefaction and construction methods to create a layered strategy that incorporates material selection and the social/cultural needs to enable places of shelter and gathering through community empowerment, education and the knowledge of how, what, and where we rebuild.

By examining the definition of resilience, the thesis forms a set of constructional and spatial systems that facilitate program adaptations and structural redundancy. This rebuilding process is urban and potentially regional in scale, where local instances for architecture in the form of an educational center, relief/workers housing and fabrication workshops are created to help with initial rebuilding of affected areas and displaced persons.

ACKNOWLEDGEMENTS

I would like to thank my mother Vicky, Jessica and my family for all the support given and sacrifices made throughout my studies. I also dedicate this to Felix, Yiran, Ben and Warren who have helped make this thesis possible. Thank you to my peers who have shared so many experiences and who have helped along the way. Thank you to Diogo, Roger, and Cristina for providing me the opportunities to go see what the world has to offer. Special thanks go to my supervisor Catherine Venart for her guidance and support during my thesis work and throughout my time at the school.

CHAPTER 1: EARTHQUAKES: A GLOBAL DISASTER

Recent major high-magnitude earthquakes have brought into question the ability of cities to withstand high-magnitude earthquakes. In fact, 90% of earthquakes occur along the Pacific 'Ring of Fire', where a continuous series of oceanic trenches, volcanic arcs, and volcanic belts and/or plate movements occur (Figure. 1). The 2011 Tohoku earthquake in Japan occurred at a fair distance from Tokyo, where the Next Big One was predicted to hit. Likewise, the 2013 Bohol earthquake or the 2014 earthquake that hit Chile was determined not to be the Next Big One either. Meanwhile, the Cascadia region in North America has not experienced a major earthquake since approximately 1700; the Next Big One is imminent and is predicted to be a concentrated rupture reaching magnitude 9 or greater.

While there has been an established field of research in building technology in response to natural disasters, there is a need to address the real need for shelter, comfort, and security in these situations. It is an issue that must be addressed through architecture, where the challenge lies in creating an intervention that can mitigate the effects of earthquakes and provide a symbol of community resiliency and permanence.

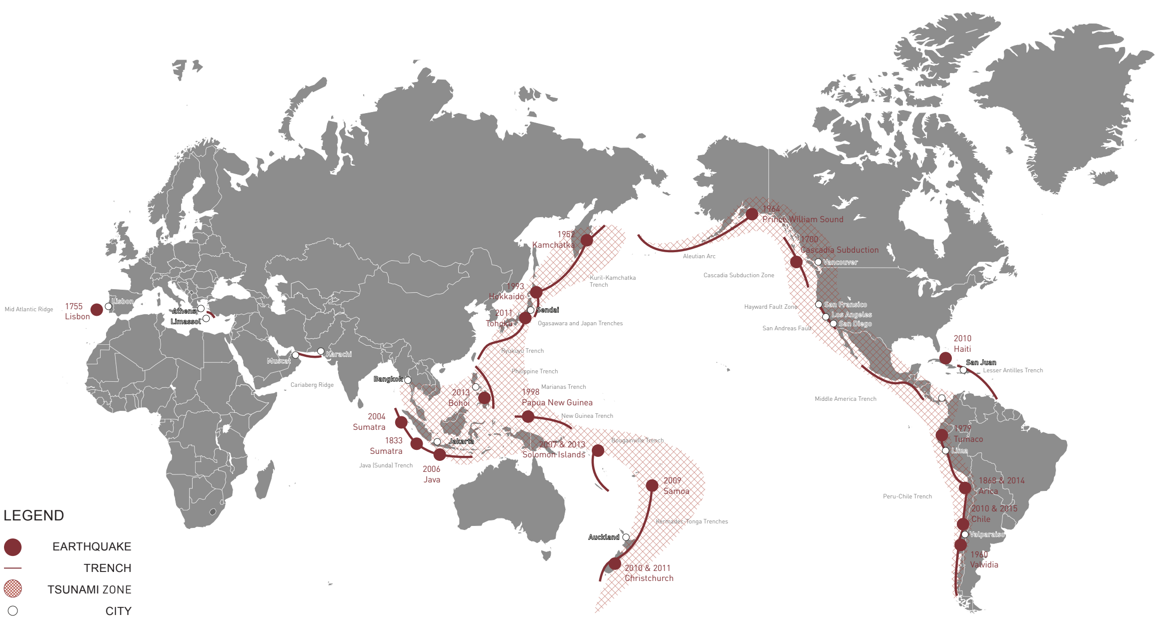

Figure 1. World map locating the 'Ring of Fire' and the recent occurrence of earthquakes and tsunamis, map of world, 2015; from Google Maps.

Christchurch has been perceived as one of the few cities immune from earthquakes in New Zealand. However, this perception changed after the 2010/ 2011 earthquakes as the city was greatly affected by soil liquefaction, bringing panic and confusion to its 375,000 residents. The thesis uses Christchurch as a case study to create a methodology for rebuilding cities that have been shaken by earthquakes and affected by soil liquefaction. The thesis is intended to develop a layered strategy that incorporates social/cultural needs to understand (knowledge), and simultaneously enabling places of safety for people to gather, be sheltered and have agency. It investigates soil liquefaction and how to rebuild. These rebuilding strategies take on the definition of resilience, by pairing the basic principles of shelter and gathering with a construction methodology of redundancy and adaptation. So, how can this definition of resiliency translate into an design strategy suitable for post-earthquake urban environments?

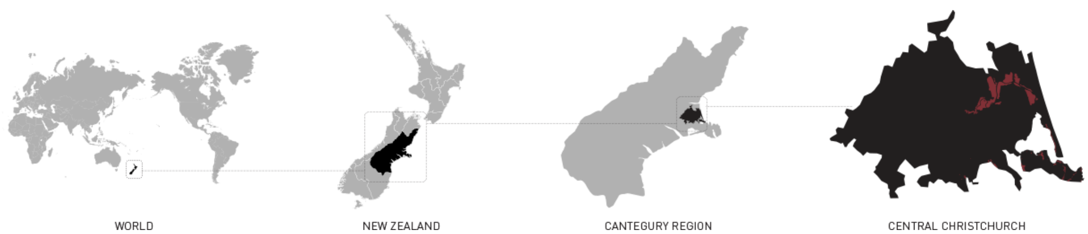

Figure 2. Central Christchurch (New Zealand) would serve as the site of exploration, map of New Zealand, 2015; from Google Maps.

CHAPTER 2: CHRISTCHURCH: A CITY'S HISTORY

Christchurch, known as the Garden City of New Zealand, has gone through drastic urban rebuilding efforts from the devastating earthquake in 2011. With the Otakaro River cutting through the center of the city, Christchurch is a city that is vulnerable to earthquakes and soil liquefaction due to its geological make up.

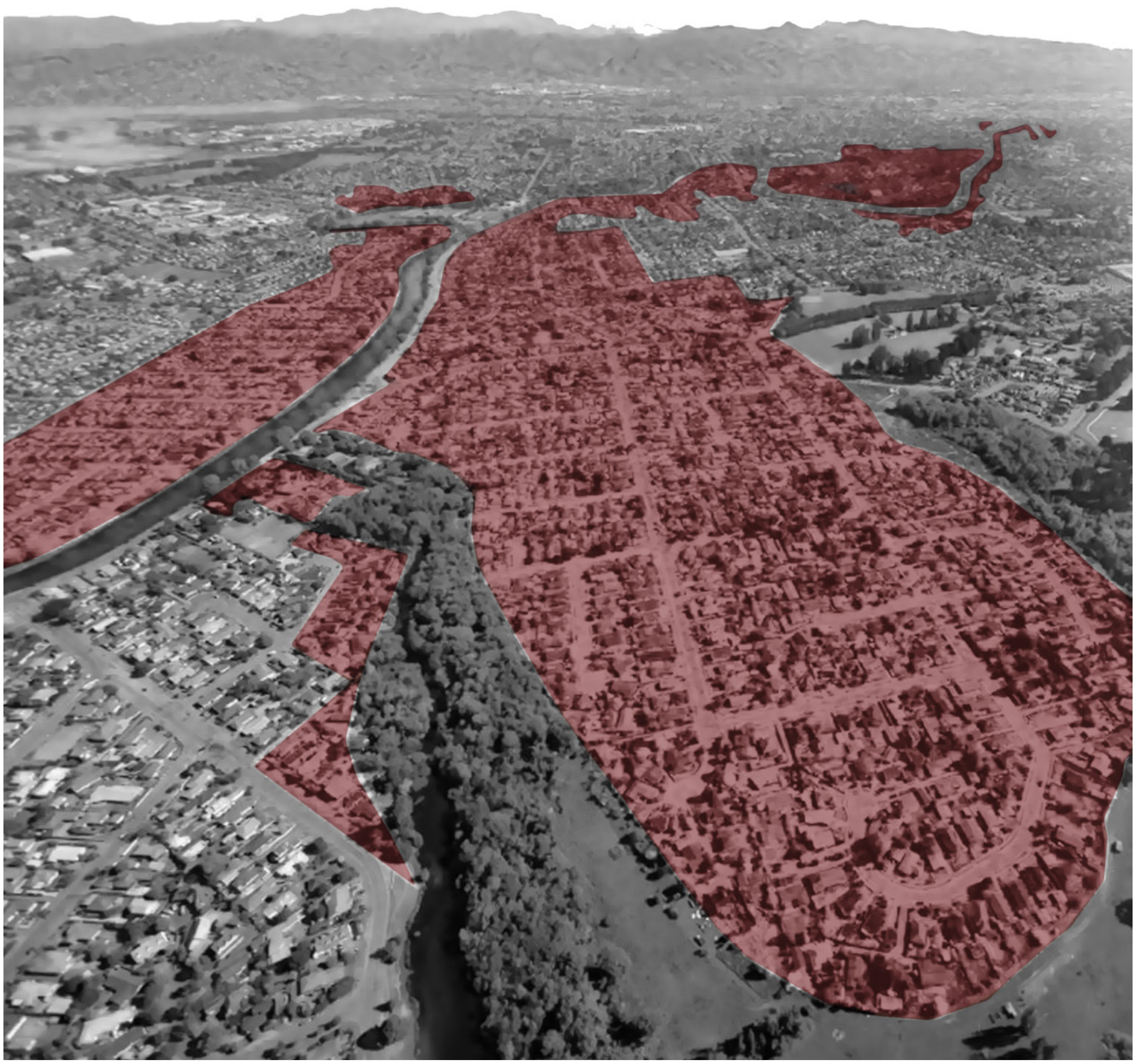

Figure 3. Aerial perspective revealing the most devastated areas in Christchurch, aerial photo of East Christchurch, 2012; from Christchurch City Libraries.

Geological Formation

In geological terms, Christchurch is built on land of very recent formation. Most of it sits on the seaward edge of a plain which slopes gradually from its inland edge, against the foothills of the Southern Alps, to the coast. The plain was formed by the out-wash from glaciers which were eroding the Southern Alps. One of Canterbury's major glacier-fed rivers, the Waimakariri, flows a short distance north of the city. At different times the site of Christchurch has been both far inland and below sea level. The sea last covered the site of Christchurch perhaps 7,000 years ago. Since then sea levels have fallen slightly and gravel and other sediments have accumulated against the northern side of the volcanic hills of what is now Banks Peninsula (Figure. 4).

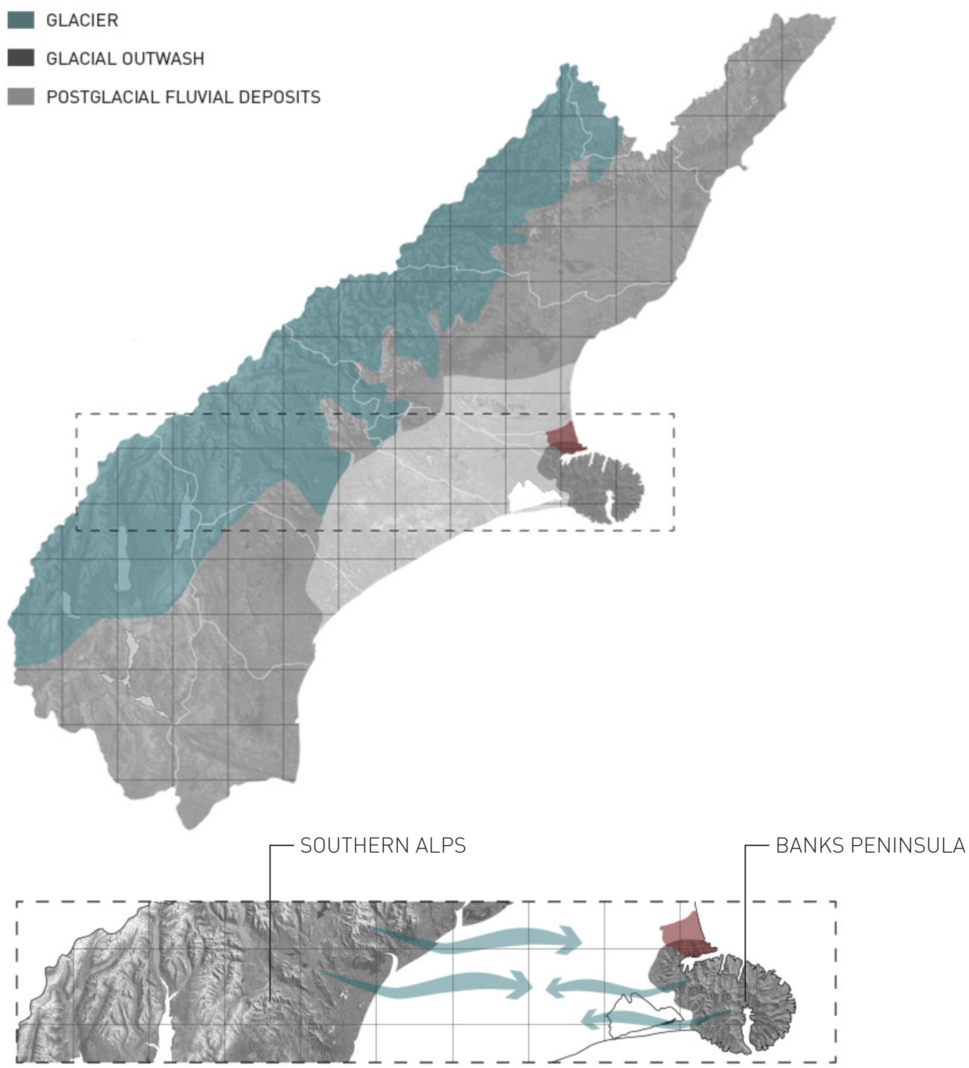

Figure 4. Canterbury region and geological formation of Christchurch, map of Canterbury Region, 2015; from Christchurch City Libraries.

The city is built on what was a mosaic of lobes of shingles deposited by the Waimakariri River, swamplands and waterways located south and east of these shingle lobes, and belts of sand hills running parallel to the coast. These geological features combine to create a water basin in eastern Christchurch that is extremely vulnerable to soil liquefaction (Figure 5).

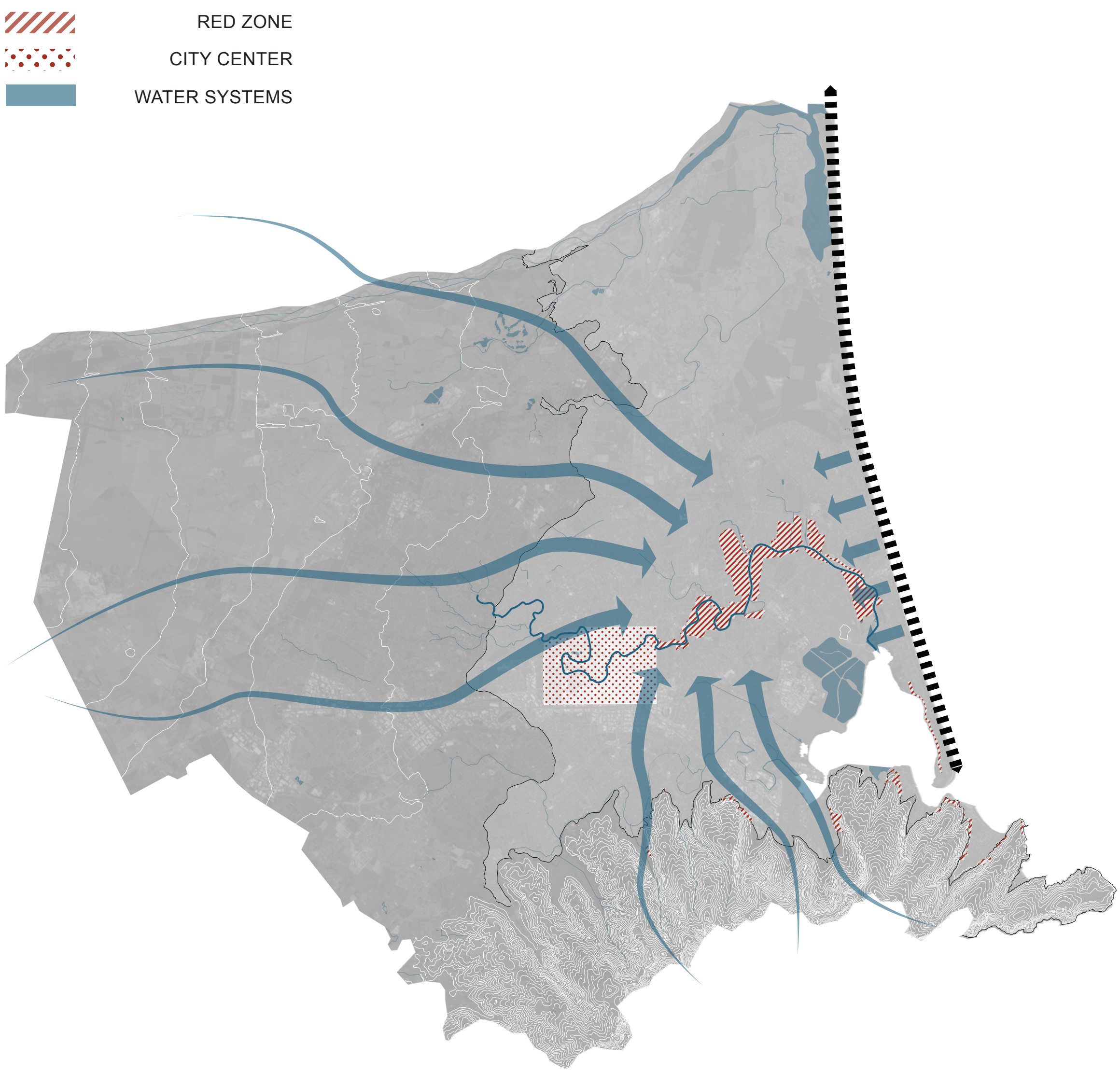

Figure 5. Geological Features of Christchurch creates a water basin that traps water within the city core, map of Christchurch City; data from Christchurch City Libraries.

City Development

The city of Christchurch today provides physical, relatively intact evidence of the practical and ideological concepts as a typical colonial settlement (Figure 6), using a British colonial plan overlaid on to the city center in the early 1800s. The city started expanding eastward towards the coast as well as inland into the city Christchurch is today.

Figure 6. Settlement of Christchurch in 1850 and city expansion to present day; data from Christchurch City Libraries.

The formal, geometric layout was typical of contemporary approaches to urban design for new towns. Streets were laid out on a grid broken by the course of the Avon River. Land was set aside between the northern, eastern and southern sides of the grid and the respective Town Belts for later expansion of the city. This geometric layout becomes a positive starting point for a rebuild, as the grid provides a matrix for setting up the clean up process in the early phases of the intervention.

A straggling village of small wooden buildings developed in 1851. The first buildings were cottages, houses, shops and hotels. There was, initially, no marked concentrations of buildings in particular areas. Gradually, shops and hotels became somewhat larger and concentrated in the few blocks that became the central city. Only churches were significantly larger than other buildings.

In the 1860s, Christchurch eventual made the transition from building in wood to brick and stone. The first substantial stone buildings which began to rise were all public buildings. While new buildings were erected in stone and masonry, the Gothic style was introduced for formal representation rather than seismic design.

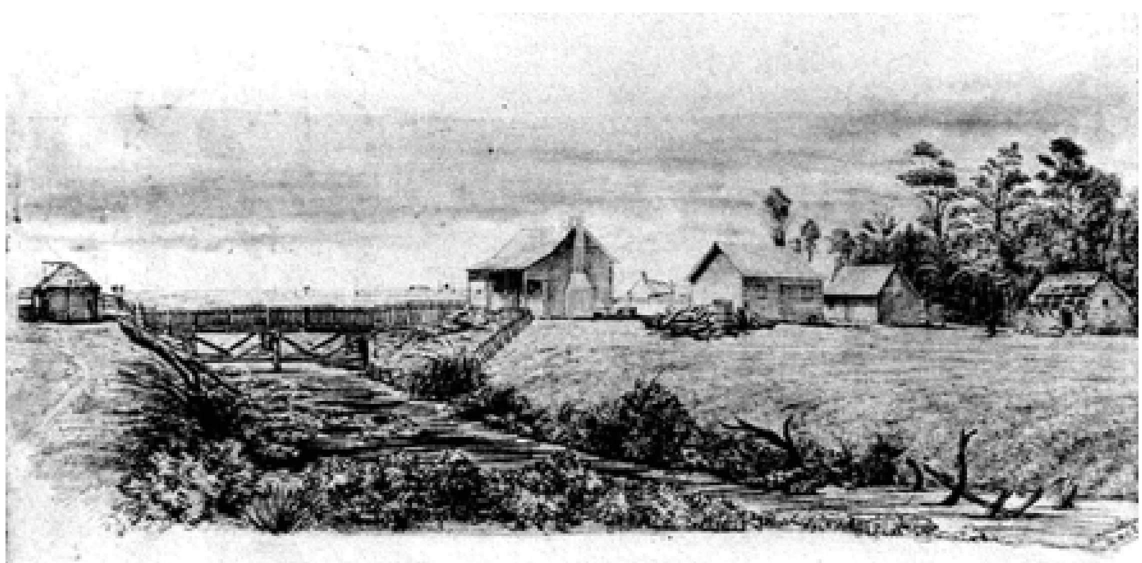

Figure 7. Wood buildings built during early settlement in Christchurch near the Avon River, 1810; from Christchurch City Libraries.

Figure 8. Christchurch became a city filled with masonry buildings, 1860; from Christchurch City Libraries.

The first of these modern high-rise buildings, the Government Life building on the Square, was belatedly introduced the glass curtain wall to Christchurch in the 1980s. However, these new buildings were not designed for seismic conditions, as Christchurch was seen as a city that would not be affected by earthquakes at the time.

After the 2010/2011 earthquakes, suburban communities near the eastern shore and along the river, which cuts through the city fabric, were most affected. As most residential buildings were built from masonry, many homes collapsed. With damage to buildings and infrastructure initially weakened by the magnitude 7.1 Canterbury earthquake of 4 September 2010 and its aftershocks, significant liquefaction affected the suburbs, producing around 400,000 tonnes of silt. The initial quake only lasted for approximately 10 seconds, the damage was severe because of the location and shallowness of the earthquake's epicentre in relation to Christchurch and previous quake damage. Subsequent population loss saw the Christchurch main urban area fall behind the Wellington equivalent to decrease from second to third most populous area in New Zealand.

From examining the historical development of Christchurch, we can see how imported building methods such as stone and masonry does not translate well in earthquake prone countries. In fact, the seismic events in Christchurch was a disaster waiting to

Figure 9. Christchurch city after the earthquakes in 2010/2011, 2011; from Christchurch City Libraries.

CHAPTER 3: SOILS, EARTHQUAKE ISSUES AND STRATEGIES

Earthquake hazards include any physical phenomenon associated with an earthquake that may produce adverse effects on human activities. While they are often used as synonyms, it is useful to distinguish between 'hazards' and 'risk'. According to Wang, hazards are the natural phenomena that might impact a region, regardless of whether there is anyone around to experience them or not.[1] On the other hand, risk refers to what we stand to lose when a hazard occurs. While risks can be usually be measured in dollars or fatalities, hazards can include ground shaking, tsunamis, soil liquefaction, and fire.

The main earthquake hazard is the effect of ground shaking. Shaking of the ground caused by the passage of seismic waves, especially surface waves near the epicentre of the earthquake are responsible for the most damage during an earthquake. The intensity of ground shaking depends on the conditions of the local geology make up, as solid bedrock is far less subject to intense shaking than loose sediment.[2]

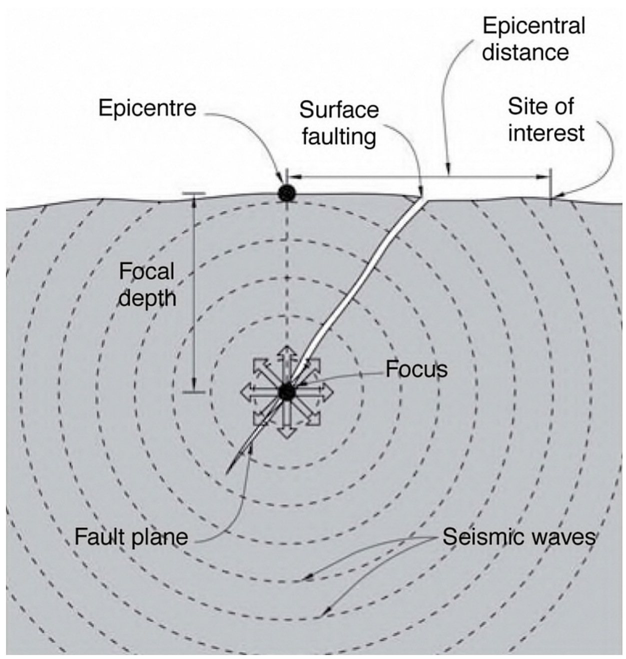

Figure 10. Andrew Charleson, Autonomy of an earthquake sequence, from Charleson, Seismic Design for Architects Outwitting the Quake.

1. Zhenming Wang, "Understanding Seismic Hazard and Risk Assessments: An Example in the New Madrid Seismic Zone of the Central United States" (Paper presented at the 8th U.S. National Conference on Earthquake Engineering. San Francisco, U.S.A. April 18-22 2006).
2. Eric Dickson et al, Urban Risk Assessments: An Approach for Understanding Disaster and Climate Risk in Cities (Washington, D.C: World Bank, 2012), 6-9.

The duration and intensity of the earthquake are subject generally to the size of the earthquake. As the distance from the epicentre drops off so the intensity of the shaking decreases. Buildings can be damaged by the shaking itself or by the ground beneath them settling to a different level than it was before the earthquake.

Soil Liquefaction

Liquefaction is the mixing of sand or soil and groundwater (water underground) during the shaking of a moderate or strong earthquake. When the water and soil are mixed, the ground becomes very soft and acts similar to quicksand. If liquefaction occurs under a building, it may start to lean, tip over, or sink several feet. The ground firms up again after the earthquake has past and the water has settled back down to its usual place deeper in the ground. It is a hazard in areas that have groundwater near the surface and sandy soil.[3]

Buildings can also be damaged by strong surface waves making the ground heave and lurch. Any buildings in the path of these surface waves can lean or tip over from all the movement. The ground shaking may also cause landslides, mudslides, and avalanches on steeper hills or mountains, all of which can damage buildings and hurt people.

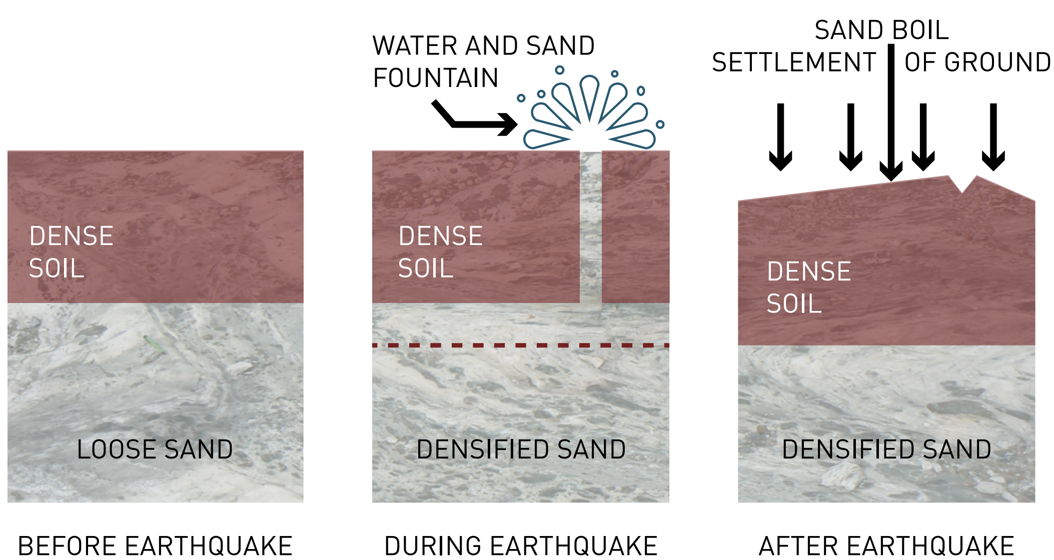

Figure 11. Effects of soil liquefaction during an earthquake sequence; data from Christchurch City Libraries.

3. M.L. Taylor, et al. "Characterisation of Ground Conditions in the Christchurch Central Business District," *Australian Geomechanics Vol 47 No 4 (2012)*, 43.

There are many natural factors that make Christchurch vulnerable to earthquakes and soil liquefaction. Located adjacent to the Alpine Fault, Christchurch possess a potential for magnitude 6-8 earthquakes to frequently occur around fault lines within the city. In addition, Christchurch's soil makeup, which consists of deep soft sediment underlying the city, means that earthquake velocity and acceleration can be increased in many parts of the downtown core.[4] Since it is surrounded by volcanic rocks and a saturated sand and silt coastline, water gets trapped within the layers of sediment underneath, making Christchurch extremely vulnerable to landslides and soil liquefaction,

Moreover, Alluvium (loose soil and sediment) beneath the city reduces the structural response at high frequencies and amplifies the lower frequency shaking. This seismic activity means that mid to high rise level buildings could experience resonant shaking. The strains experienced by pipelines means they could break. If liquefaction occurs the sewerage system and treatment station could be severely damaged. Liquefaction can also affect main electrical supplies.

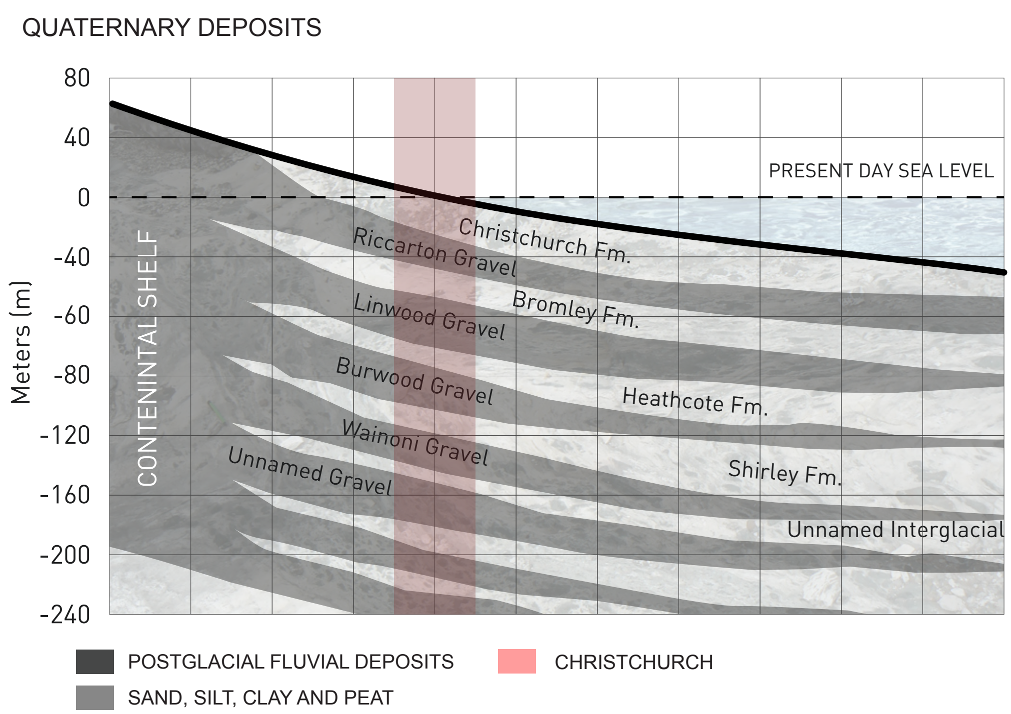

Figure 12. M.L. Taylor, Geological section representing the deep soil make up of Christchurch; data from Taylor, *Australian Geomechanics Vol 47 No 4 (2012)*.

4. Ibid., 43-44.

A Post-earthquake City

Although an extensive reconstruction master plan has been put in place for the central city area, eastern Christchurch, an area greatly effected by soil liquefaction, is still left unattended.

Figure 13. Over 7500 housing units have been affected soil liquefaction; forcing families to evacuate from their homes and communities, 2012; from Christchurch City Libraries.

Why Buildings Failed

The devastation in Christchurch caused many modern buildings and masonry houses to fail. There are two main sources of building failure: buildings built from concrete/masonry construction and foundation failures from soil liquefaction. Up until the mid 1980s, many buildings were not designed to be ductile. In other words, they were built for strength, but with rigidity rather than the flexibility needed to absorb the energy of a huge quake. Concrete and masonry are building materials that have high compression strength but fails under tension and lateral forces, hence it easily fails under an earthquake (Figure 14).

Secondly, building foundations were not designed to withstand soil liquefaction. Foundations were not designed to anticipate soil liquefaction, as the design relied on the soil's original load bearing capacities to keep the structure afloat. Once the soil liquified, houses started subsiding into the ground (Figure 15). In addition, concrete slabs cracked from lateral spreading, as they were swayed from the lateral forces of the earthquake.

Figure 14. Collapsed masonry house devastated from seismic forces, 2011; from Christchurch City Libraries.

Figure 15. House sinking into the liquefied soil, 2011; from Christchurch City Libraries.

In addition, tree loss has resulted from mass soil movement, soil liquefaction, rockfalls, and land slips. With thousands of trees are scheduled for removal, there is a major change in the existing soil environment, which requires existing trees to adapt. It is important to recognize that spatial patterns of tree loss were highly localized.

Many of the benefits provided by urban forests are well understood. However, trees and green spaces provided additional benefits during earthquakes and in the aftermath. Can this notion of urban reforestation be used as an ecological solution to mitigate the effects of soil liquefaction?

Community Resilience

As seen in Christchurch, earthquakes can greatly devastate towns and cities, and also test a city's ability to bounce back and rebuild a resilient community. The idea of community resilience becomes essential to a city's ability to recover from catastrophes. It can be defined as the ability to adapt, evolve or change techniques and methods of repairing areas of vulnerability in ways that do not put people at risk.[5] It is an important attribute that should be translated into architecture, as there is a need to create ecological solutions that could evolute over time. Buildings are programed in ways that could adjust to a community's needs, and structures are assembled to withstand seismic activity. This chapter examines the definition of community and resilience to identify the primitive ideas of shelter, gather, and adaptation that should be considered for building in seismic zones.

What is Community?

A community is a social unit of any size that shares common values, or that is situated in a given geographical area. It is a group of people who are connected by durable relations that extend beyond immediate genealogical ties, and who mutually define that relationship as important to their social identity and practice. When a community is involved in building its own environment, there is a stronger sense of ownership and attachment to the resulting surroundings. Using the power of social empowerment, the presence of a community creates a 'Spirit of Place' embodied by a community's cultural identity.

5. Community & Regional Resilience Institute, Definitions of Community Resilience: an Analysis, 2-10.

In his book *Genius Loci - Towards a Phenomenology in Architecture,* Nobert-Schultz suggests that the 'Spirit of Place' is recognized as the 'concrete reality man has to face and come to terms with in his daily life', as the concrete reality is defined by things having material substance, shape, texture and color, which determine an 'environmental character' that is the essence of place.[6] By using this concrete reality, a cultural identity can be developed as these realties determine the world that we live in. It is to a high extent a function of places and things. The associations between places and objects of identification become a spatial structure that facilitates orientation and a sense of belonging within a community.

These environments can be categorized into two types of places: a natural place and a man-made place. The term 'natural place' denotes a series of environmental levels, from continents and countries down to the shaded area under an individual tree. All these 'places' are determined by the concrete properties of earth and sky. On the other hand, the man-made place denotes a series of environmental levels, from villages and towns down to houses and their 'presencing' from the boundaries.

Architecture should be a combination of these definitions to visualize the genius loci, and the task of the architecture is to create meaningful places, whereby helping man to dwell in an urban environment. 'Home for All', a temporal community center, exemplifies this visualization. The community was involved in every step of the design process, designing and building the project together as a part of the design team. The building material was harvested from the shores where the tsunami hit, as the community believed that the reclaimed wood is a living memory of their lost homes.

This project serves as an example of how materiality can strengthen the effects of creating an anchor building to forge a stronger sense of community. It becomes a vehicle that visualizes the genius loci, seamlessly merging natural and man-made places into architecture that reflects the values of being a community within the natural environment. Not only does architecture become a vehicle for communities to strengthen their genius loci and cultural identity, but it also becomes a bond in the communal effort to rebuild the broken city. In *Anti-Object*, Kuma argues that this mindset prevents us from establishing a healthy relationship with the external world. He suggests that an alternative form of architecture is

6. Christian Norberg-Schulz, Genius Loci - Towards a Phenomenology in Architecture. (New York: Rizzoli, 1980), 11-13.

Figure 16. The resulting intervention became a social gathering space for the affected communities within the Tohoku region, 2012; from Japan Architecture + Urbanism.

not only desirable but possible by establishing a seamless relationship between building materials and the natural environment.[7]

What is Resilience?

In addition to looking at the definition of a community, we need to define what it means for a community to be resilient. Resilience is an inherent and dynamic attribute of the community, where adaptability is at the core of this attribute. It can occur either in response to or in anticipation of a crisis. Any adaptation must improve the community relative to its state after experiencing adversity. This can best be detected by considering the level of functionality of the community after a crisis.

This attribute should also be developed in a suitable and sustainable manner, organically growing from the historical traces of a community that can sustain over time. Alexander suggests that the built environment must be much more than a collection of ‘bolt-on’ mechanisms. The parts have to be continuously mutually adapted or ‘re-factored’ into its natural surroundings. They help build up a patterns catalogue that helps create complex systems by putting the patterns together into an architectural language. In turn, this language becomes a kit of parts that can build larger-scale entities out of elements of tried applications with meaning. However, when communities adapt to the wrong things such as images, short-term greed, or to the clutter of mechanics, they become a series of disastrous failures. These maladaptations can be described as

7. Kengo Kuma, Anti-Object? The Dissolution and Disintegration of Architecture (London: Architectural Association, 2007), 2-10.

'antipatterns', describing things that appear attractive but are unsuitable for a particular environment.[8] The Gothic style stone and masonry buildings can be described as 'antipatterns' unsuitable for Christchurch.

Geographical System for Geographical Questions

To rebuild Christchurch, we must create a layered strategy that satisfy these requirements: a resilient material against seismic actions, a construction methodology that is adaptive, and a strategic process that involves the community. Hence 3 rebuild phases are proposed create an urban timber network that addresses the issues involved in this thesis's rebuilding process. It incorporates the needs for safety, gather, shelter and social empowerment that creates a closed system for rebuilding a devastated city. In fact, they help define the meaning of community resilience and how it translates into architecture.

The notions of gather and shelter are the earliest forms of community building processes. In times past, people build their own homes, grew their own food, and made their own clothes. Knowledge of the building crafts and other skills of providing life's basic needs were generally passed along from father to son, mother to daughter, and master to apprentice. To create a methodology for rebuilding post-earthquake urban environments, a notion to forming a pattern language that creates a suitable sense of place is required. As a starting point, we can return to the simple notions of shelter and gathering, providing knowledge that could be passed down and shared within a community.

By using these primitive principles, architecture becomes a structure with diversity, complexity and emergence. Fujimoto calls to abandon the top-down approach for a bottom up design strategy, as a call for a catalytic architecture presented in its incomplete state. We should design for relationships that create 'an open ended resolution of design' that allows life to take unpredictable form.[9] Additionally, it is necessary to create adaptable building programs that would allow for multiple uses at different times. This type of architecture should be a place of gathering for sharing and transforms into a place of shelter when the community is devastated by natural disasters (Figure 17/ Figure 18).

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8. Christopher Alexander, A Patterned Language: Towns, Buildings, Construction (Oxford University Press. 1977), xli-xliv.
9. Sou Fujimoto, Sou Fujimoto: Primitive Future (Tokyo: Inax Publishing, 2008) 24-33.

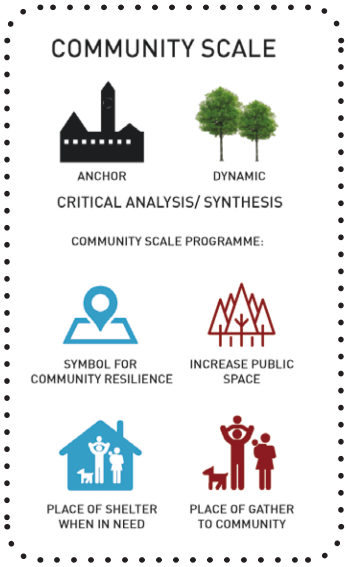

Figure 17. Community scale and building scale temporal programs that adapts to a community's needs.

Figure 18. The building programme can shift between a place of shelter to a place of gather.

CHAPTER 4: REBUILDING STRATEGIES

Initial Responses

The initial step is to identify key sites suitable for setting up an Emergency Education Complex. A mapping strategy is used to determine the number of interventions required for establishing a community network. Some factors are identified as critical attributes to finding these sites. It is essential to find resources for immediate needs, services for health and security, and identify the major infrastructures that allows access to these sites. On a secondary level, the ideal sites should also be close to lumber manufacturers and green spaces within the city.

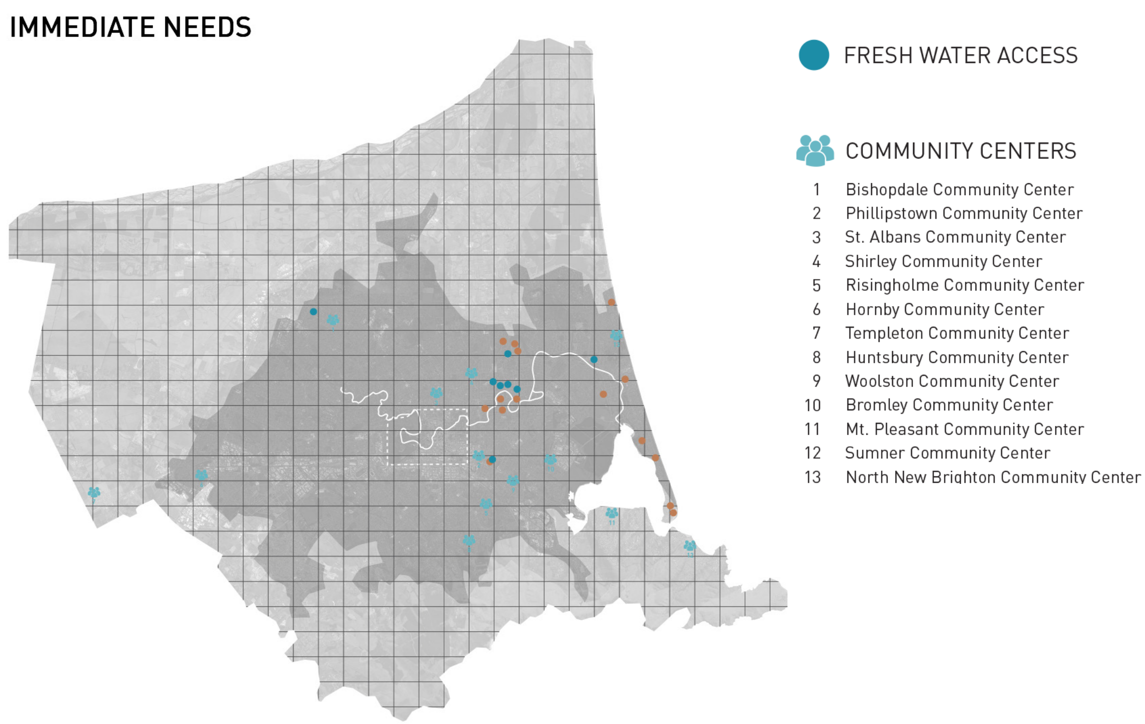

Figure 19. Map locating community centers for shelter and water access; data from Google Maps.

SERVICES

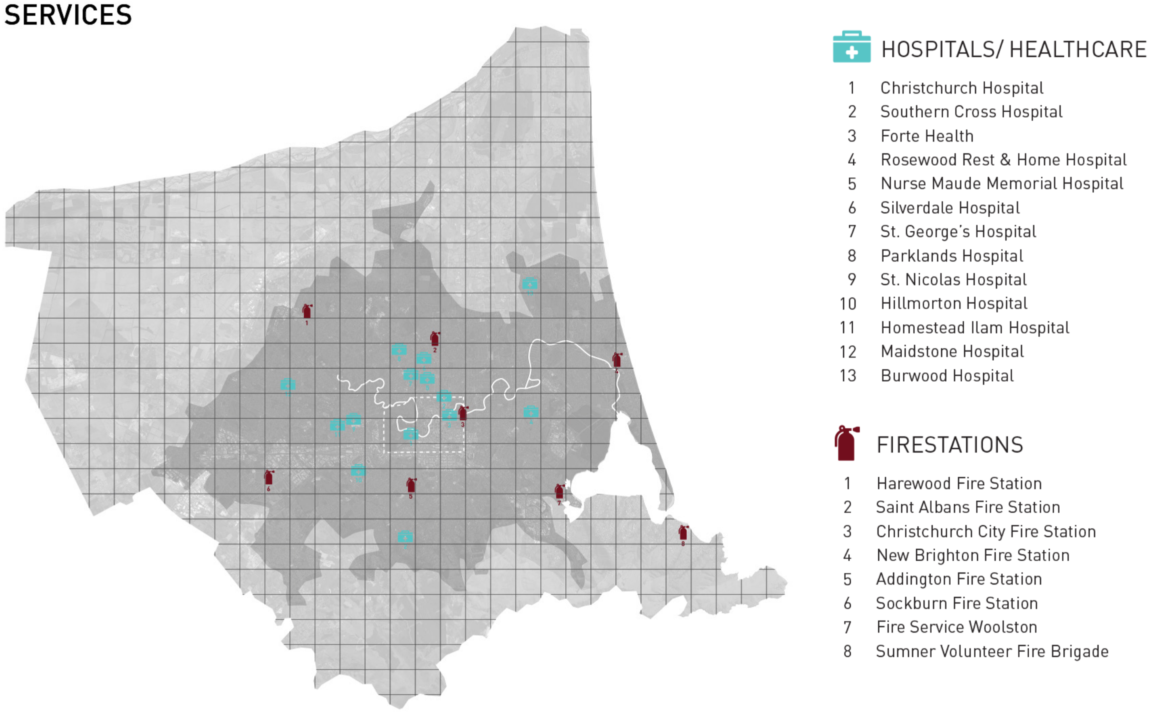

Figure 20. Map locating hospitals and firestations for health and security; data from Google Maps.

INFRASTRUCTURE

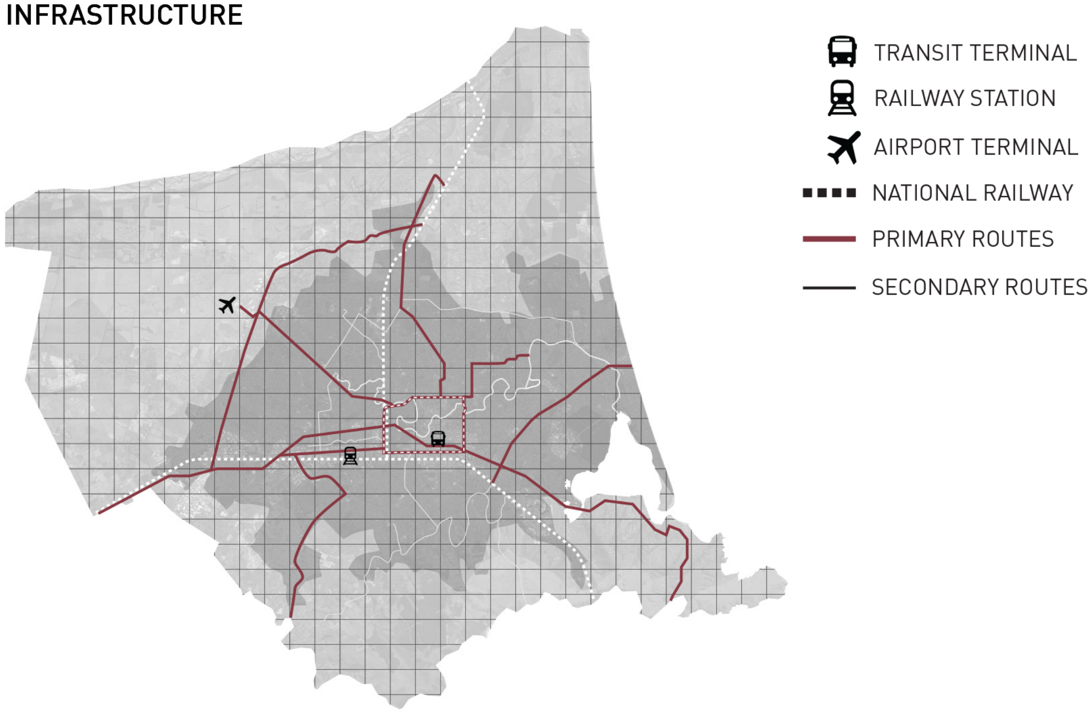

Figure 21. Map locating major routes and transportation systems; data from Google Maps.

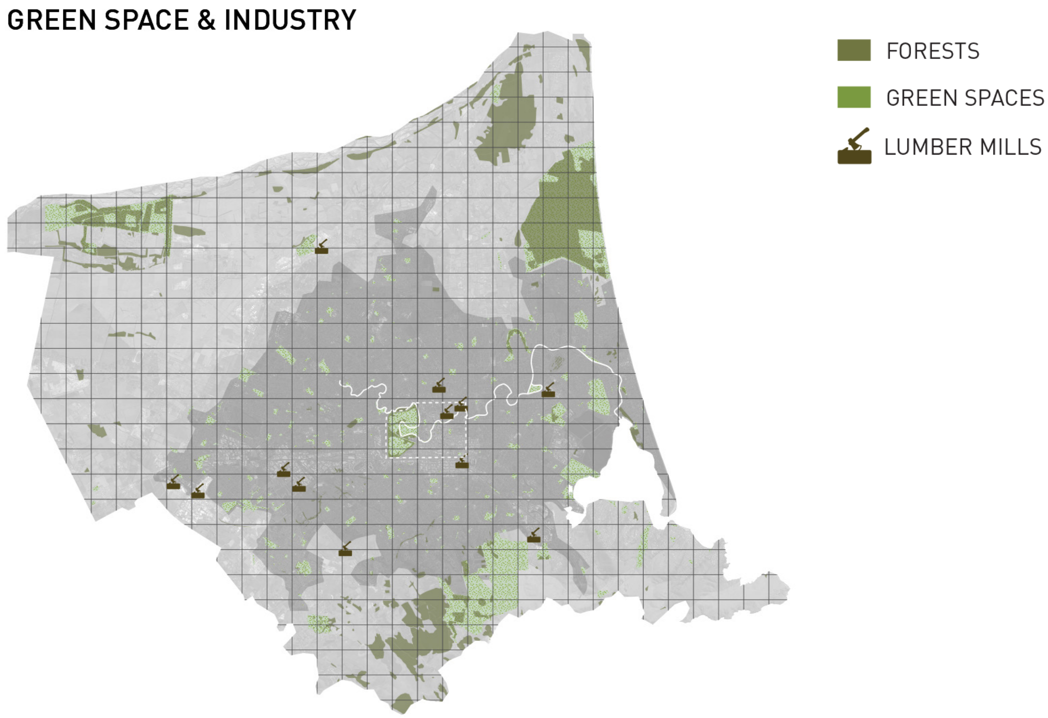

Figure 22. Map locating timber manufacturers and green spaces; data from Google Maps.

East Christchurch

Known as the Red Zone, east Christchurch consists of some of the oldest historical suburban developments within the city. Over 7500 residential buildings are being demolished from the damage caused by the earthquakes. These buildings are no longer suitable for habitation as they are structurally unstable. 3 ideal sites are selected to help rebuild the Red Zone.

Figure 23. Montage model of East Christchurch mapping the affected buildings along the Avon River; data from Google Maps and Christchurch City Libraries.

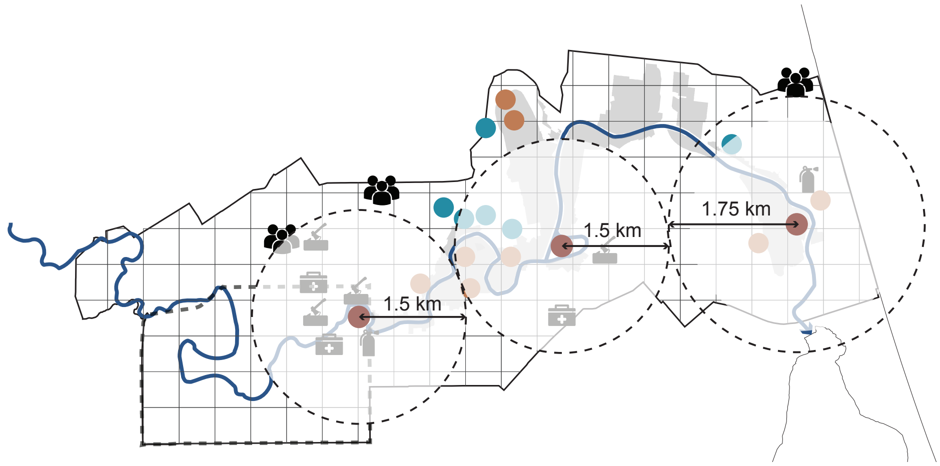

Figure 24. Locating sites of intervention from mapping parameters; data from Google Maps.

The Emergency Education centers are then deployed on these sites that are within a 2.0 kilometre radius of one another to ensure that they are accessible to the communities (Figure 24). In each of the sites, the following sequence of events occurs:

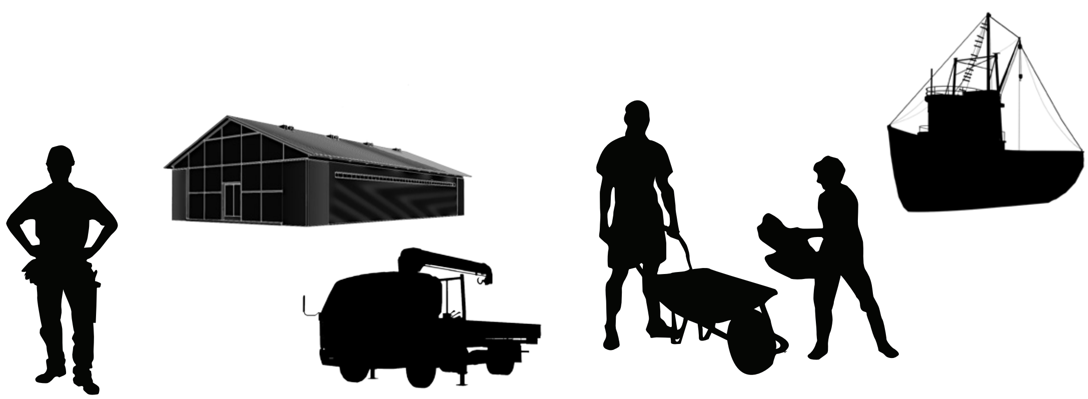

Figure 25. Illustration of identifying existing services and infrastructure that are essential to the clean up.

The Clean up (0-5 years)

A worker's housing complex is established for waste management after the disaster, categorizing materials that could be used for clean infill or rebuilding infrastructure. Trucks and Barge boats are used for transporting waste and recyclable materials. The housing complex can also serve as temporary accommodations for those who have lost their homes from the earthquake. (Figure 25)

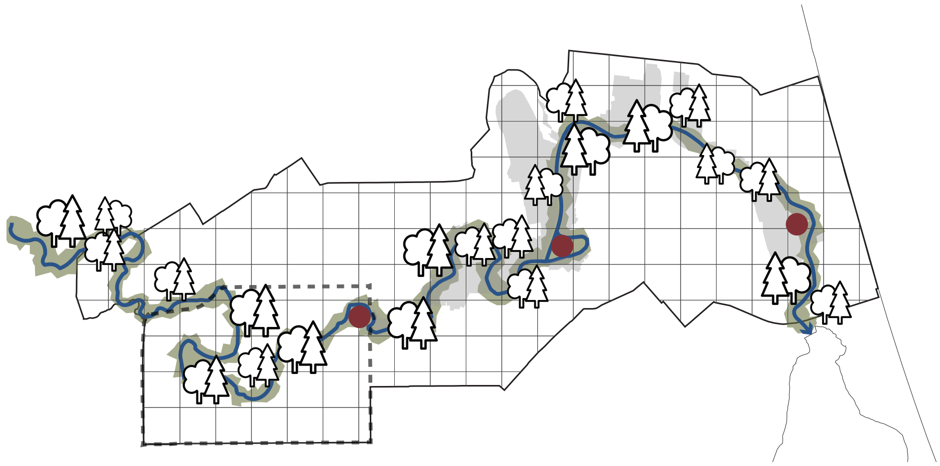

Figure 26. Planting a natural barrier along the Avon river and establishing community hubs on sites

Tree Planting (5-10 years)

Once clean up is complete, a green urban forest would be installed as a natural barrier against the Avon river. (Figure 26) The urban forest becomes a system that mitigates water penetration from the river into the soil. To do so, white birch and douglas-fir, 2 main species that are common around the south island of New Zealand, are the chosen species for the natural barrier. A community wood shop is added to the complex to manufacture parts for the rebuilding phase (Figure 27).

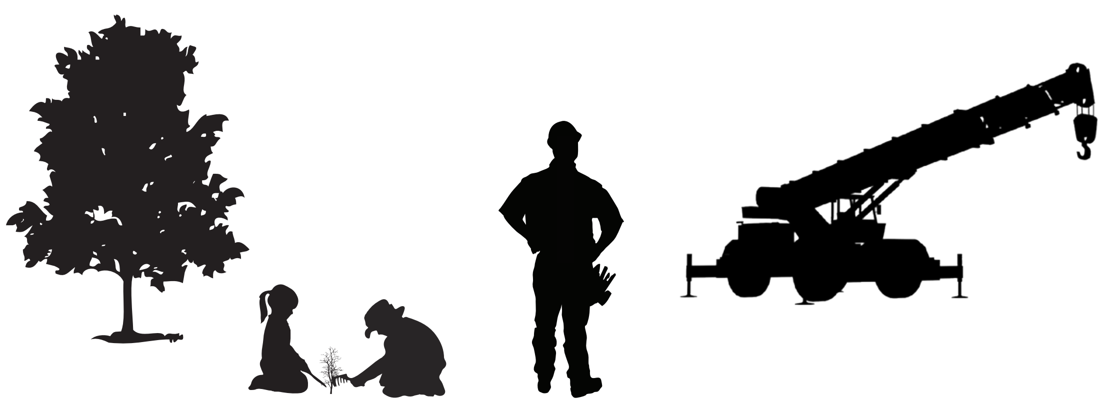

Figure 27. Illustration of the tree planting process and wood shop addition.

Figure 28. Amount of years for a tree to mature for harvesting; data from Arbor Day Foundation.

The community wood shop is installed as a link between the forest and the rebuilding process. Not only does the forest act as a natural barrier, but it can also be harvested to rebuild or replace buildings through out the community. The trees can be harvested once it reaches a pole diameter between 16 to 24 inches within a 20 year growing cycle.

The two tree species are planted for different uses. White birch is commonly used for exterior finishes, as it is smaller in diameter and produces members suitable for plywood and cladding. On the other hand, douglas fir is used for structural members, as it produces larger members that can be laminated and engineered into structural components.

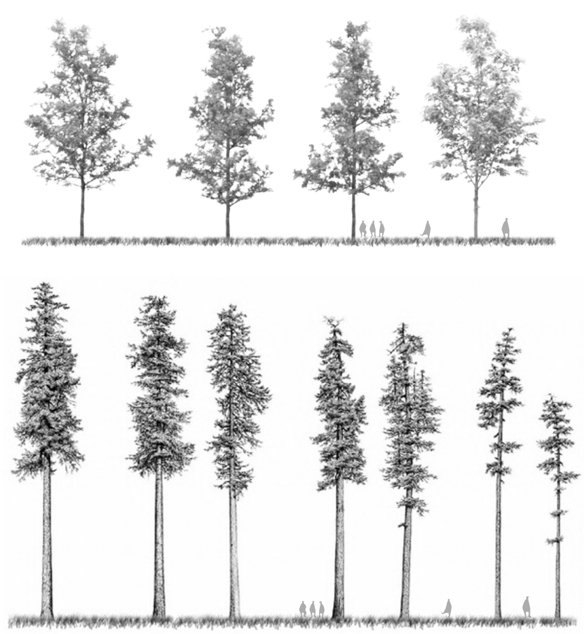

Figure 29. Comparison between White birch and Douglas-fir; data from the Arbor Day Foundation.

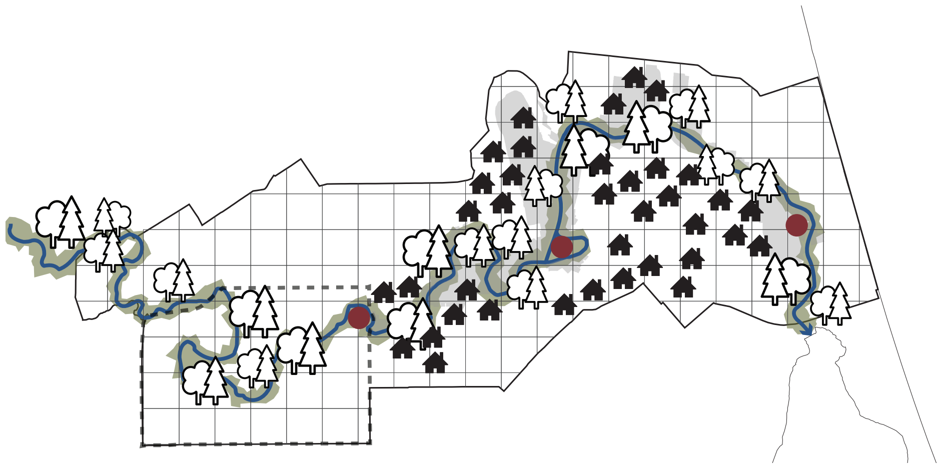

Figure 30. Initial sites become starting points for sharing knowledge to rebuild communities.

Rebuild Red Zone (10-15 years)

As the urban forest continues to develop, the community wood shop is set up to start the rebuilding process. A new pattern of integrating nature within an urban environment emerges from the ruins left behind (Figure 30). A new expansion is added to the complex, as it becomes an education center that can teach communities in building methods that can be assembled by a few individuals (Figure 31).

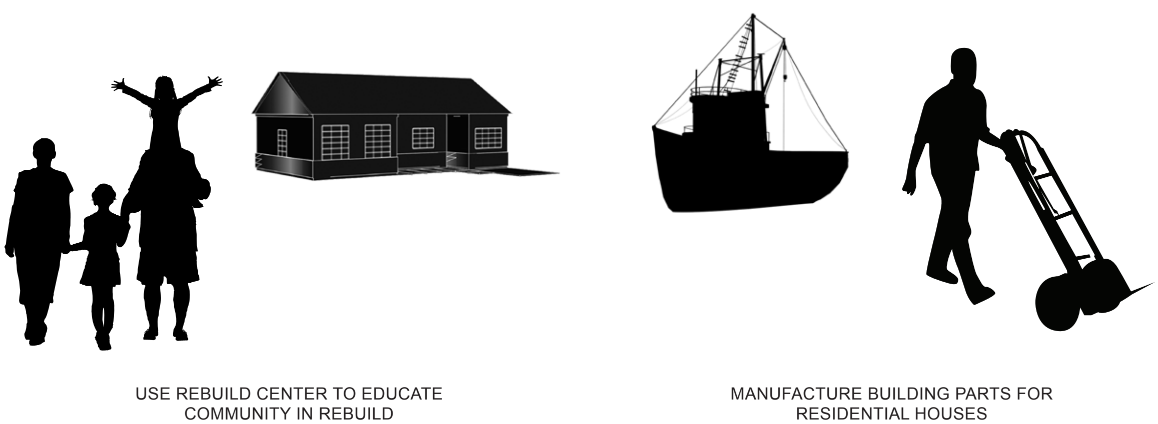

Figure 31. Illustration of using the rebuild center as a starting point for rebuilding the Red Zone and utilizing barge boats for transporting building materials

As the rebuilding phases are established, we must seek a resilient material that can withstand seismic activity. This material should be light weight, ductile and adaptive in nature, giving the flexibility it needs for different types of structural systems.

CHAPTER 5: RESILIENCE IN MATERIAL

Wood as a Resilient Material

Wood has inherent characteristics that offer advantages over concrete, masonry and steel building designs. As a result, wood can be an ideal material in areas prone to seismic activity.

The key to any seismic design is ensuring good behavior, not sufficient brute strength. This is particularly true for wood-frame structures, which are assigned a high ductility factor (Figure 32). Wood building systems often inherit redundancy and ductility through the multiple load paths afforded by their very architecture.[10] While North American timber codes are not particularly clear on this issue, but the principles of capacity design must be applied to the design of wood-frame structures as they would for any other structure.

Wood-frame systems, with solid design and construction, are proven to withstand the effects of powerful earthquakes. Wood's versatility and structural performance offer a range of additional benefits and make it ideal for a number of building types and geographies.

Light weight

Most earthquake damage is caused by seismic waves that force the ground to move. When the ground motion is strong enough, it causes the building's foundation to shake. Earthquake forces are proportional to a structure's mass, so heavy steel and concrete structures experience greater forces. Wood-frame construction is substantially lighter than other types of construction and has a high strength-to-weight ratio. As a result, properly designed and built wood-frame structures perform well during seismic activity.

Ductility

Wood-frame structures have numerous nailed connections and joints. This provides inherent ductility compared to most rigid masonry and concrete systems. Wood-frame buildings can flex, absorbing and dissipating energy when subjected to sudden earthquake forces.

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10. John Fernandez, Material Architecture: Emergent Materials for Innovative Buildings and Ecological Construction. (Oxford: Architectural Press, 2006), 256.

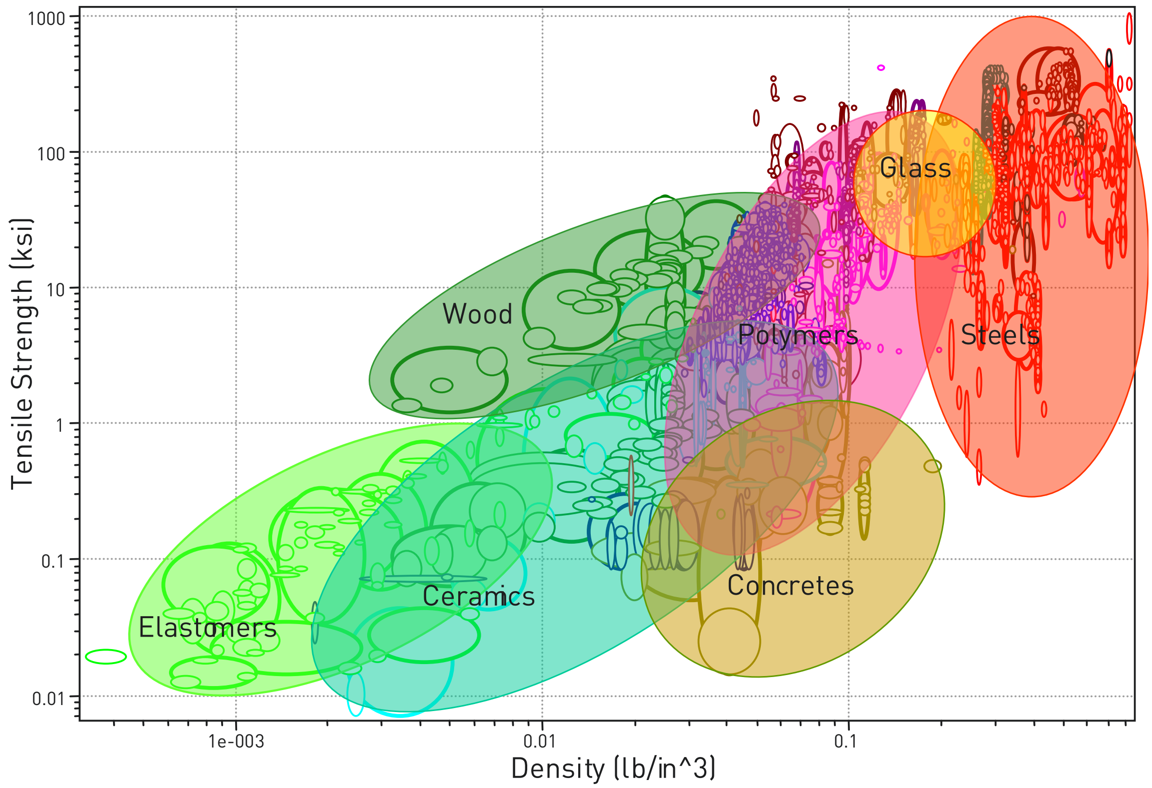

Figure 32. John Fernandez, Measurement of a material's tensile strength to density ratio, from Fernandez, Material Architecture: Emergent Materials for Innovative Buildings and Ecological Construction

Redundancy

Similarly, sheathing and finishes attached to structure provide redundant load paths for earthquake forces. These numerous small connections and load paths dissipate seismic forces. Should some connections be overloaded or fail, adjacent connections will usually provide alternate load paths and help avoid collapse. This said, systems with poorly designed load paths will be prone to damage or even collapse, regardless of the material used.

Strength and stiffness

An earthquake's lateral forces tend to distort building walls, causing them to rack. Shear walls in wood construction provide necessary racking resistance. The stiffness and resistance of walls can be augmented in areas prone to strong earthquakes by increasing the thickness of structural panels, stud size, and number or size of nails.

Connectivity

Securely connecting a structure's walls, floors and roof framing make it a single, solid unit, which is critical to withstanding earthquake forces. All structural elements must be anchored to the building's foundation to resist racking, sliding and overturning during an earthquake. Standard connections and tie-downs manufactured for high-load designs make this a simple task.

Material and Construction Methods

Material Abstraction

By identifying wood as the main material of construction, the architectural language can be applied to this material as the palette for an architectural intervention. Reconnecting with it's cultural past, wood is a material that relates to Christchurch's history as a wooden city in its early development. The approach is formed by some of the standardized building products such as raw lumber, light wood timber, heavy timber, and cross laminated timber panels. These processes are then transformed into 5 architectural actions: Harvest, Nest, Isolate, Interlock and Anchor (Figure 33).

Figure 33. Atmospheric perspective integrating architectural actions into the proposed urban forest

Harvest: Raw lumber

This process is an attempt to use raw lumber as the mean of construction; utilizing a bent wood building technique that would put the material under a heat steaming process, making the material more malleable (Figure 34). It preserves the inherit material properties of waste wood and raw lumber that can be harvested and processed for lamination. However, it might not be suitable as the method of construction for a rebuilding process, as it requires more processes to prepare the material for construction use compared to standardized products.

Figure 34. Abstract model of Harvesting Raw Lumber as building material

Nest: Standard lumber

This process is a translation of standardized lumber products into planar elements that can be used as a way of material storage, urban furniture and fenestration. A 'nest' is formed by stacking the material in a grid formation (Figure 35). It can be an effective way of preserving building materials and a temporal representation of a rebuilding process. The height and area coverage of the nest would change according to material production and consumption over time. On the other hand, the nest needs a set of parameters for material spacing, stacking and area coverage for each level so it is safe for inhabitation.

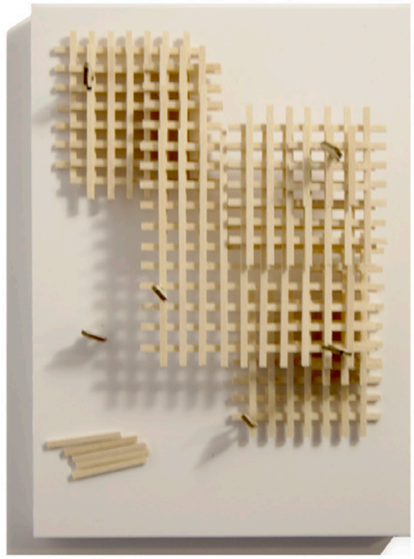

Figure 35. Abstract model of Nesting Standard Lumber as building material

Isolate: Heavy timber

This process is a translation of Heavy timber construction into a set of isolated supports at the ground level for structural stability (Figure 36). It resembles a similar stacking technique to nesting with the intention of creating the structure for public architecture. It becomes a method of creating an exploratory building that showcases a set of construction detail and assemblies that can be used for the reconstructing process. On the other hand, finer exploration is required to create flexible junctures between each member to absorb the seismic energy created when an earthquake occurs.

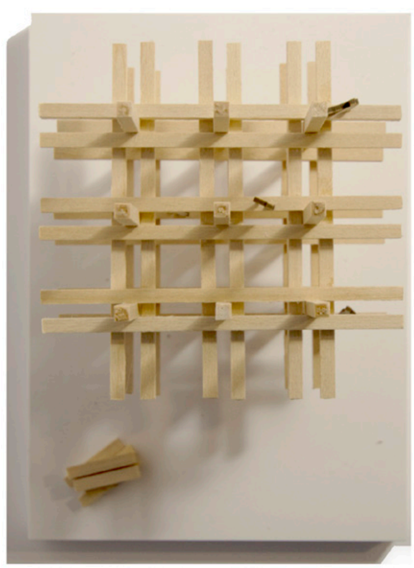

Figure 36. Abstract model of Isolating Heavy Timber as building material

Interlock: Cross Laminated Timber

This process is a translation of cross laminated timber (CLT) panels into a set of interlocking planes to create a three dimensional labyrinth of inhabitation (Figure 37). The spacial sequences resembles an adaptive primitive language that resembles nature. However, this process does not offer a stable structure for architecture. A set of parameters for material spacing, stacking and area coverage for each level so it is safe for inhabitation.

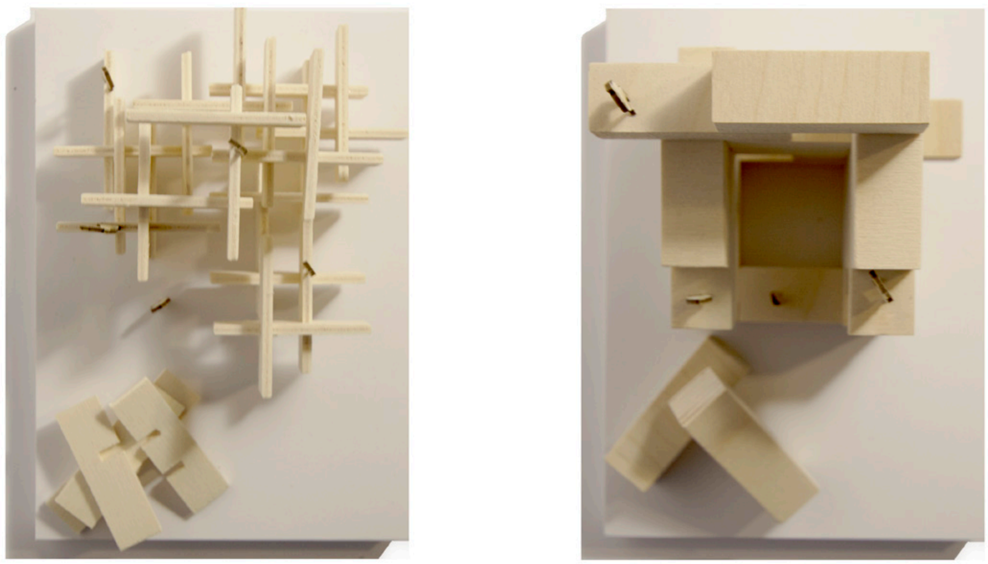

Figure 37. Left) Abstract model of Interlocking Cross Laminated Timber Panels as building material
Right) Abstract model of Anchoring Inhabitable Timber Frames as building material.

Anchor: Inhabitable timber

This process is a translation of lumber products into inhabitable boxes that could be stacked together to form architecture; the shear mass and volume of the pieces is an expression of anchor, safety and security (Figure 37). It can produce a monumental building that becomes a symbol of way finding and a place for shelter and gather. However, the nature of stacking boxes on unstable ground needs to be resolved.

Abstraction to Building Parts

The material abstractions above becomes a starting point for identifying a kit of parts that are suitable for building in a seismic zone. Each abstraction becomes a part of an integrated system that can respond to the effects of earthquakes and soil liquefaction.

To create a kit of parts derived from the different types of wood assemblies, a practical solution is required for each of the following issues. There needs to be a solution for building foundations when building on liquefied soil and structural systems that can resist and adapt to seismic forces. Moreover, there is a need for innovation in assembly connections that would preserve a building's structural integrity after an earthquake.

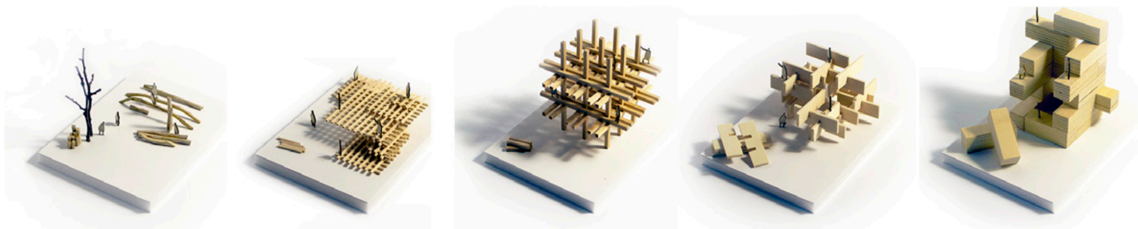

Figure 38. Summary of Derived Language Palette from potential wood building assemblies.

Building Foundations

The main concepts of foundation systems designed for soil liquefaction includes having isolated supports with structural redundancy. These concepts are utilized in three broad categories of design: deep piles, site ground improvements, and surface structures with shallow foundations.[11] Each foundation system is an ideal solution for different ground types.

Deep Pile Foundation

Deep pile foundation involves sinking piles a long way underground to reach stable ground not susceptible to liquefaction or lateral spreading (Figure 39). Deep piling will not be an option on land with a major risk of liquefaction or lateral spread, as this strategy requires a solid bearing layer of soil for the piles to rest on for structural capacity.

Site Ground Improvements

This technique is new to residential housing but has long been used by civil engineers for road building. Land is strengthened by one of two methods: mixing cement with the ground to make it denser, or compacting up to 2 meters of earth to give a better

11. Andrew Charleson, Seismic Design for Architects Outwitting the Quake (Oxford: Architectural Press, 2008), 113-117.

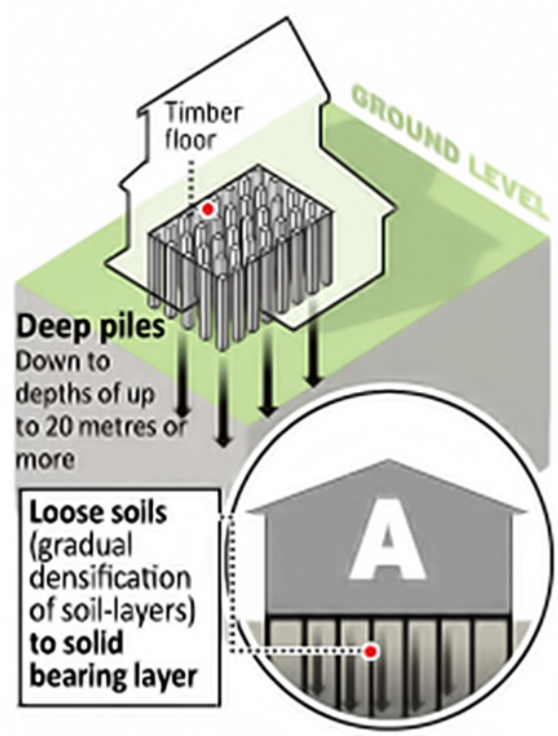

Figure 39. Deep pile foundation - suitable for loose soils with a solid bearing layer below,2012; from New Zealand Building Performance.

crust for building on. Once treated the land can be piled or have a concrete pad placed on top of it (Figure 40). However, this method is also not suitable on land with major liquefaction risk. Anywhere with liquefiable soil deeper than 10 meters would not be suitable for this method.

Surface Structures with Shallow Foundations

This technique involves having lightweight building materials and shallow foundations as the main building system. Heavy materials such as concrete are avoided and substituted with wooden assemblies. This option may be used on some of the worst affected lands. A gravel raft will be laid below the piles, which will be tied together with a concrete underslab (Figure 41). Highly variable ground conditions warrant different foundation types over a building plan the impact of their relative stiffness on horizontal force paths needs special attention.

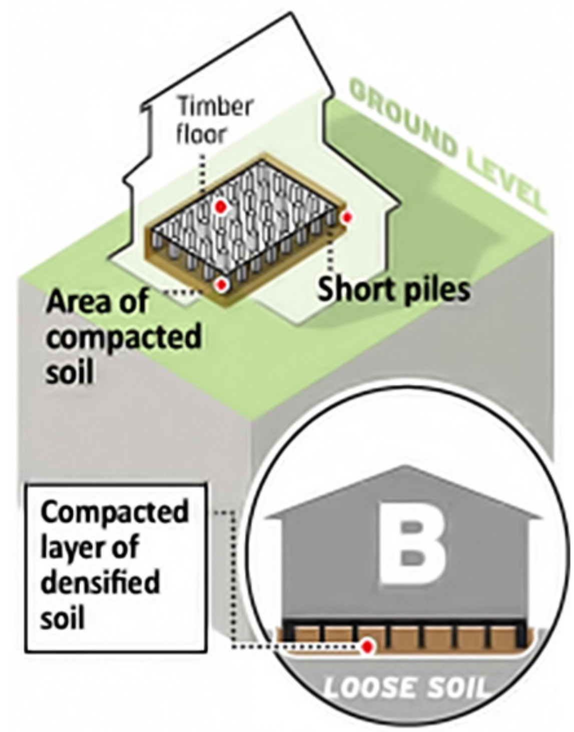

Figure 40. Site Ground Treatment - suitable with short piles after treating the soil with cement to create a compacted layer of densified soil, 2012; from New Zealand Building Performance.

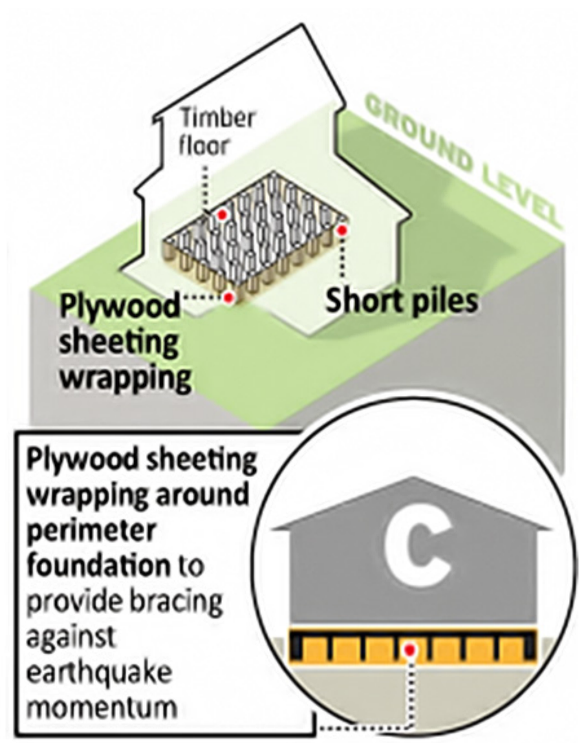

Figure 41. Surface structures with Shallow Foundations - suitable for building on worst affected grounds and used with site ground treatment techniques, 2012; from New Zealand Building Performance.

CHAPTER 6: PROCESSING, GROWING AND HARVESTING TO BUILDING PARTS

Existing Systems

To resist horizontal seismic forces successfully buildings must possess strength and stiffness, and ductility. It becomes one of the most desirable structural qualities of seismic resisting structures. If the intensity of earthquake shaking exceeds the strength of a brittle member, whether it is be it a beam or column, the member breaks suddenly, possibly leading to building collapse.

The choice of vertical structural systems to resist horizontal seismic forces is quite limited. The three most common systems are using shear walls, crossing bracing members, or moment frames as the main strategies for lateral resistance (Figure 42).

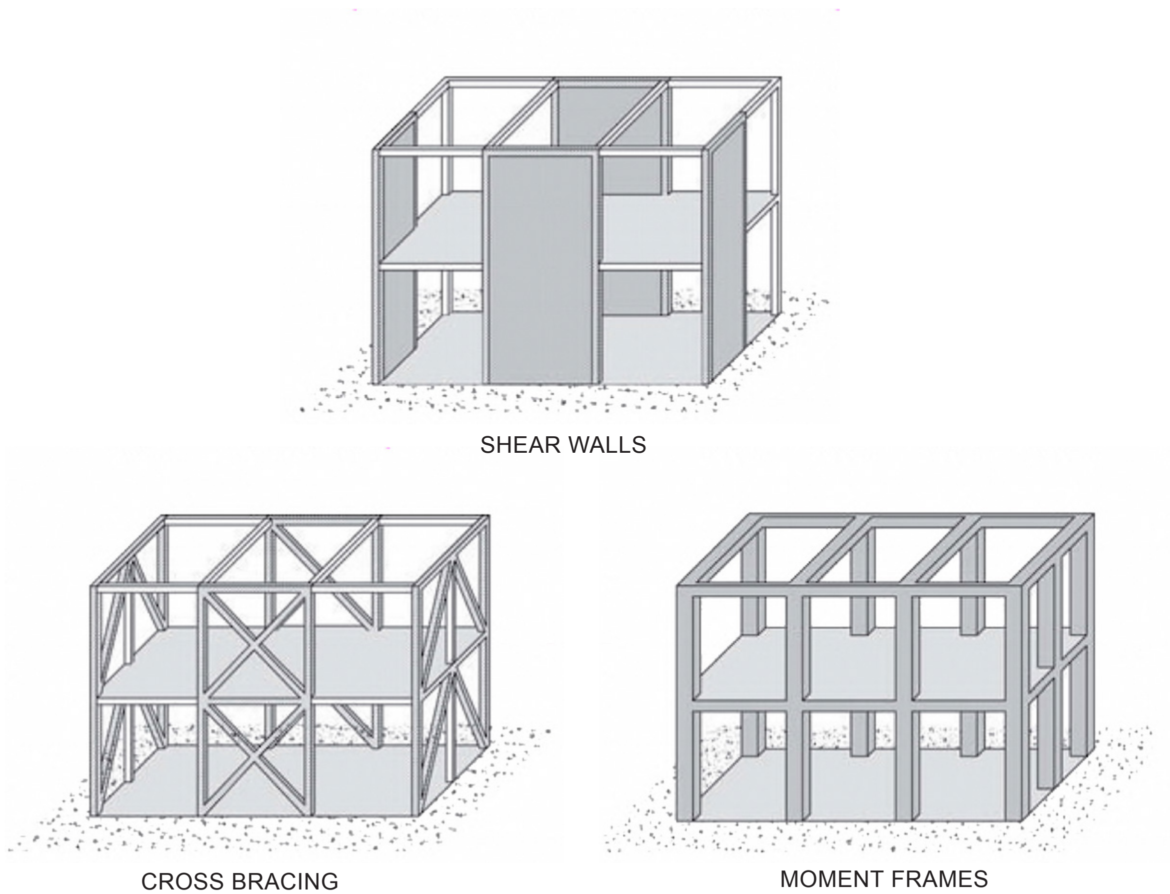

Figure 42. Andrew Charleson, Illustration of the three main strategies of lateral resistance, 2008; from Charleson, Seismic Design for Architects Outwitting the Quake

Pairings and Redundant Systems for Resiliency

A mix of structural systems is created when walls and moment frames work together to resist horizontal forces. In a moment frame structure, inter storey deflections or drifts of a moment frame are greater near its base than further up its height. On the contrary, a different situation occurs with a shear wall, where acting in parallel with a wall, a frame resists most of the upper forces including inertia forces from the wall itself (Figure 43). As Elsesser suggests, multiple systems 'can each serve a purpose'.[12] For instance, one system is used to add damping and to limit deflection or drift and another is used to provide strength. Using multiple systems can also serve to protect the entire structure by allowing failure of some elements without endangering the total building.

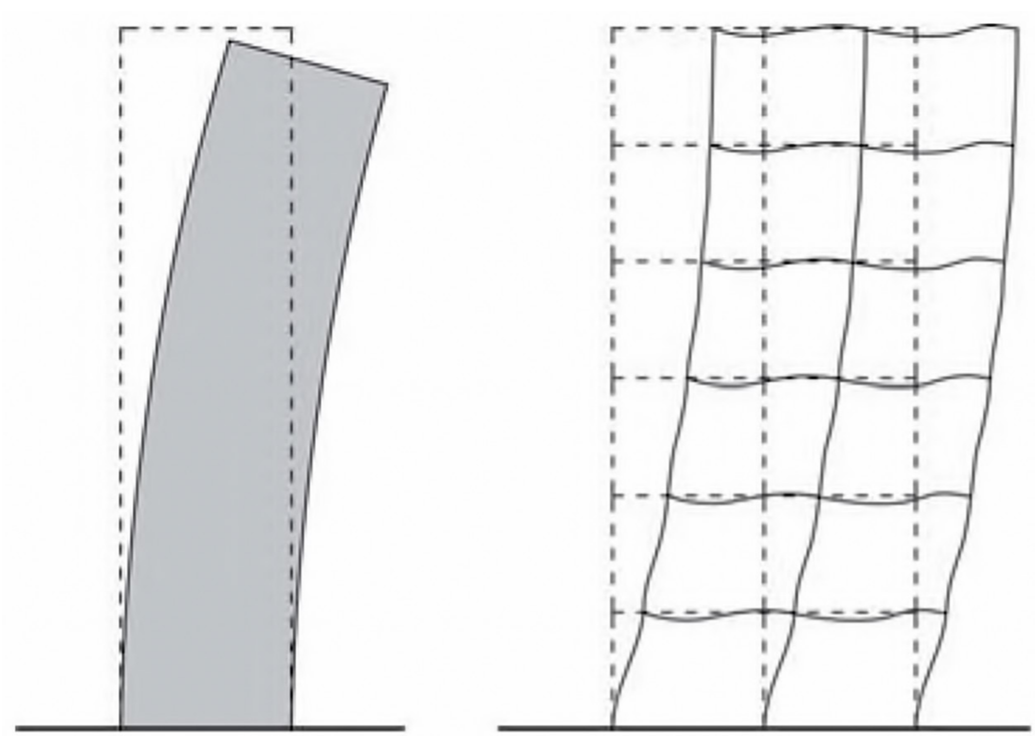

Figure 43. Andrew Charleson, Illustration showing how different systems react differently to seismic action and combine to protect buildings in different ways, 2008; from Charleson, Seismic Design for Architects Outwitting the Quake

12. Eric Elsesser, "New ideas for structural configuration" (Paper presented at the 8th U.S. National Conference on Earthquake Engineering, San Francisco, U.S.A. April 18-22, 2006).

The house in Shinkawa, by Yoshichika Takagi, is constructed with two structural systems in play: a modular post and beam system combined with shear walls for lateral resistance (Figure 44). This is a common method of using a mixed system for building construction, with a mix of wooden post and beam construction along with light wood frame shear walls.

Figure 44. Enclosed winter garden; showing a combination of shear walls and moment frames as a mixed system, 2011; from Yoshichika Takagi + Associates.

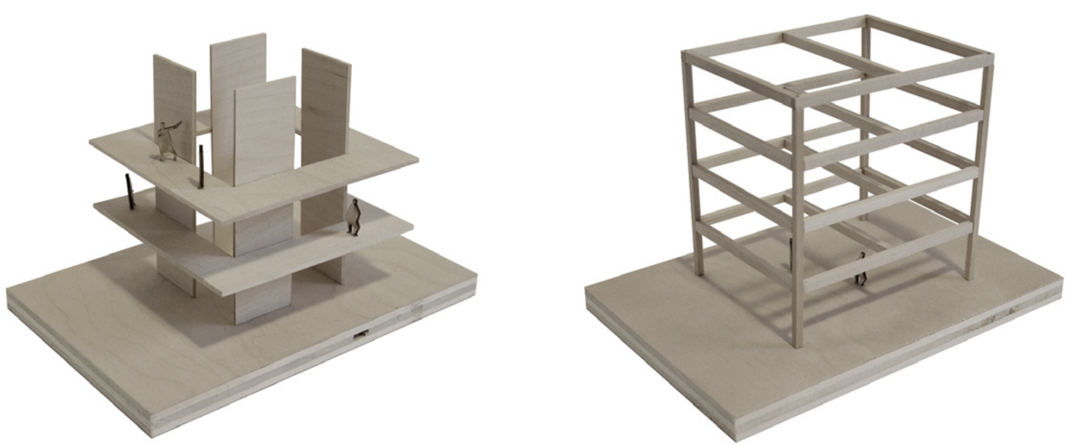

Figure 45. Takagi combines the use of shears walls and moment frames for this mixed system. Left) Model of Shear Walls Right) Model of Moment Frames.

The house was conceived by Shigaru Ban after working on the reconstruction of Kobe following the 1995 earthquake. Ban saw the severity of injuries and damage caused by falling furniture and realized its strength as a primary structural component. By integrating structural components into furniture, Ban created a set of prefabricated modules that can be used as structural and space-defining elements (Figure 46).

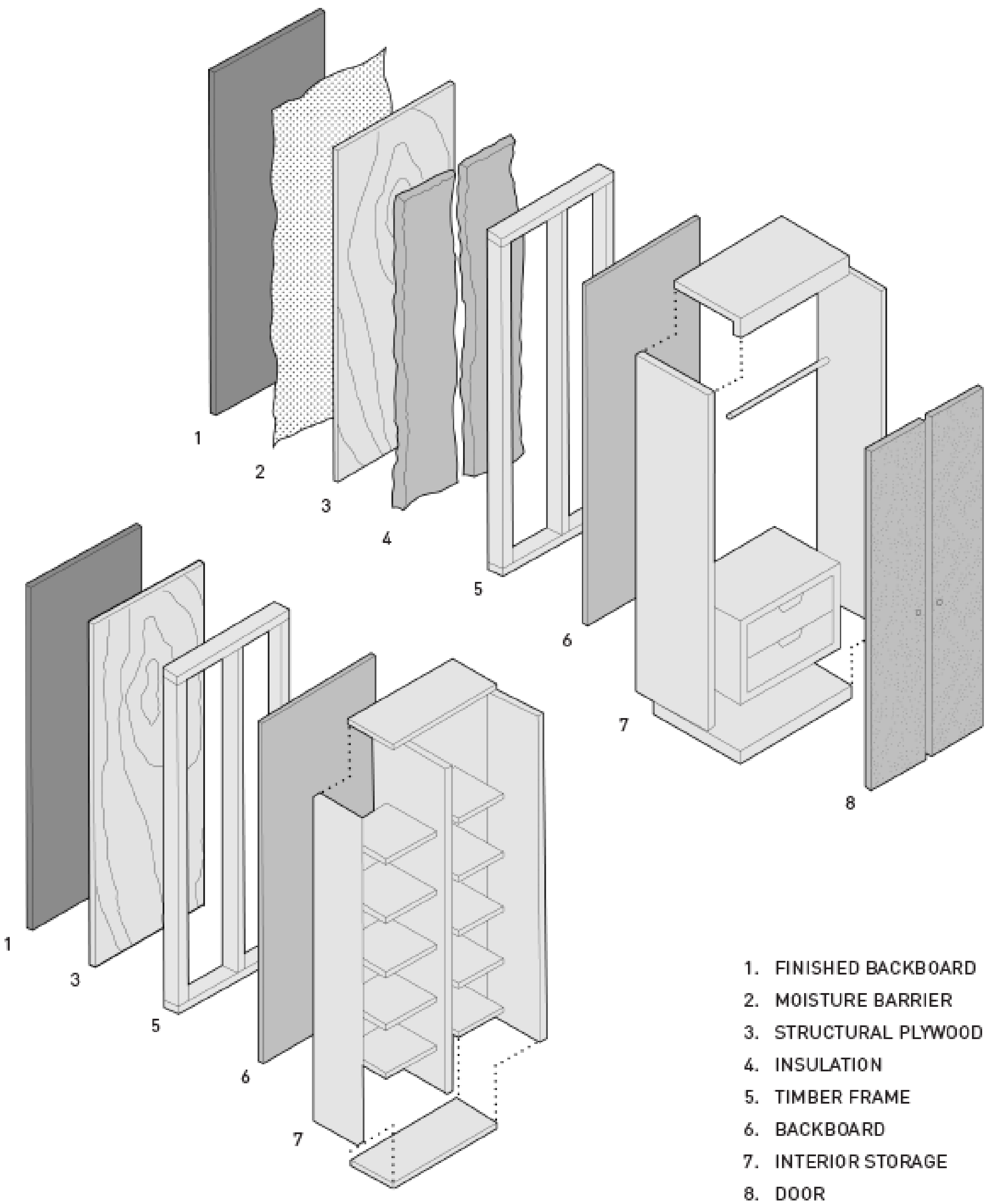

Figure 46. Matilda McQuaid, Exploded axonometric drawing of structural furniture modules, 2003; from McQuaid, Shigeru Ban

Figure 47. Matilda McQuaid, Photo of a minimal space with embedded functions within the walls, 2003; from McQuaid, Shigeru Ban

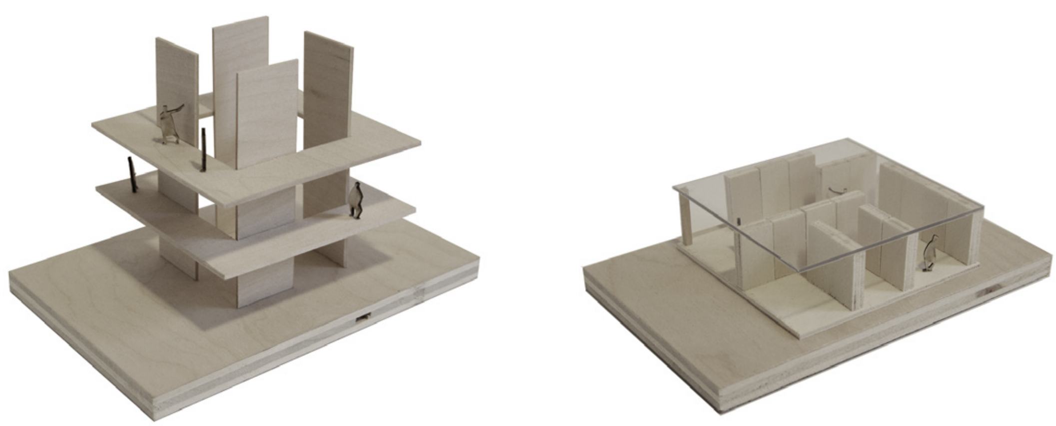

Figure 48. Ban combines the use of shears walls and furniture modules for this mixed system. Left) Model of Shear Walls Right) Model of Furniture Modules

Each prefabricated unit are constructed with 12mm thick structural plywood, giving it shear resistance to lateral forces. The embedded moment frames provide vertical support. Furniture and storage functions are also integrated into these units, making them a synthesis of function and structure (Figure 47). Each unit becomes an isolated structure that also provides structural redundancy for the overall system.

System Mock up

The furniture modules act as isolated pieces within a system, as each module has an individual reaction when put under lateral stress (Figure 50). However, there needs to be a connection that keeps the modules from twisting in the perpendicular plane. This system has the flexibility to create different plan layouts, particularly for single storey residential houses. There is potential in the furniture module to become the simple building block that can create community buildings (Figure 51/ Figure 52).

Figure 49. 1:10 mock up of the furniture modules in CLT construction.

Figure 50. Each module reacts in isolation when put under lateral stress.

Figure 51. The furniture modules can easily be used for domestic buildings as it was intended for residential design.

Figure 52. A staggered formation of the modules that could be used to create community or monumental buildings.

The five-story pagoda was brought into Japan from India via China in the 6th century. In Japan no pagodas have ever suffered serious damage from earthquakes. Since the end of the Meiji era, many researches have studied the earthquake resistance of five-story pagodas. And several factors of earthquake resistance of them has been pointed out, such as friction damping and sliding effect of the wooden joints, base isolation effects, balancing toy effects of deep eaves and bolt fastening effect of the center column (Figure 53).

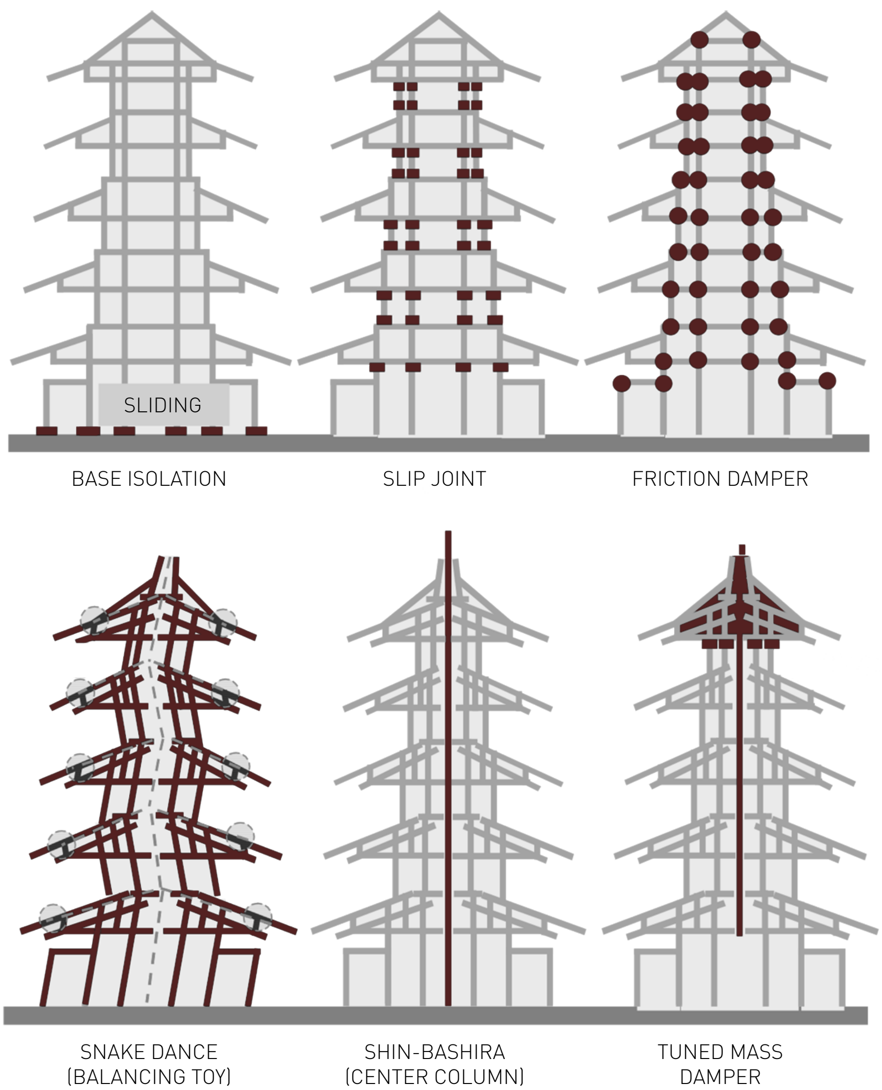

Figure 53. Koji Nakahara, Vibration devices of the pagoda typology, 2000; from Nakahara, Earthquake Response of Ancient Five-Story Pagoda Structure of Horyu-Ji Temple in Japan

The following six points can be listed as its structural features:[13]

1. The main structural elements consist of wood.
2. There are many joints or connections such as the “kumimono” or complex joints connecting many wood members.
3. A framework in which each story is independent and no column ties them together.
4. The center column supports the ornamental structure on the top independently of the main structure. The columns in the first story are not tied down to the foundation.
5. Its natural periods are around 1 second, and these are rather long considering the height of its structure.

System Mock up

The pagoda can be separated into 6 pieces, with each piece consisting of a roof and wall assembly. The first and top floors are weight down to counter balance one another and to keep the floors in place by compression. Each floor uses a slip joint connector to achieve the ‘balancing toy’ effect when put under lateral stress (Figure 54).

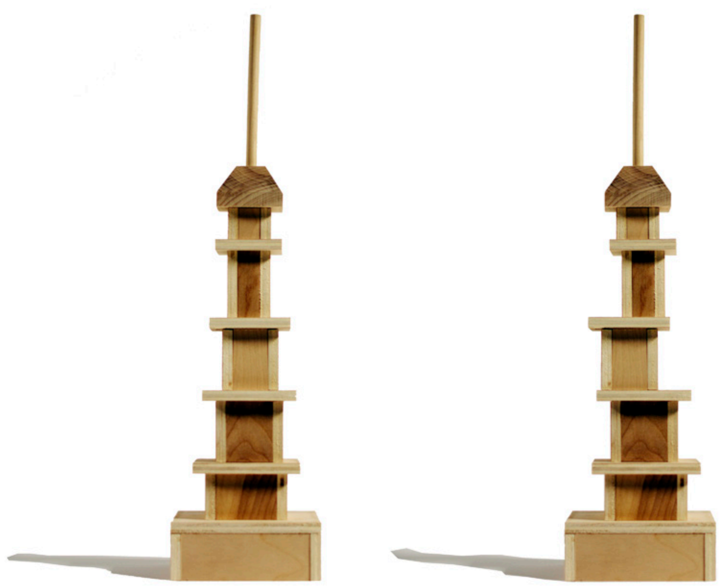

Figure 54. 1:50 Pagoda model, demonstrating how the pagoda turns into a ‘balancing toy’ as a result of lateral stress, each floor reacts separately and is held together by the roof and the central column.

13. Koji Nakahara, et al. “Earthquake Response of Ancient Five-Story Pagoda Structure of Horyu-Ji Temple in Japan” (Presented at 12th World Conference on Earthquake Engineering, Auckland, New Zealand, January 30th - February 4th, 2000)

The system pairings demonstrate how mixed systems are required to achieve a system that is adaptive with structural redundancy. In fact, there other parts that can combine to create structures for different building uses (Figure 55). By having an adaptive structural system, the architecture can have an adaptive program that changes according to the needs of a community.

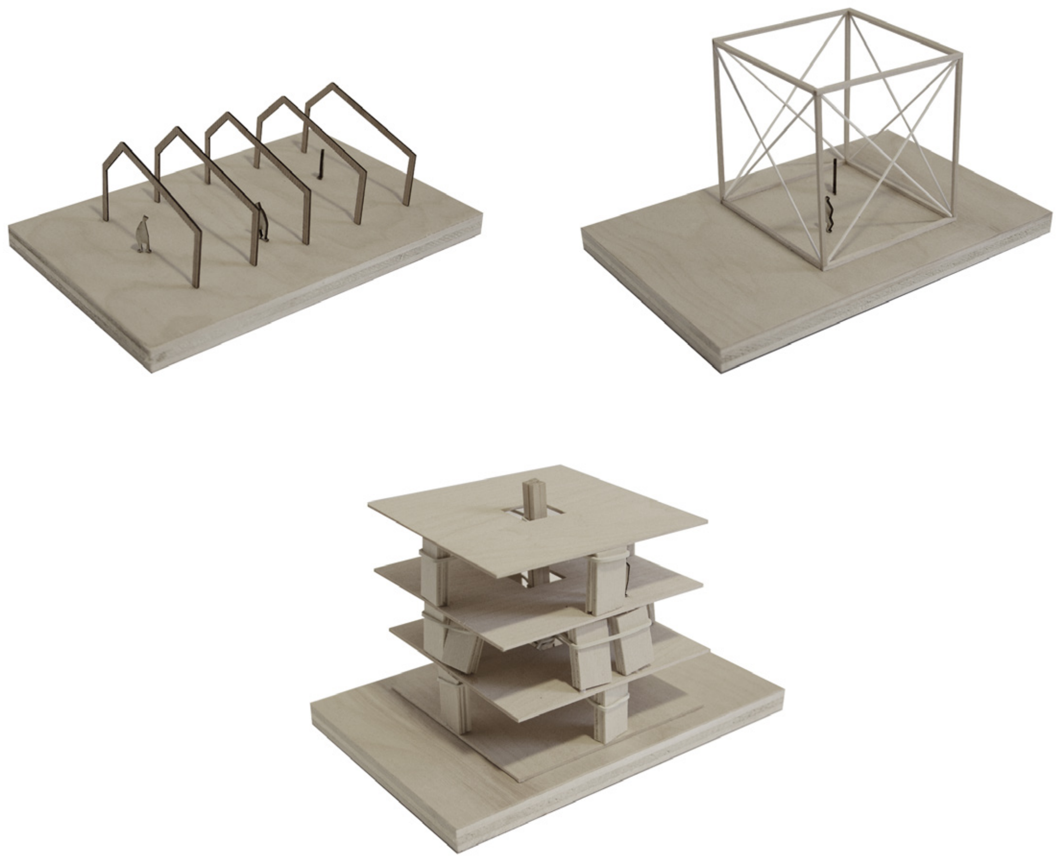

Figure 55. Other pieces that can be paired to make an adaptive structural system
Top Left) Model of Long Spanning Frames Top Right) Model of Cross Bracing Elements
Bottom) Model of A Modular Pagoda

Wood to Wood Connections

While they can take any shape or form, moment frames primarily transfer force through the use of rigid connections between columns and beams, as they are subject to relatively large bending moments as it drifts or deflects sideways while resisting seismic forces. Although they can be manufactured in most common building materials, moment frames are mainly manufactured in glue-laminated and laminated veneer lumber (LVL) in countries with vasts amounts of forests available. The main challenge is to achieve rigid connections where the beam and columns meet (Figure 56). Most of the connectors below are made from steel.

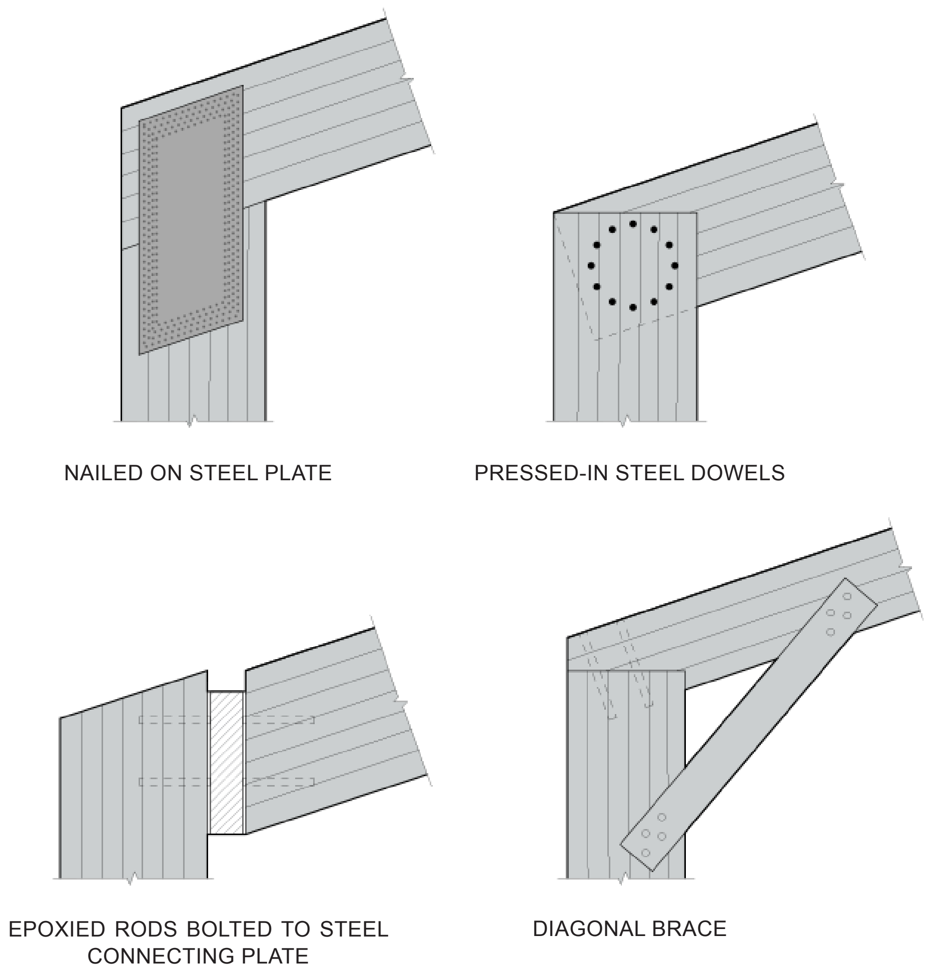

Figure 56. Andrew Charleson, Illustration of various types of rigid moment connections common in seismic design, 2008; from Charleson, Seismic Design for Architects Outwitting the Quake

Moment frames exhibit two failure mechanisms under seismic force overload. Plastic hinges (structural fuses) can form at the top and bottom of columns that are one storey in height at the ground level. The earthquake energy is only absorbed in several locations within the system, badly damaging the columns in the process (Figure 57). An ideal situation would spread the earthquake energy throughout the entire system, which will require creating weaker beams with plastic hinges at the ends. The more hinges located within the system, the less energy absorbed and less damage per hinge.

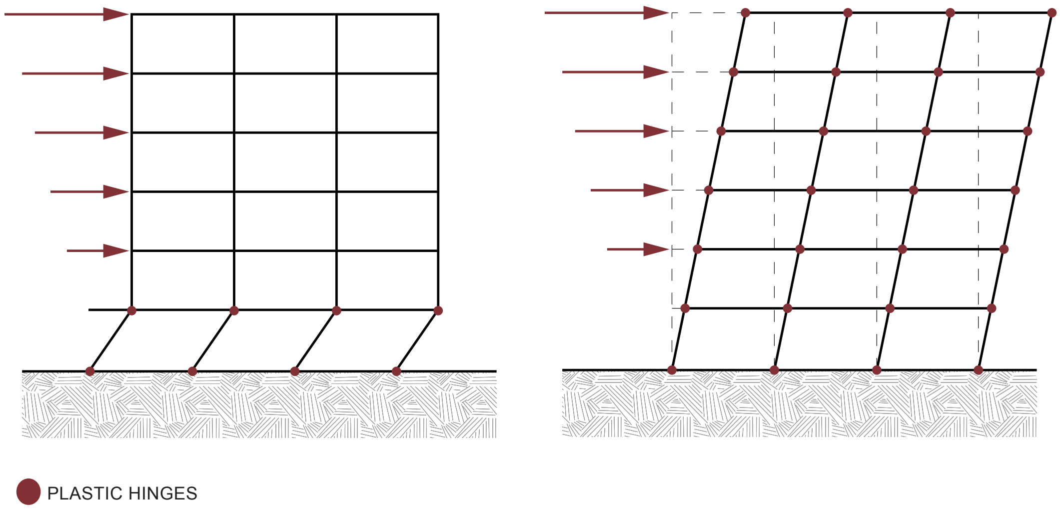

Figure 57. Andrew Charleson, Illustration of lateral forces being dissipated over plastic hinges, 2008; from Charleson, Seismic Design for Architects Outwitting the Quake.

Connection mock up

Putting these ideas to test, a 3 types of connections are examined to determine how it is affected by lateral forces. The connection types include: 1) nailing and gluing, 2) screwed in fasteners, and 3) wood joint connectors. There are a few hypothesis for this test. Firstly, the nails and glue connections would fail under lateral forces, as the nails would slip out from the material. Secondly, the screws would damage the material resulting from the lateral actions. Lastly, the wood joint connections would require gluing between the joints to ensure the assembly stays in place (Figure 58).

Figure 58. 1:10 material testing with 3 types of connections. Left) Glue and nail. Middle) Screwed in fasteners. 3) Wood joint connectors.

Findings

By testing different types of connections used in wooden construction, we can hypothesize that wooden joint connectors are desirable for seismic resistance structures. Minimal damage is found in the juncture as the connection is formed from a single material compared to tests with metal fasteners. In fact, we can apply this connection detail to a mixed modular system that allows for structural redundancy in different building typologies; translating a set of structural principles into architecture.

Structure into Architecture

Case Site: Oxford Terrace

Oxford Terrace, one of the 3 identified sites suitable for creating an Emergency Education center, is used as a case site for implementing these rebuilding strategies (Figure 59). The rebuilding phases will be applied to this site in the form of relief/ workers housing in phase 1, a community wood shop in phase 2, and an educational center in phase 3.

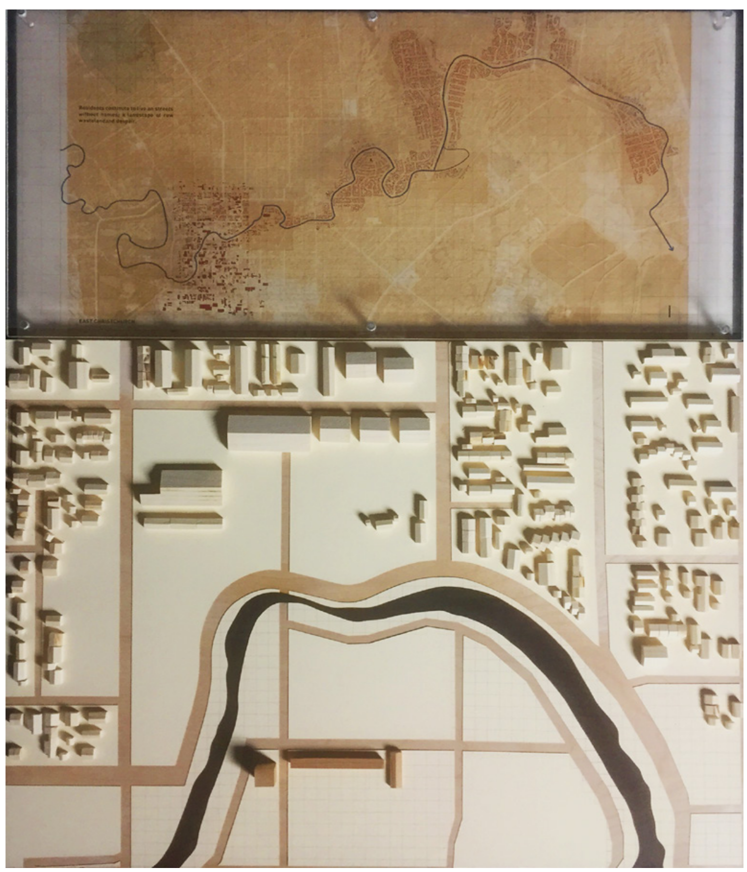

Figure 59. 1:1000 site model locating Oxford Terrace and the remaining urban fabric after the earthquakes in 2010/2011; data from Christchurch City Libraries.

Figure 60. Photo montage of the clean up sequence in phase 1

Phase 1: Worker's Housing

A worker's housing complex is established for waste management after the disaster, categorizing materials that could be used for clean infill or rebuilding infrastructure. An existing warehouse is identified for sorting materials; trucks and barge boats are used for transportation (Figure 61).

Figure 61. Site plan illustrating clean up strategies and establishing workers' housing complex

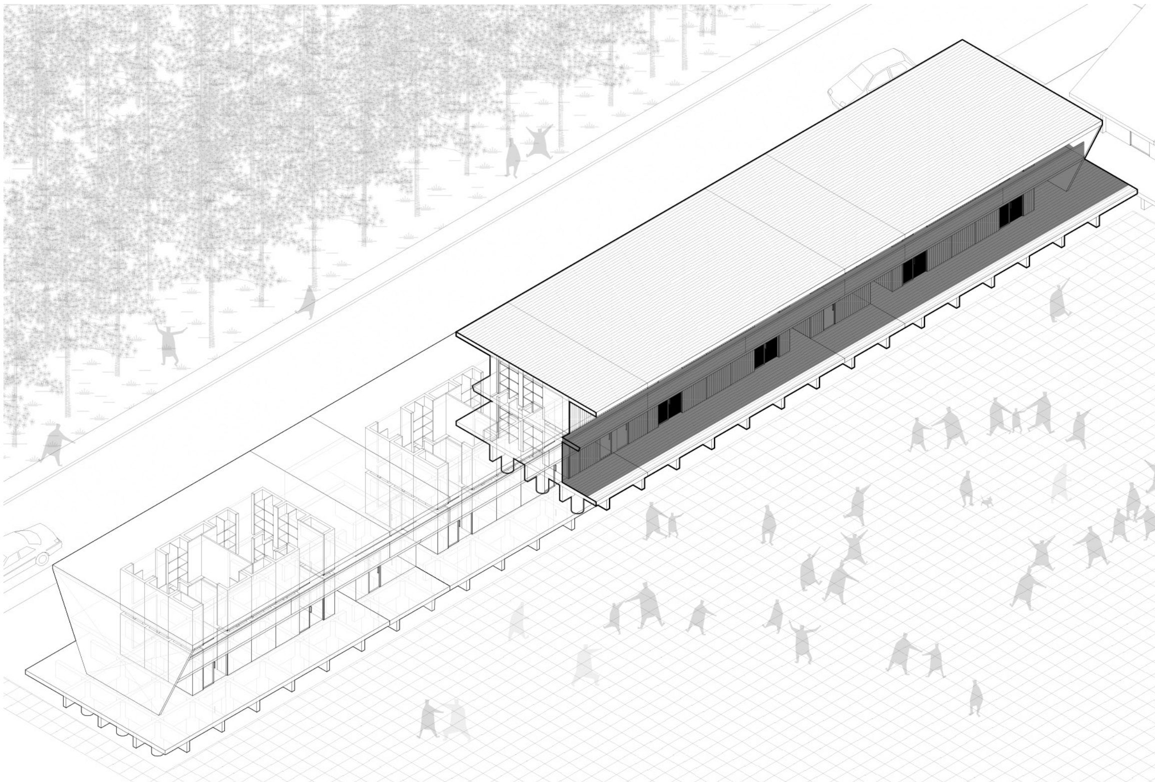

Figure 62. Axonometric drawing of the workers' housing complex in phase 1

Modular Housing Typology

Modular Cross Laminated Timber units are used to create a structure that could be stacked, where the function of the units can change from being worker's housing into classrooms and workshops when in need (Figure 63).

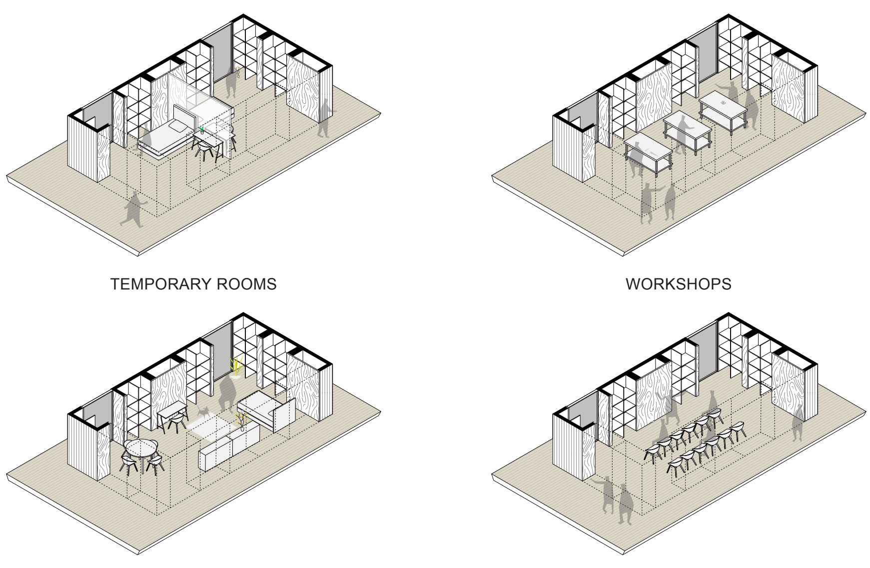

Figure 63. Axonometric drawing of modular rooms with adaptive programs

Structural System

The system uses a shallow pile foundation with interlocking CLT panels as the floor connectors. The structural CLT furniture modules, connected by friction wood joints, is used to create spaces. Isolated stairwells are used as shear cores, which are tied to the floors plates by tension (Figure 64).

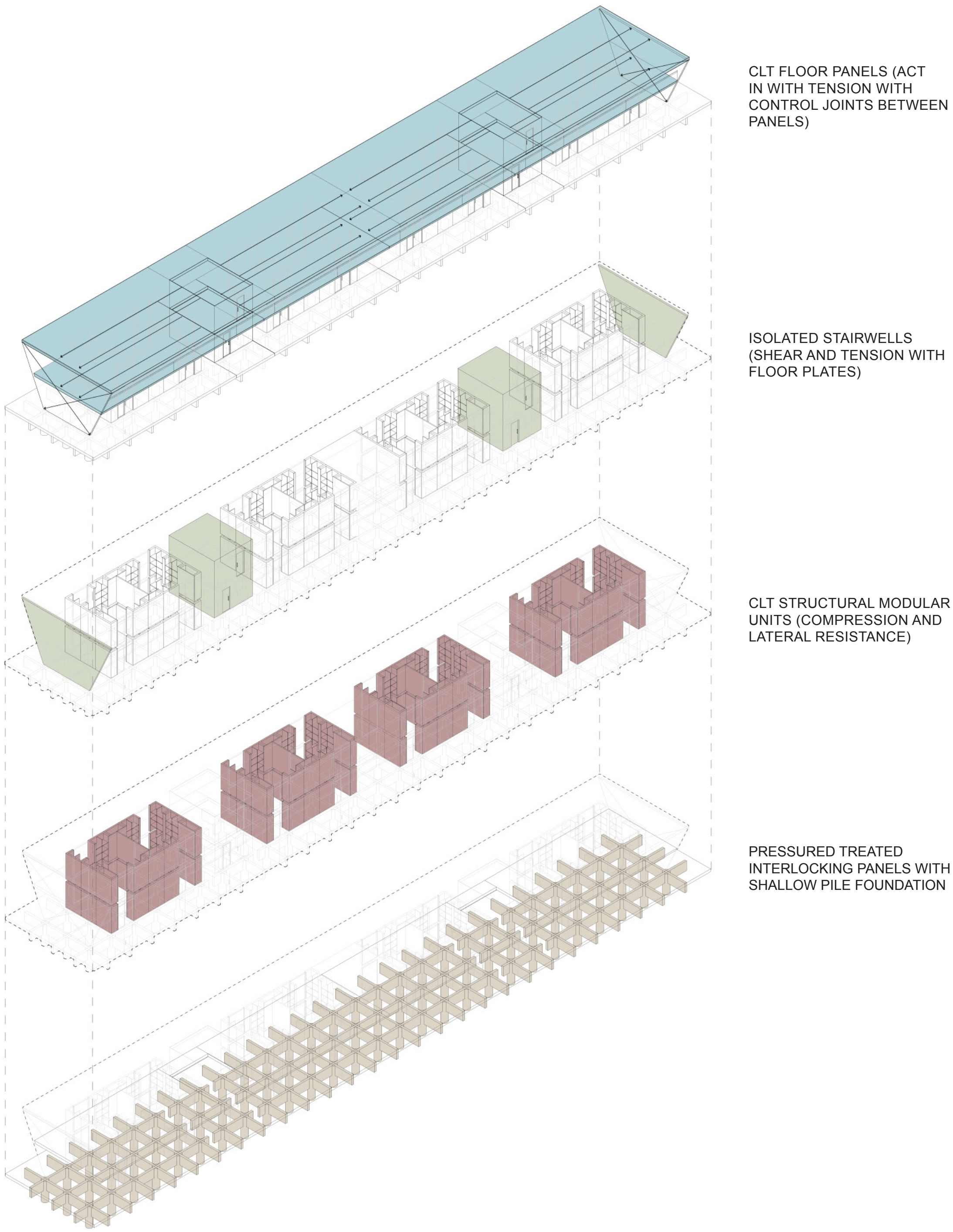

Figure 64. Axonometric drawing of the modular structural system

Building Assembly

The building envelope is formed by a series of wood joint connections between the floor, walls, and roof. A rain screen facade is detailed for moisture protection, and a green roof assembly is installed to create a heavy roof that compresses each floor into place (Figure 65).

Figure 65. 1:30 Sectional perspective of the building assembly for phase 1

Presentation Model

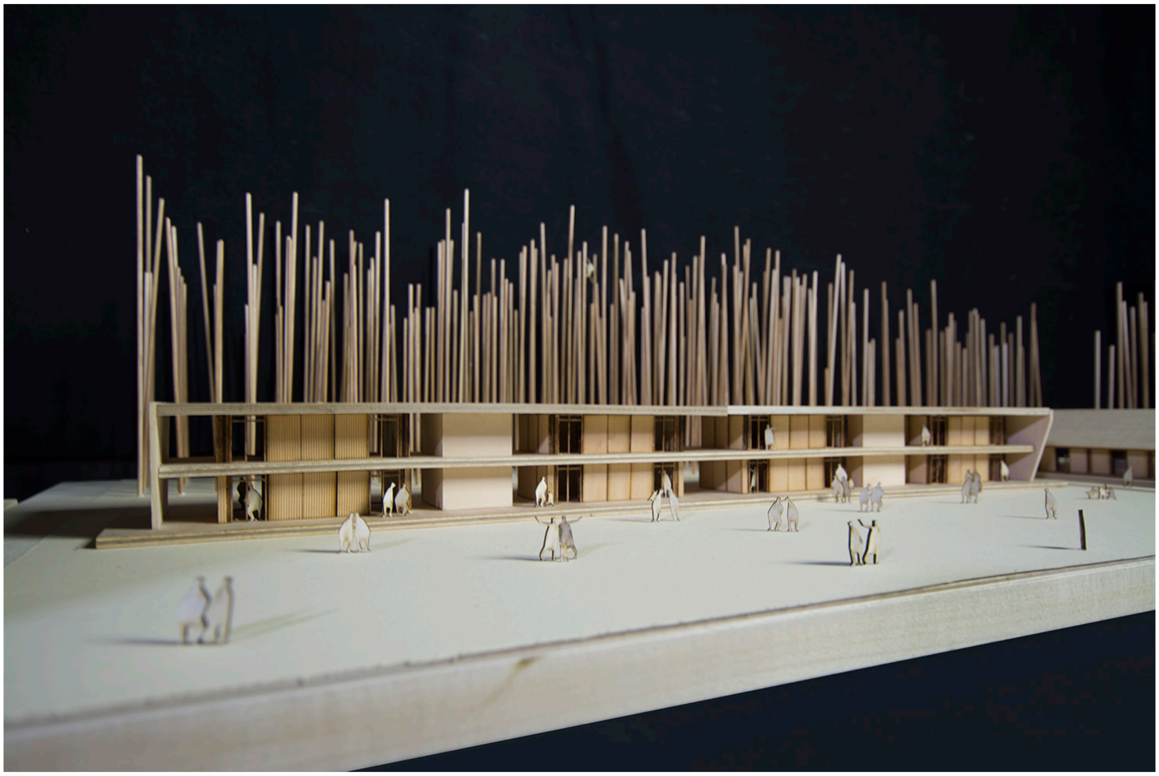

Figure 66. 1:100 Concept model of the relief/ workers' housing building

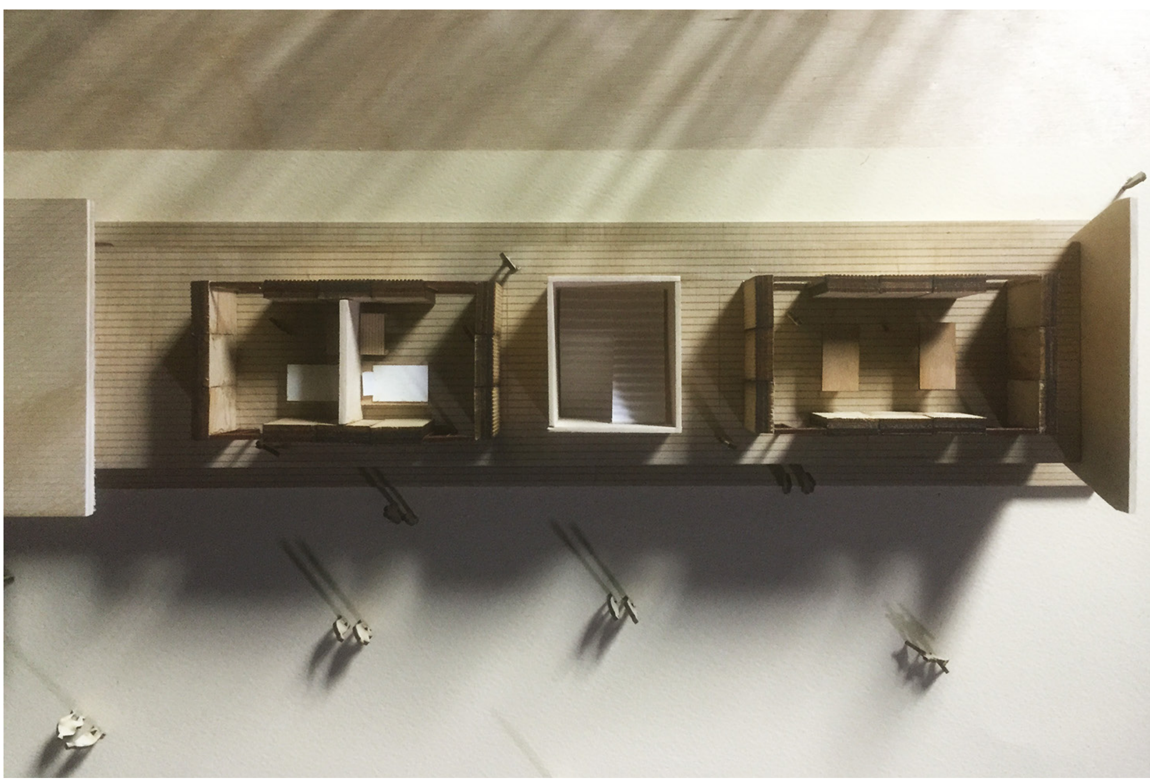

Figure 67. Aerial view of the interiors of the housing units

Figure 68. Photo montage of the tree planting sequence in phase 2

Phase 2: Community Wood Shop

Once clean up is complete, a green urban forest is installed as a natural barrier against the Avon river. A community wood shop is added to the worker's complex (Figure 69).

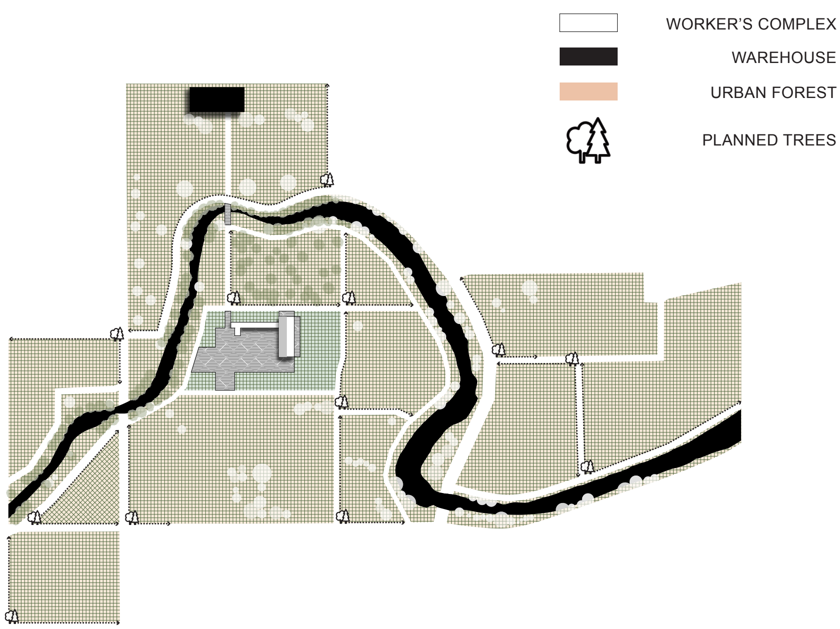

Figure 69. Site plan illustrating tree planting strategies and creating a community wood shop

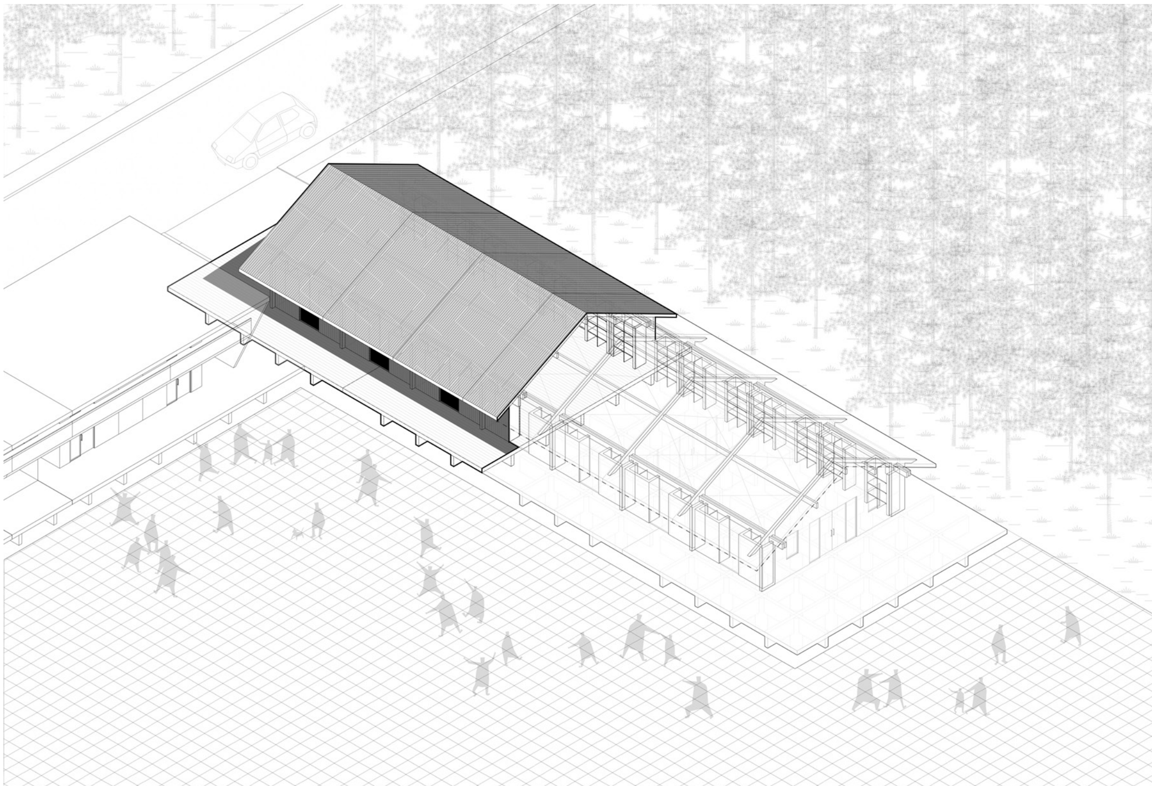

Figure 70. Axonometric drawing of the community wood shop in phase 2

Long Span Building Typology

The structure is created from the modular CLT units and moment frames, where the floor and roof act as diaphragms for lateral resistance. The wood shop creates a place of gathering for workers and the community, as it consists of a gathering hall, wood shop, and storage for building materials (Figure 71).

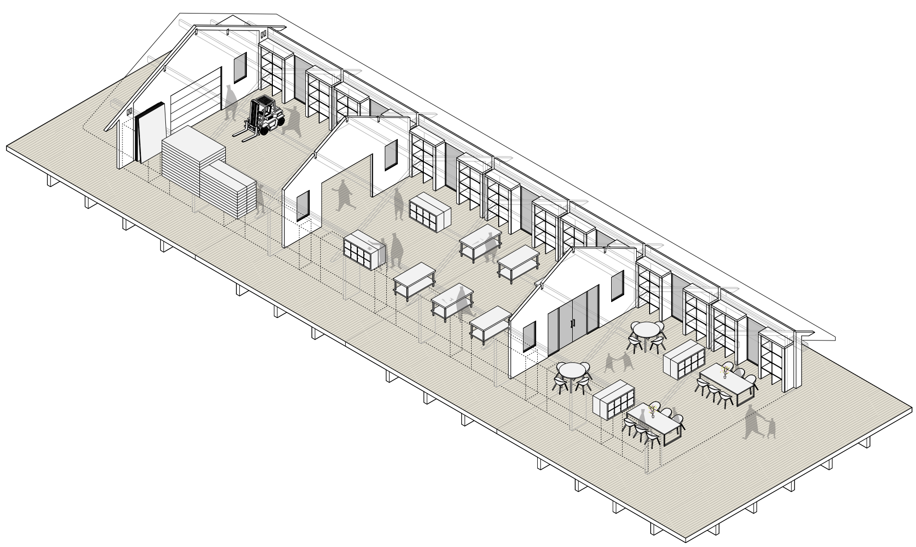

Figure 71. Axonometric drawing of the wood shop containing gathering programs

Structural System

A moment-frame/ structural modular system is used for a long span building typology. The structure is separated into compartments that are connected by a series of control joints to allow for movement during an earthquake. CLT roof panels and cross braces are used for lateral resistance (Figure 72).

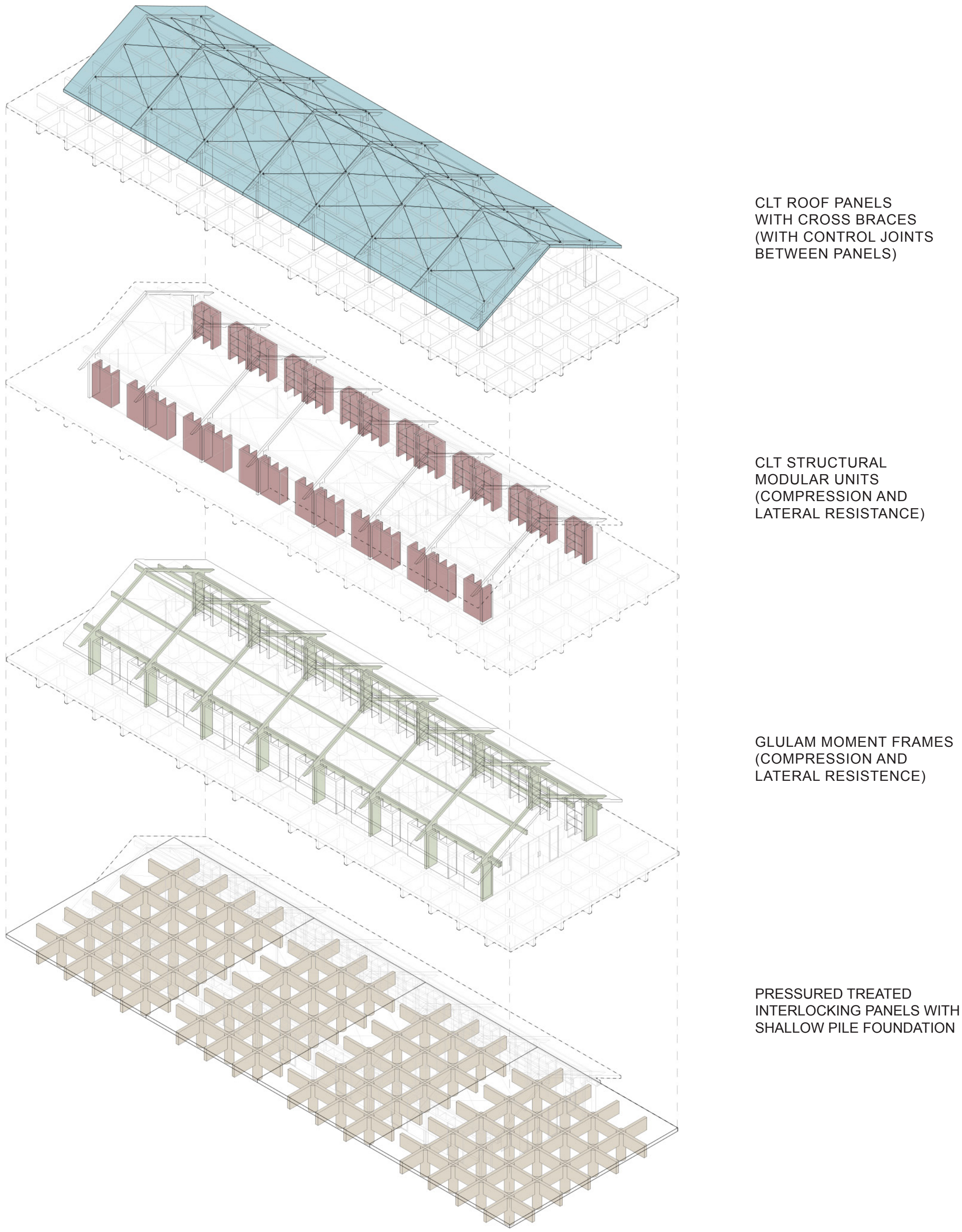

Figure 72. Axonometric drawing of the long span structural system

Building Assembly

Similar to phase 1, the building envelope is formed by a series of wood joint connections between the floor, walls, and roof. However, the glulam moment frames are connected with self-tapping fasteners for creating moment connections. In addition, cross braces are installed on the underside of the roof for redundancy in lateral resistance (Figure 73).

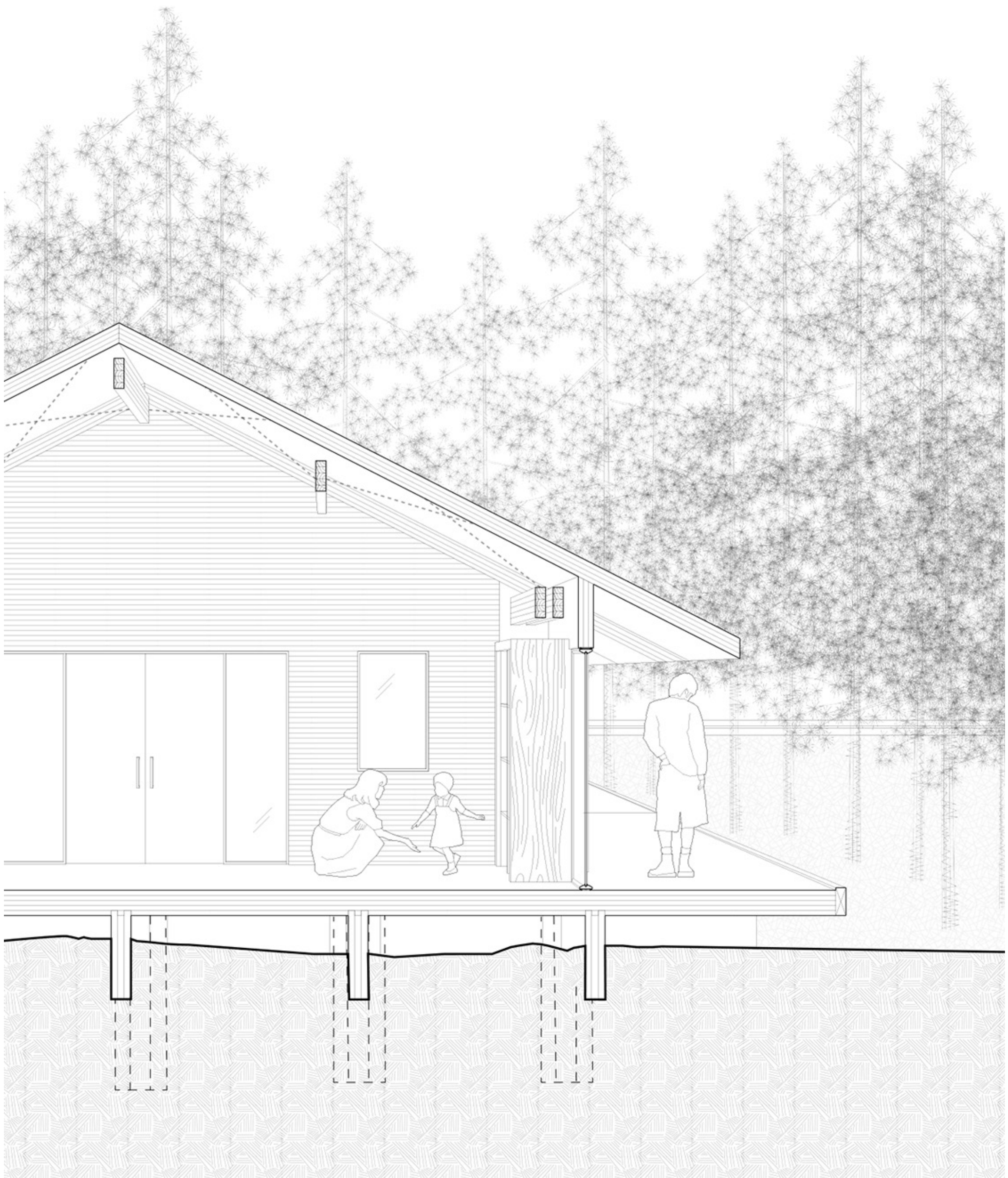

Figure 73. 1:30 Sectional perspective of the building assembly for phase 2

Presentation Model

Figure 74. 1:100 Concept model of the community wood shop

Figure 75. Perspective of the main entrance to the wood shop

Figure 76. Photo montage of the rebuild in phase 3

Phase 3: Education Center

Upon completion, the wood shop will manufacture building assemblies to be shipped to the next rebuild site. A community education center is built for sharing knowledge and techniques to rebuild. (Figure 77).

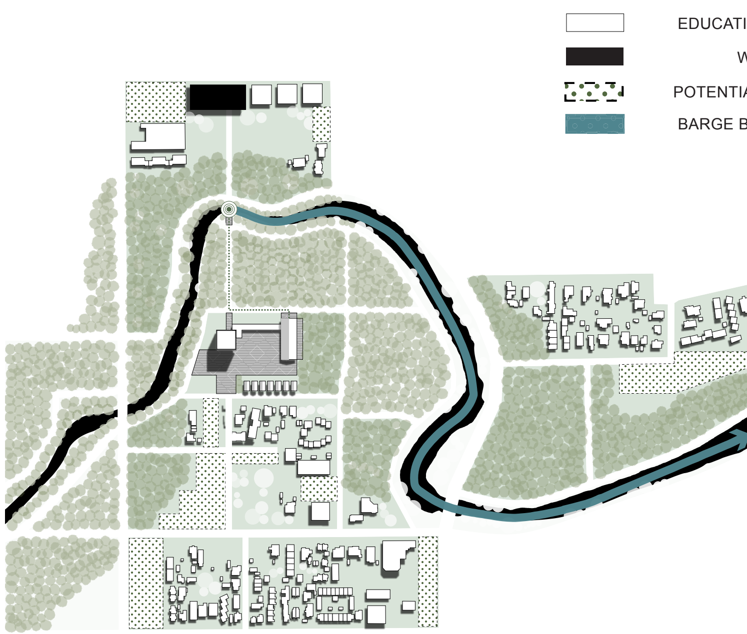

Figure 77. Site plan illustrating rebuild strategies and creating an education center

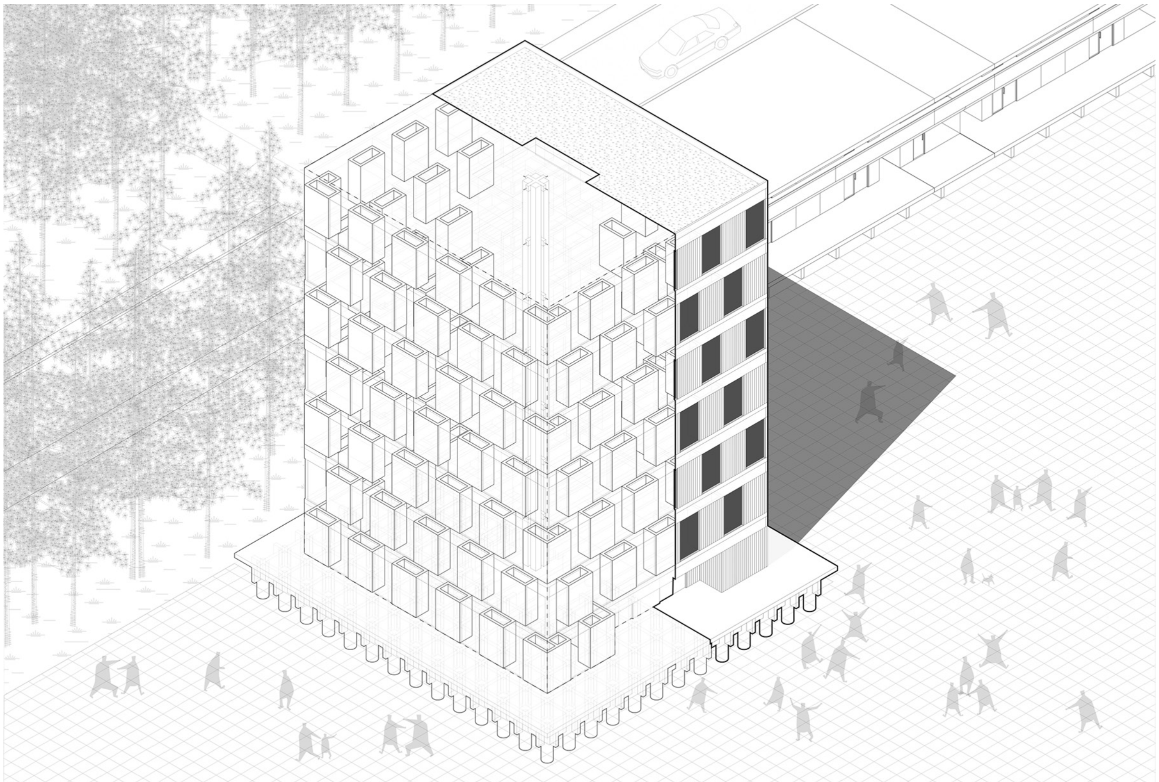

Figure 78. Axonometric drawing of the education center in phase 3

Education Center: High Rise Building Typology

The modular pieces are spaced and staggered from floor to floor, creating a single skin structure that is tied down to a central column at each floor plate. The floors act in tension with the column for lateral resistance. The education center serves as a place of gather and a place of shelter depending on the community's needs (Figure 79).

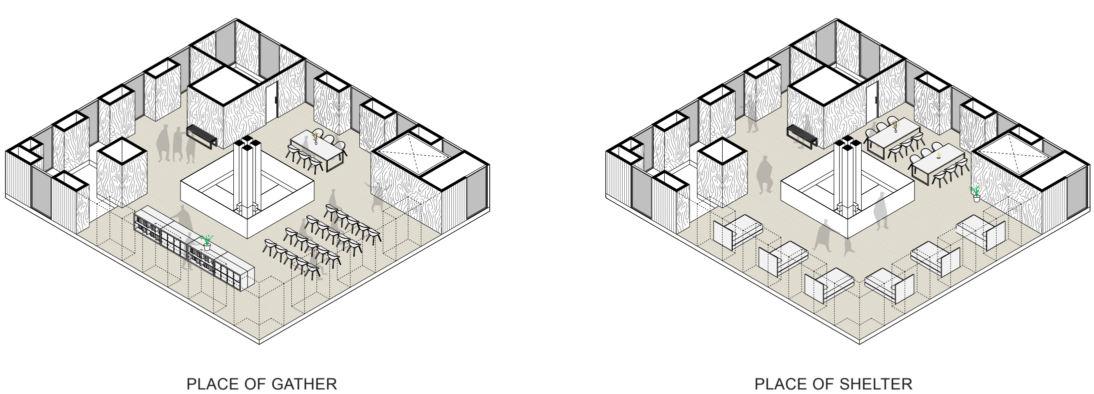

Figure 79. Axonometric drawing of the community containing gathering/ shelter programs

Structural System

The modular system is staggered and overlapped between each floor to create a 'skin-like' facade for each elevation. The overlap allows compression forces to be carried down to the ground and creates continuous shear walls for each facade. A central column is used support the roof structure while being put into tension with each floor (Figure 80).

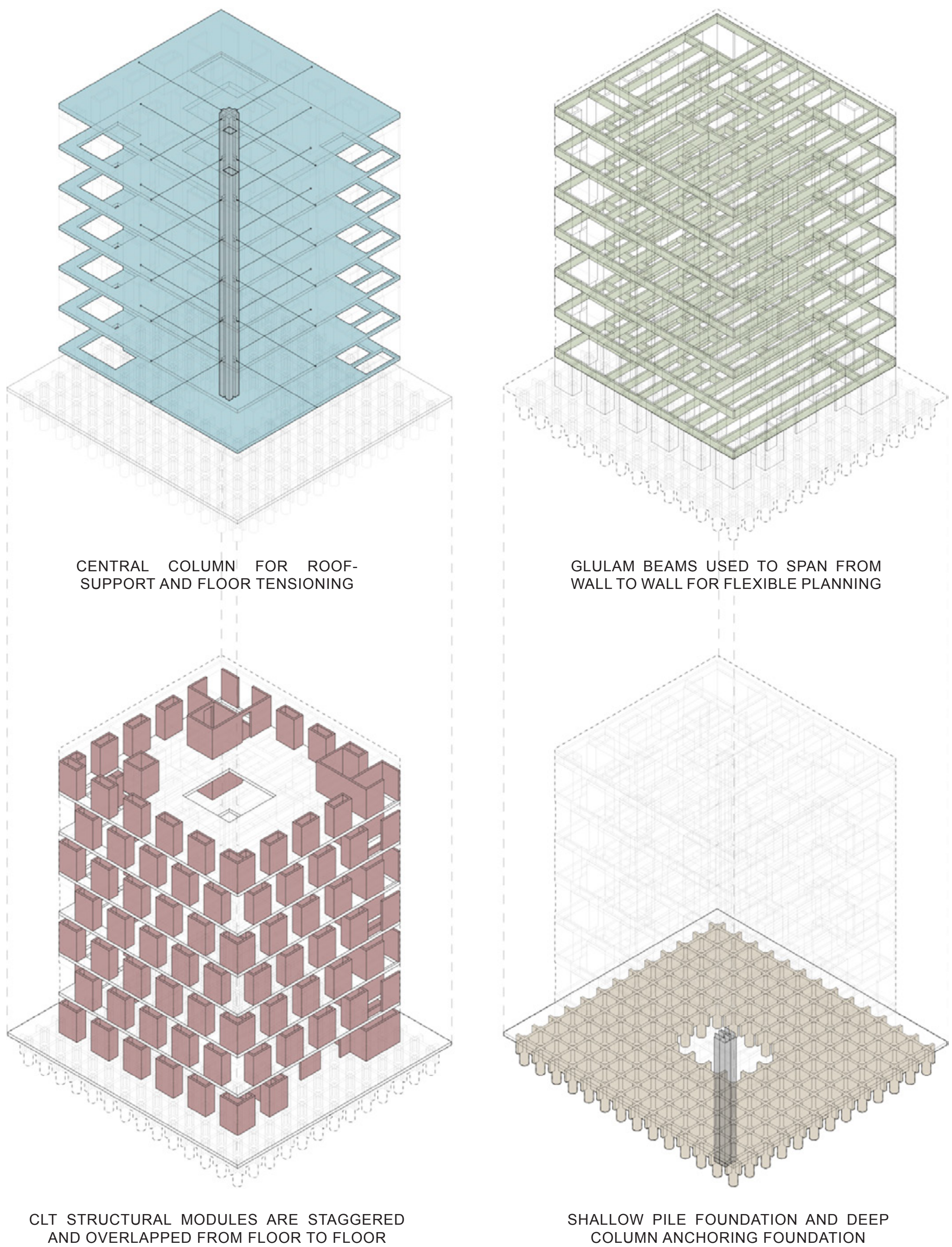

Figure 80. Axonometric drawing of the high rise structural system

Building Assembly

Similar to the previous phases, the building envelope is formed by a series of wood joint connections between the floor, walls, and roof. A system of glulam beams are used to allow for a free plan configuration for each floor. A rain screen facade is detailed for moisture protection, and a green roof assembly is installed to create a heavy roof that compresses each floor into place (Figure 81).

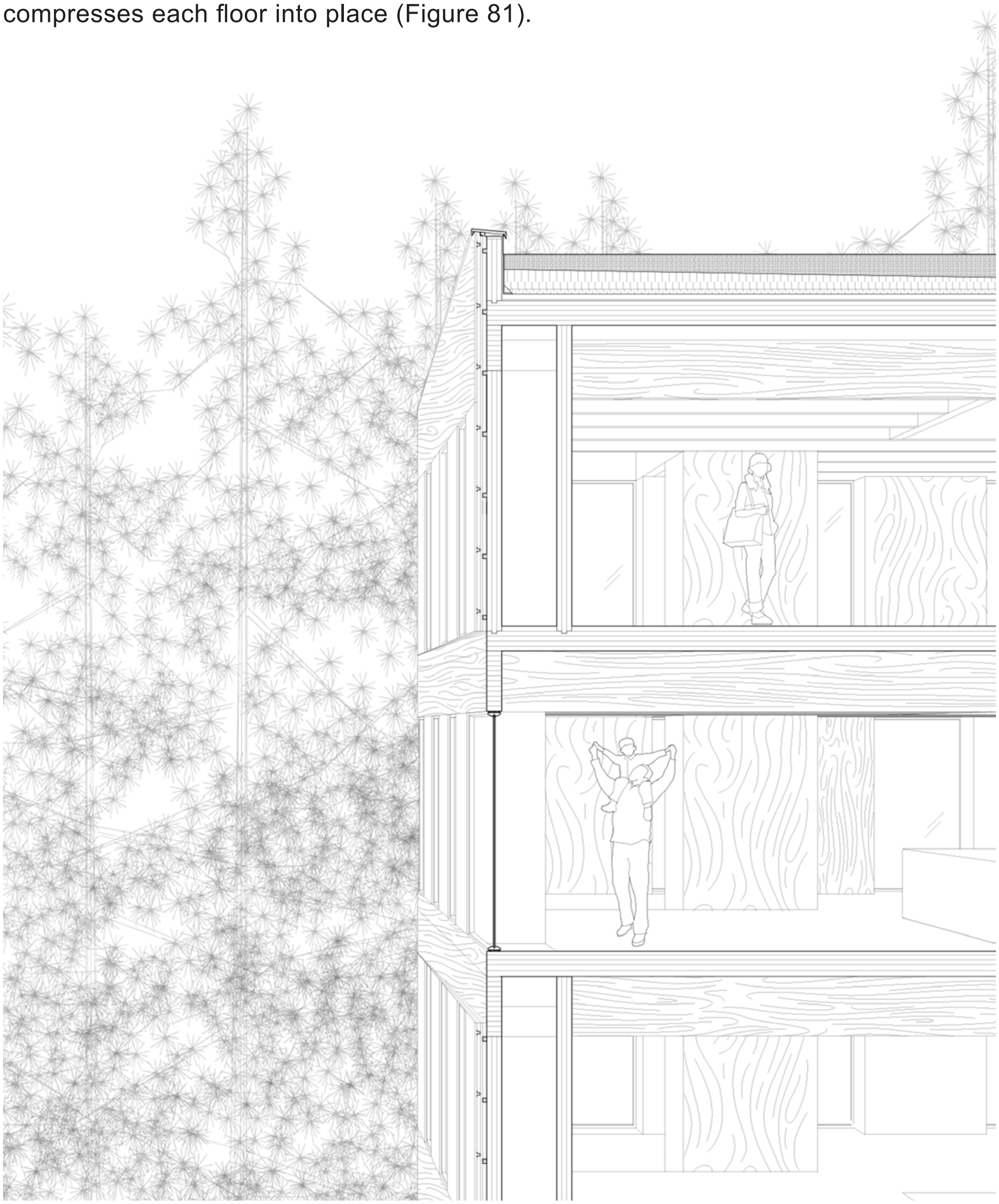

Figure 81. 1:30 Sectional perspective of the building assembly for phase 3

Presentation Model

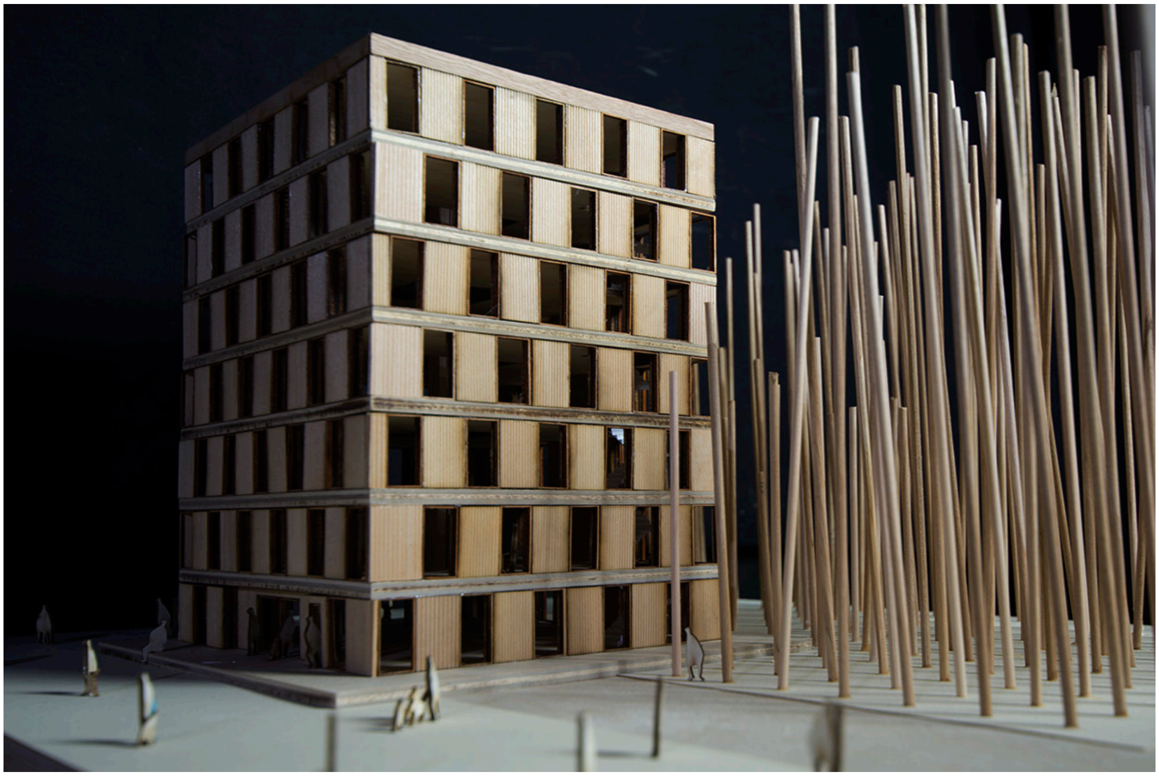

Figure 82. 1:100 Concept model of the education center

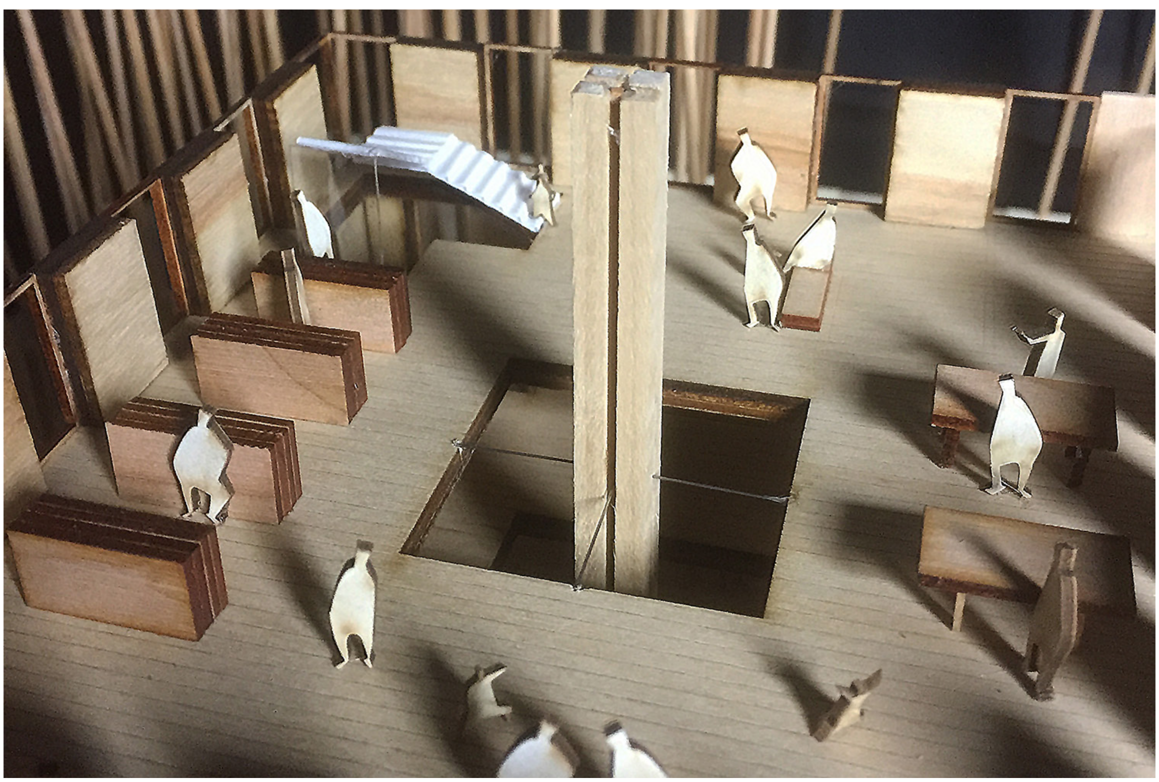

Figure 83. Aerial perspective of the community center interior

CHAPTER 7: REBUILD TOWARDS A PRIMITIVE FUTURE

The overall strategy for rebuilding in Christchurch within each of the 3 sites represents an adaptation of structure that pairs up structural assemblies that have been described in the kit of parts. The architectural form becomes secondary to how the system pairings adapt to different building types. A system created from structural CLT modules, CLT floor panels and isolated stairwells are used to create workers' housing; structural CLT modules and moment frames are used for the community wood shop; and structural CLT modules, tensioned CLT floor panels, and a central column system is used for the educational center. These pairings demonstrate how the integrated whole is stronger and more resilient than the sum of its parts, creating a layered system designed for structural redundancy. In doing so, architecture is formed that allows for social programs that can adapt to a community's needs through time. Each building is designed to have multiple uses, serving as a place of gather and a place of shelter when an earthquake occurs in Christchurch.

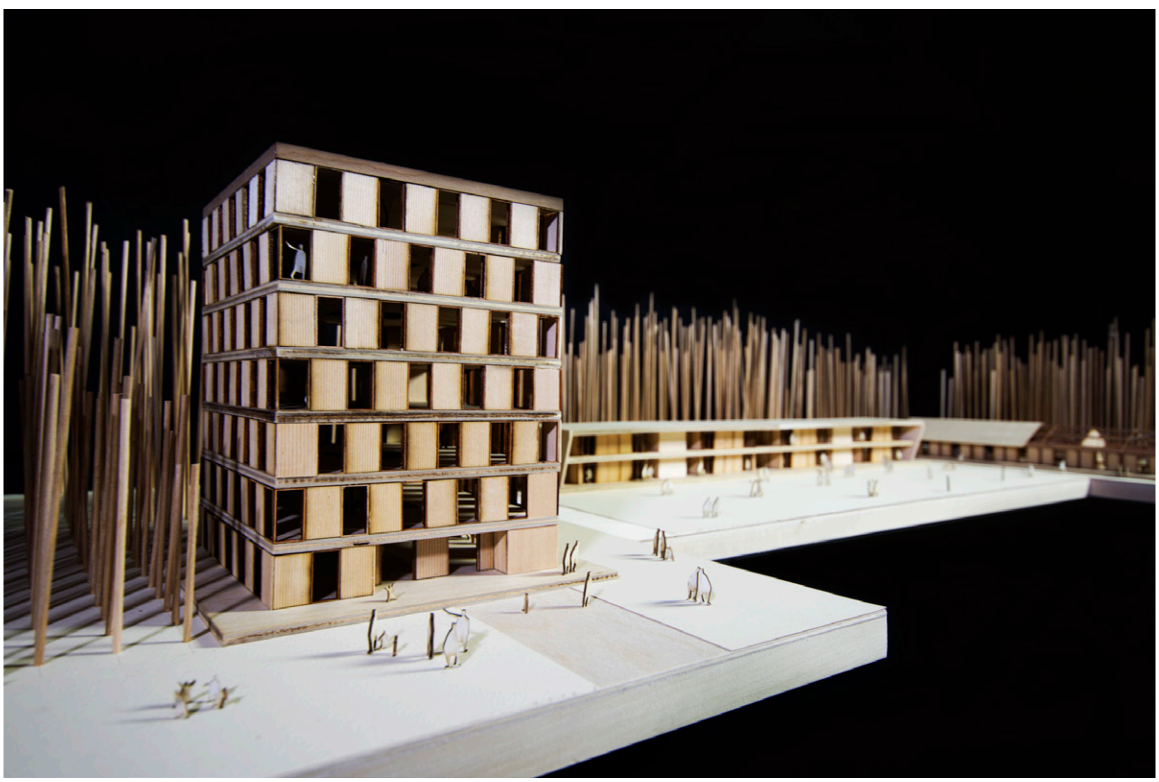

Figure 84. 1:100 Concept model of the emergency education complex

More research is required to further examine different types of building assemblies and how they interact under different seismic scenarios. In addition, further development for the wood joint connections are needed to determine its allowable thresholds when under lateral stress. A large scale mock up of these connections can give an accurate reading of how different connectors interact with the material during an earthquake simulation. It can also help determine the type of wood joint to be used in different scenarios, creating stronger connections between the floor/wall/roof assemblies.

Throughout the process, we can see how the definition of community resilience can be translated into a set of architectural and potential programmatic strategies for post-earthquake environments. We must understand the definition of resilience to determine where and how to rebuild. At its very core, the thesis creates a layered strategy that incorporates the social and cultural needs to understand knowledge, gather, shelter, safety and social empowerment that deals with the bigger issues of how, what, and where we rebuild. It is a strategy applicable to all cities that are susceptible to earthquakes and soil liquefaction, where communities need to create spaces with adaptability and rebuild with a new resilience and a sustainable primitive future.

APPENDIX A: RECONSTRUCTION MASTER PLAN, CONSTITUCION, CHILE

A post-tsunami reconstruction master-plan was developed by Elemental after an 8.8 Earthquake that struck Constitución in 2010. Being a coastal country, Chile cannot afford to abandon developing around the shores. Evidence shows that infrastructure is useless to resist the energy of displaced water. Hence a geographic strategy was proposed. Firstly, a coastal forest able to produce enough friction to reduce the energy of the waves instead of trying to resist them. The topography underneath has to be rough and bumpy to repel and dissipate the waves' momentum, minimizing the area with prohibition of use and habitation. In addition, a sculpted terrain designed to help dampen the effects of seasonal river flooding, occasional tsunamis and rising sea levels. It offers a fresh way of thinking about how cities can contend with the ravages of climate.

Figure 85. Alejandro Aravena, Illustration of creating a coastal forest as a natural barrier against water dissipation and tsunamis, 2011; from Aravena, Elemental: A do Tank.

APPENDIX B: VALPARAÍSO CULTURAL CENTER, CHILE

Many architects have created work that can be classified as an antipattern that can be harmful to an urban environment. Valparaíso, regarded as the cultural capital of Chile, was in need of a world-class performance and exhibition space within the city. The municipality invited Pritzker award winner Oscar Niemeyer for the initial design, which included a theater opening toward both a 300-seat theater and a plaza. The complex was to be built on the site of a former jail, a space which local artists had occupied for years. However, many community members charged that the proposed structure did not respect the Valparaíso's traditional aesthetic and would rob local artists of a space in which to carry out their activities. By superimposing a new design on to the urban fabric, Niemeyer created an antipattern that was not suited for Valparaiso.

The government decided to retract Niemeyer's design and held a public competition to select an architect to design the cultural center. The winning proposal, by H.P.L.S. Arquitectos, created a scheme that incorporated all of its existing context. It is based on three areas of different environments from the adaptation of the prison, the consolidation of the park within the cloister and the incorporation of a new public building that contributes to the existing urban environment.

Figure 86. Taking advantage of the flat condition of the site, a horizontal section cut of the existing wall is made to maintain the relationship between the site and its neighbourhood.

Figure 87. H.P.L.S. creates an urban intervention that can be a part of the city plan by programming the roof of the new building as exterior parking and creating a multipurpose place for the community.

The design was intended to intensifying existing pedestrian routes by creating an independent and recognizable connector piece from the exterior street into the cloister, which connects both sides of the site and establishes a connection with Alegre and Concepción hills. It is an urban intervention that became a part of the city plan by programming the roof of the new building as exterior parking and creating a multipurpose place for the community.

The proposal was able to analyze and recognize the existing patterns within the urban fabric and apply an organic approach to build on the site. As shown in this project, a pattern language is necessary for creating a catalogue that can organize complexity into a mutually adaptive system.

APPENDIX C: THE HALF GOOD HOUSE, ELEMENTAL, CHILE

As a part of my Rosetti Scholarship Project, my research focused on the social housing projects by Elemental, concentrating on the 'half good house' typology and it's creation of a 'spirit of place'.

The typology began as a way of dealing with extremely low budgets, allowing governments to provide housing to citizens at incredibly low prices, but nevertheless creating homes that would provide for the needs of residents and even gain value over time. The practice accepted all the restrictions and re-framed the problem of social housing.

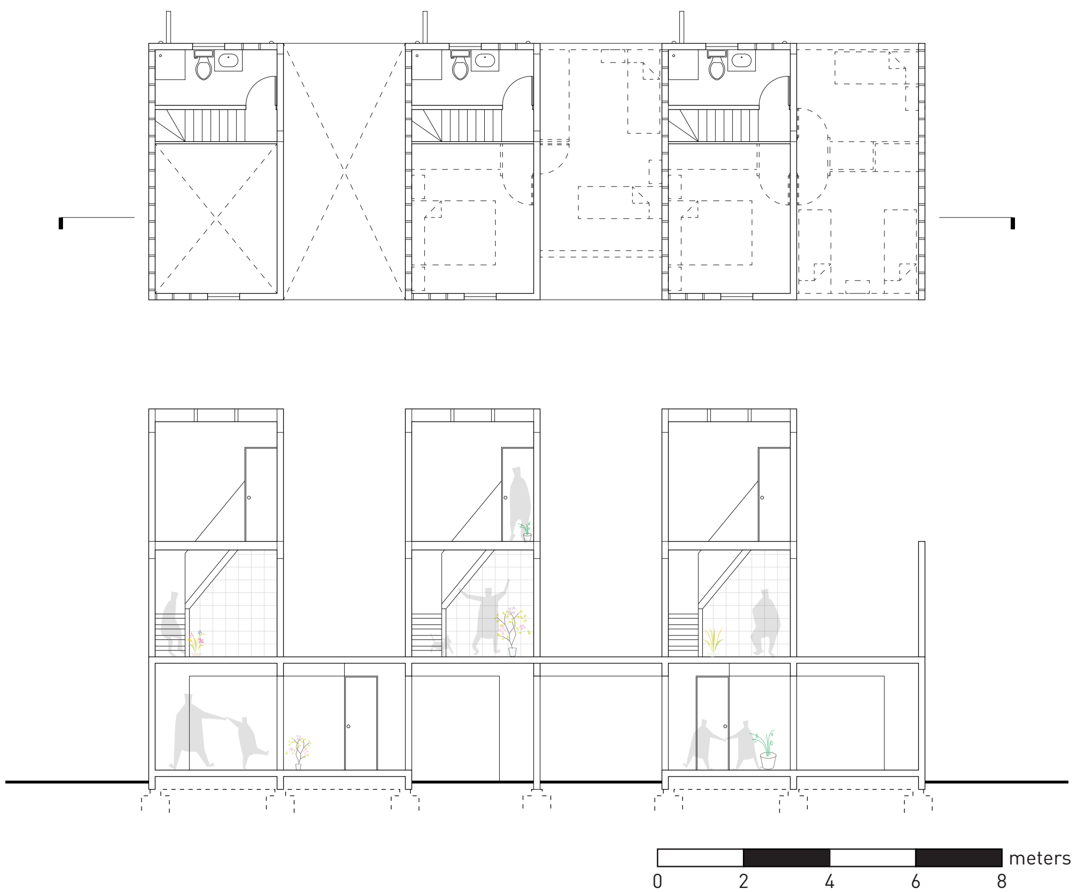

Figure 88. Floor plan and sections of the modular housing units created for incremental design by Elemental, data from Aravena, Elemental: A do Tank.

1) Half of a good house instead of a small one. Instead of considering a 30 - 40 square meters small house, why not try to think of a 30 - 40 square meters as half of a medium income good house, building half of the house that a family cannot afford on their own.

2) A unit able to gain value over time. Identify a set of design conditions that could make that public money gain value over time and perform as an investment rather than a social expense.

The Half-house typology has been a successful implementation of an open modular system for domestic scale buildings. However, the sense of ownership and community does not extend beyond the walls of the housing developments. Can this design method be translated into the scale of a public building, where a strong level of engagement from the community can help development a place where everyone can feel they belong; where they feel they can be at home.

Figure 89. The modular units are modified according to each family's take on their own identities.

APPENDIX D: TREE SPECIES INFORMATION

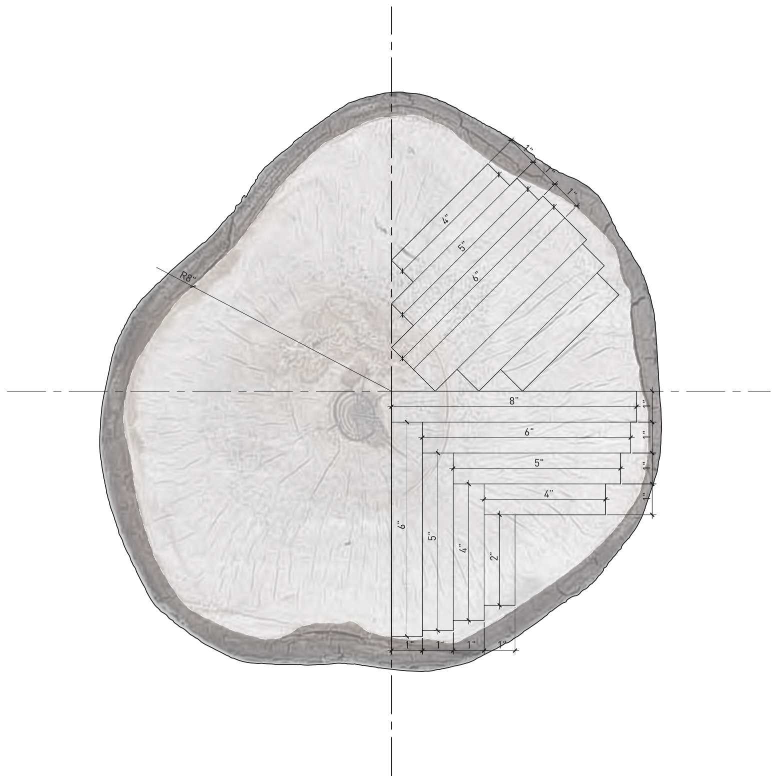

Figure 90. White birch tree log section with potential standard lumber cuts; data from Timber Processing: Lumber, Composites and Engineered Products.

White birch

White birch has been a native species found in New Zealand for generations. It is used for lumber, veneer, plywood and pulpwood. White birch has the potential to produce high-value lumber. The species has long been a favorite of the wood turning industry for domestic products such as dowels, pegs, and toys and finish quality building materials such as plywood and exterior cladding finishes.

White birch has commonly been used as fireplace and wood stove fuel because it has a high heating value. In addition, the sap of white birch is made into syrup (though requiring 2 to 3 times more sap than sugar maple). In their natural environment, white birch generally live about 80 to 100 years. In the stressful environment of a typical lawn, birch only live about 30 to 40 years.

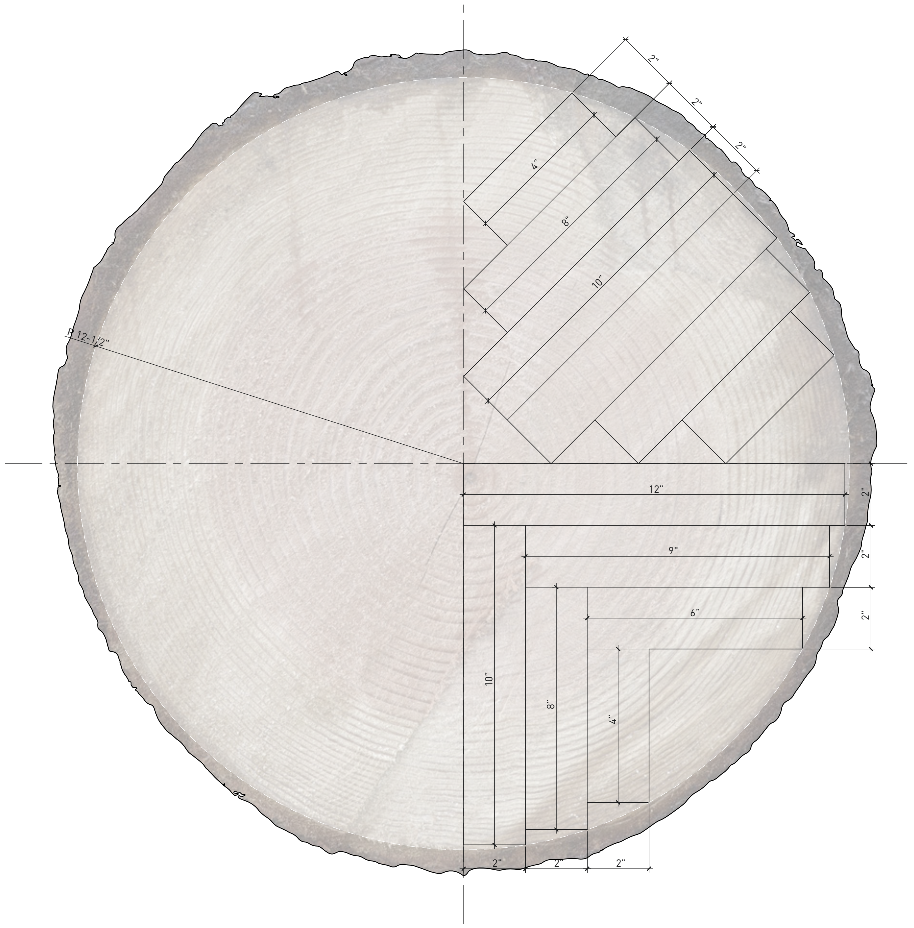

Figure 91. Douglas-fir tree log section with potential standard lumber cuts; data from Timber Processing: Lumber, Composites and Engineered Products.

Douglas-fir

While Douglas-fir is an imported species, it has been planted for over a century within the country. It is primarily used for building and construction purposes due to its strength advantages and availability of large dimensions from old-growth trees. It is one of the finest timbers for heavy structural purposes, including laminated arches and roof trusses. Structurally, it is used in the form of lumber, timbers, pilings and plywood.

Decay resistance helps this species live to great age; trees 600-800 years old are not uncommon in certain parts of its range with long fire return intervals. Trees 1,000 years or older have been recorded from several parts of its range, including several individuals between 1,300 and 1,400 years old.

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