

**INTEGRATING STRUCTURE, SYSTEMS, AND SPACE:  
CLT + STEEL**

by

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## **ABSTRACT**

This thesis examines building system integration for Cross-Laminated Timber (CLT), an emerging engineered wood building product. CLT is structurally robust, constructionally efficient, and environmentally friendly, but the fledgeling product remains under-utilized, and its full potential has not been realised. As a versatile and highly advantageous alternative to conventional structural systems, newly engineered wood products such as CLT could leapfrog concrete and steel structural systems. Despite its benefits having a vast amount of documentation, the development and exploration of CLT as part of a fully integrated building system have been limited. The study of critical junctures ranging from the scale of the detail to the size of the building will investigate opportunities to realise the benefits of CLT entirely. This thesis proposes a multi-functioning steel system to complement and complete CLT. A series of steel seams integrate both the structural connections and building services simultaneously. The multi-functioning steel components will further develop how connections and systems can be woven together to create a clean, minimal architectural expression. Ultimately, the steel system will highlight and expose the full functionality and beauty of CLT, while making an undressed wood building.

## **ACKNOWLEDGEMENTS**

This thesis is dedicated to my mother, Carolyn Campbell; you are the strongest person I know and I am blessed to have you as my mother. Thank you for your continual support, your strength and your love.

This thesis is in memory of my father, George Campbell; you were a natural architect and you taught me to work and build with my hands, Thank you. We miss and love you.

To the rest of my family; Taiya, Jake and Jessie I could not have done this without you. Thank you so much.

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## **CHAPTER 1: INTRODUCTION**

### **Material Culture**

#### **The Contemporary Disconnect**

##### *Material and Meaning*

Architecture exists at the intersection between humans and the natural environment. At its most fundamental level, the need for shelter leads us to create structures from materials gathered from the environment. These structures, in turn, either beautify or degrade the environment. Through this very basic yet crucial activity, architecture becomes an integral part of the environment and participates in a cycle that makes our existence possible. Architecture, as the tectonics of materials coming together to make usable space, requires vast amounts of natural resources. The appropriation and extraction of these resources can be either done responsibly or destructively. Despite the balance and resilience of the environment, our place within it has become increasingly fragile and dangerously uncertain. The unforeseen consequences of human development have had dramatic and often adverse effects, such as global warming and climate change, and have set off an irreversible chain of events. These changes have ultimately resulted in the degradation of the world we live in and have put our very existence into question. It is paramount that the ways in which we build are deeply rooted in nature, bearing in mind that the economy of the environment is essential to our survival.

There is an increasing disconnect between the building practices that we employ and the values that we supposedly hold. The material culture in which we currently find ourselves often overlooks the negative impacts of materials such as concrete because of the convenience that they provide. Deeply entrenched building practices in the design and construction industries have produced a kind of inertia, that even if we recognise their inherent destructiveness, continue to be used. Every material choice in architecture, whether directly or indirectly, has implications on the environment and communicates our relationship to the world we inhabit. Each material has advantages and disadvantages regarding their extraction, manufacturing, production and use. Set in our ways, we seem to have forgotten the importance of preservation and are ignorant of the effects that we have on the environment. Our actions have compromised our ability to adapt our practices and have subsequently propelled and subjected current and future generations to a perilously fragile environment.

##### *The Challenges of Today*

The construction and maintenance of buildings comprise 50% of all resources we use (Pérez-Lombard et al. 2008, 394). With climate change, we are obligated to redefine our building methods. It is imperative that architecture begins with appropriate materials choices that reflect our values. Rapid growth since the industrial revolution has spurred sloppy, unforeseen and

unsustainable development (Singh 2010). The repercussions of this are being felt currently and have forced us to reconsider how we design and build.

That being said, we need to look back at what we have done well rather than reject the past as a mistake. We need to improve upon what works to develop alternatives that are motivated by our values. As Michael Green notes in *Tall Wood* (2012), “For more than a century, mid-rise and tall buildings around the globe have been built predominantly in concrete. These two existing materials have been excellent choices and will continue to be valuable materials in the construction of all buildings in the future... It is clear that the very fundamentals of what materials we build our buildings with are worth re-evaluating” (Green 2012, 11).

## **The Concrete Conundrum**

### *Modern Material*

As Adrian Forty wrote in *Concrete and Culture*, “concrete tells us what it means to be modern. It is not just that the lives of people in the twentieth century were transformed by, amongst other things, concrete – as they undeniably were – but that how they saw those changes was, in part, the outcome of the way they were represented in concrete”(Forty 2013, 14). For the last century, concrete has arguably been the most impactful material in architecture. It has been at the forefront of nearly every architectural movement and has changed the way that we conceive of the spaces we inhabit. Developed by the Romans more than 2000 years ago, concrete was almost entirely forgotten about as a building material until its structural capabilities were re-discovered at the turn of the 20th century. From the open floor plan to the skyscraper, concrete has shaped our cities and, in turn, our lives.

### *Adaptability*

One of the most influential early projects to adopt concrete as a structural material was the Dom-ino House (fig. 1 below), designed by a young Le Corbusier as he was starting his architectural career. The remarkably simple idea consisted of concrete slabs held up by thin reinforced columns and connected by a solid concrete stair (McGuirk 2014). Made possible by reinforced concrete, the simplified architectural expression changed the way structure and space function. The rediscovery of reinforced concrete as a material that could span long distances and therefore create an open floor plan relatively free of structural columns. Open floor plans with no load bearing walls meant that rooms and space could be designed and laid out independently of the structure, allowing variety, flexibility and adaptability over time (Brejzeck and Wallen 2014).

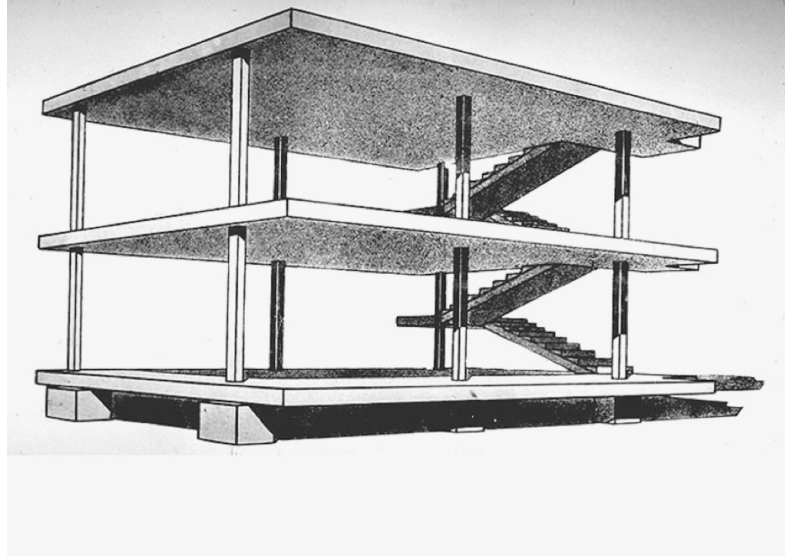


Figure 1. Perspective view of the Dom-ino system, 1914, image from Le Corbusier & Pierre Jeanneret (Vittorio et al. 2012).

### *Constructability*

Experimenting with the aesthetic properties of an otherwise basic or practical building material has always been a hallmark of the discipline of architecture (Weston 2003). California architect Irving Gill pioneered the technique in the 1920s; factory assembly lines inspired him. In the real modernist tradition, he refined a planar, undecorated aesthetic with engineering efficiency (Dispenza 2014). Tilt-up construction is an efficient and effective method for raising a complex concrete façade without the tedious vertical forming process. Gill's contemporaries capitalized on his method of erecting modern concrete façades with even greater efficiencies (Dispenza 2014). Wartime economies, however, tipped the scale for tilt-up construction's ease of use, speed of erection, and low cost (Bloomquist 2013).

### *Height*

In addition to allowing for an adaptable, open floor plan and new ideas of constructability, concrete also made it possible to build taller. More than a century ago, the skylines of cities across the world were transformed by the concurrent development of concrete and steel. Supertall buildings are a relatively recent addition to cities around the world as nineteenth-century technology made their development possible (Ali 2001). Steel became a major component in commercial building construction. Steel replaced cast iron in the 1800s since its utilisation for constructing the first skyscraper in Chicago (Ali 2001). It was discovered that structural steel beams set in concrete allowed for fire resistant and more structurally sound construction. The history of a concrete high-rise building is established in technological developments that occurred at the beginning of the twentieth century.

E. L. Ransome designed a system for framing square, twisted, steel bars with concrete slabs. The exterior concrete walls were used in the Ingalls Building in Cincinnati, the first 15-story concrete skyscraper built in 1903 by A. O. Elzner (Ali 2001). Every significant development that had been made by then was taken into consideration in designing the Ingalls Building. Standing 210ft (64m) tall the building utilised a massive monolithic beam-column framing system (Ali 2001). The floor slabs contained two-way reinforcing systems; the beams were reinforced with bent bars near the supports, hoops and continuous helices were employed in the columns to tie the vertical reinforcement together (Harris 2001). Ransome's square and cold-twisted reinforcing bar were used for the steel throughout the entire building for horizontal as well as vertical support (Ali 2001). Until about 1960, very few concrete buildings exceeded the 20-storey high mark (LePik et al 2008).

### *Downside*

The ubiquitous use of concrete in modern architecture often symbolises progress, but as Adrian Forty tells us, (Forty 2013, 23), "concrete manufacturing accounts for up to 10 percent of all the world's CO2 emissions contributing to drastic changes in our planet's climate conditions." Forty also pointed out the problem with the constant use of concrete in building, despite the continuous technological advancement in the building and material science sectors. He mentioned that we should be more open to exploring the many options technology has made available. Concrete continues to weaken the environment with high embodied energy necessary to extract, produce and transport it (Weston 2003, 40), becoming more of an environmental issue each day, it is evident that it is a poor material choice that needs to be reconsidered and replaced with a more appropriate alternative.

### *What About Wood?*

What if these ideas can be expressed similarly with wood? Mass wood systems and products are emerging rapidly and are a kin to concrete tectonically. Recently a replica of the dom-ino system has been made using only engineered wood systems in place of concrete, showing how wood can do what concrete does equally as well.



Figure 2. Venice Architecture Biennale, 2014, German architect Valentin Bontjes van Beek and students from the Architectural Association in London have built a full-size model of Le Corbusier's seminal Maison Dom-ino in the Giardini of the Venice Biennale, photograph by Luke Hayes (Frearson 2014).

This thesis looks to mass wood as an alternative and successor to replace and limit the use of concrete where possible. Specifically the use of Cross-Laminated Timber, an emerging mass wood engineered product, possessing attributes qualifying it to become the construction solution and building method of the 21st century.



Figure 3. View of New York City, 2015, Michael Green's redesign of the Empire State Building with wood as the main material (Kunkel 2015).

## Cross-Laminated Timber

### How It's Made

Despite being a remarkably simple production process, CLT was only recently made feasible by developments in large-scale machining and computer-aided design (CAD) (Tan and Vonderembse 2006). First patented in France in the 1980s and later perfected in Austria in the 1990s, the process was conceived of as a way of reducing waste in saw mills (Zimmers and Groover 1984). The process begins by joining small, kiln-dried 2"X 6" pieces of spruce, pine, and fir boards end-to-end to create extra-long members (Weder 2015). The long ribbons of wood are then cut to their final length, loaded into a hydraulic press and positioned side by side (Stauder 2013). A coat of laminating adhesive is applied to the exposed surfaces, and then another layer of boards is placed on top, perpendicular to the first tier. Panels are composed of either three, five, seven, nine or more layers. After each layer has been glued, the panels are hydraulically pressed in multiple directions to ensure dimensional stability (Weder 2015). Once the adhesive has cured, the panel is sanded to its final dimensions. Depending on the requirements of the design, openings in the panel are then precisely drilled and cut by a computer numerically controlled (CNC) milling

machine according to CAD drawings (Brandner 2013). Most CLT panels are cut to forty feet long by eight-and-a-half feet wide by sixteen inches thick, to suit their roles as floors, ceilings, or supporting walls (Steiger 2010).

CLT panels can be made up to 98' long, 18' wide and 19.5" thick. Such massive structural wood panels could ultimately change the notion of what wood can achieve altogether. This surpasses what concrete can offer regarding prefabricated building components and moves into new territory of prefabrication and construction. The result is a highly precise and accurate prefabricated panel that is renewable, lighter, equally durable and more versatile in application. The capacity to design large scale infrastructure and buildings from wood could shape an entirely different more promising future.

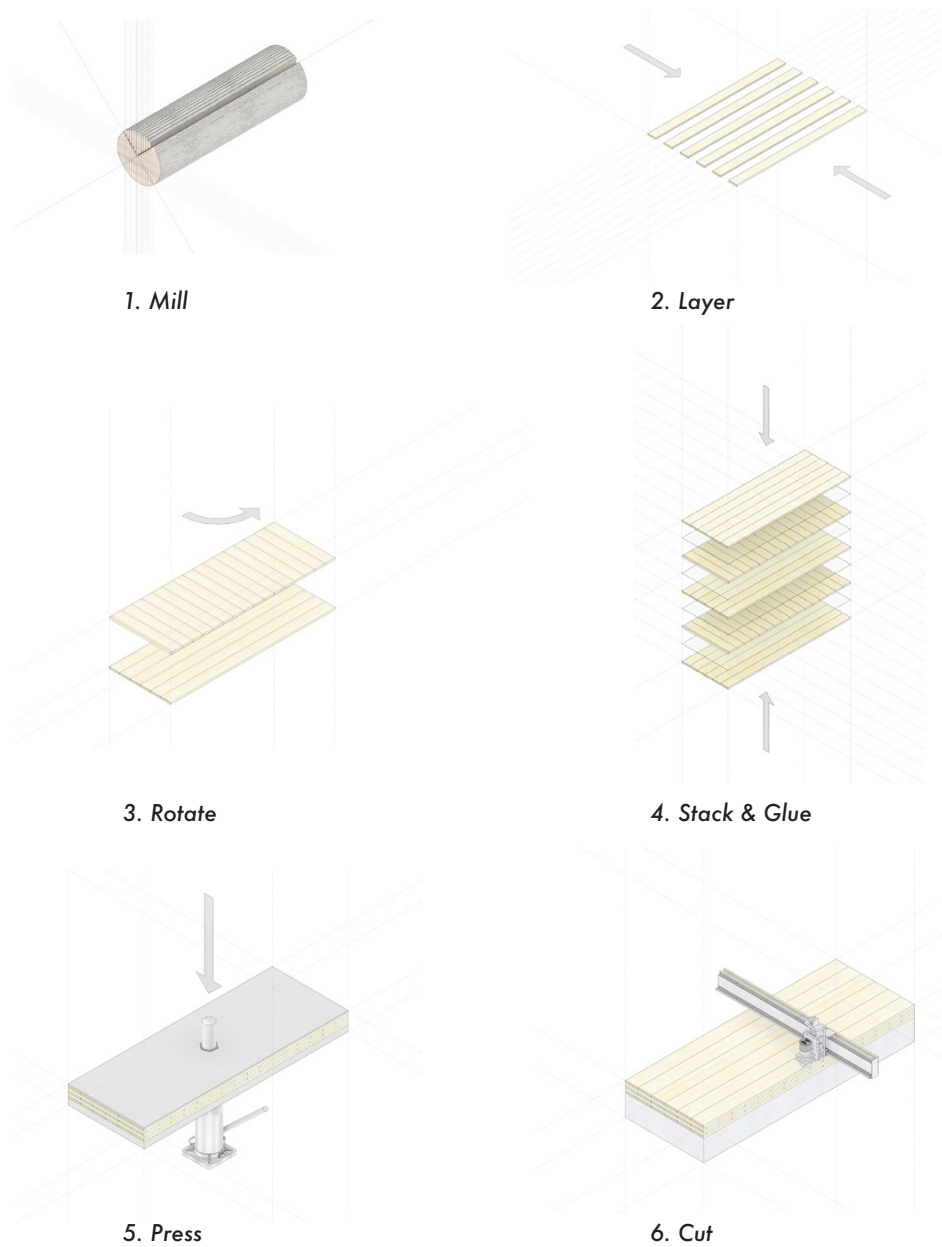


Figure 4. Illustration showing the process of making CLT wood panels.

## **Why Wood**

### *Environmental*

Wood is a natural, renewable and sustainable building material that sequesters CO<sub>2</sub>, “roughly 1.6 metric tonnes of atmospheric CO<sub>2</sub> in each weight of timber utilised and maintained in buildings” (Organschi and Waugh 2014, 18). “CLT is the only ‘carbon positive’ method for long span structures, wherein more carbon dioxide is absorbed through the lifetime of the trees than is expended through manufacture, delivery and installation” (Xlam 2016). Therefore, the more timber we use, the better it is for the environment.

### *Cost*

CLT is prefabricated with “high accuracy” and requires “no rework” this means CLT is assembled quickly on site with a “smaller site construction team.” Buildings end up being occupied earlier and need “shorter term financing” (Xlam 2016).

Wood is light, roughly “20% of the weight of concrete” (Xlam 2016), reducing time, money and energy that is needed to transport and construct CLT buildings. It also means making building footings and foundations can be reduced and simplified.

### *Health*

Using wood in buildings makes healthier living environments, improving inhabitants physical and psychological well-being. Wooden buildings and finishes “mimic the effect of spending time outside in nature” (Make it Wood 2016). “The feelings of natural warmth and comfort that wood elicits in people has the effect of lowering blood pressure and heart rates, reducing stress and anxiety and increasing positive social interactions” (Make it Wood 2016). The use of wood creates a relatable and understandable manifestation of social values in building form. Wood buildings are buildings you can feel better in and better about.

### *What’s Left to Consider*

With superior environmental, economic and social traits, wood as the solution to 21st century building conundrums is a no brainer. There never has nor will there be a better building material than wood.



## How Wood Works

### *Material Properties*

In contrast to metals, concrete, and plastics, that tend to have a uniform inner structure that gives them the same structural performance in all directions. Wood is an orthotropic material (Murdock 2014). Wood differs from other construction materials because it is produced by a living tree. As a result, wood possesses material properties that may be significantly different from other materials typically encountered in structural design. CLT multiplies the inherent structural properties of wood (Bradner 2013). Wood is good under compression parallel to the grain, enabling the tree to stand and grow upwards. It is also good torsionally enabling the tree to flex and sway in the wind (Matheck 2012). These inherent attributes are what make wood a versatile building material for a range of applications. Because of the orientation of the wood fibres, and the manner in which trees increase in diameter as it grows, properties vary along three mutually perpendicular axes: longitudinal (TBM, 3-1), radial, and tangential. The longitudinal axis is parallel to the grain direction, the radial axis is perpendicular to the grain direction and normal to the growth rings, and the tangential axis is perpendicular to the grain direction, and tangent to the growth rings (Kollmann and Cote 1984). Although wood properties differ in each of these three directions, differences between the radial and tangential directions are usually minor compared to their differences with the longitudinal direction. Wood is different due to its annual-ring-and-grain structure. You can bend and snap a small, dead, tree branch with your bare hands, but you will find it almost impossible to stretch or compress the same branch if you try pulling or pushing it in the opposite direction.

CLT panels have the cellular structure of the wood running in both directions multiplying and stabilising the strength of the wood against itself. The result is a bi-directional dimensionally stable structural building block that can span vast distances as a single surface plane.

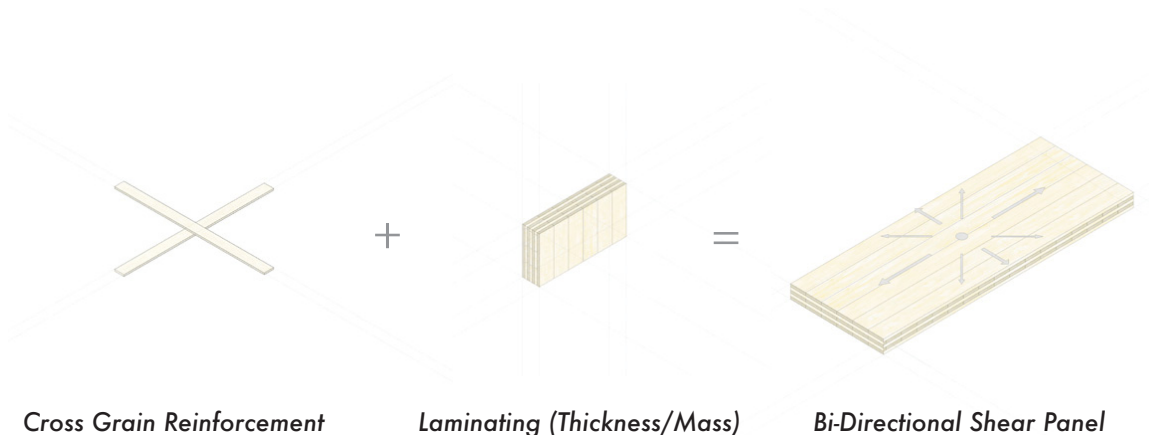


Figure 5. Diagram describing how Cross-Laminating wood makes a bi-directional shear panel.



## Potential of CLT

### *Applications*

As a building block, CLT is very versatile and can form the entire structure and be the exposed finish of the building. CLT panels can be used to wrap, frame or support more elaborate spaces. CLT panels can serve to function as tectonic elements for all architectural applications.

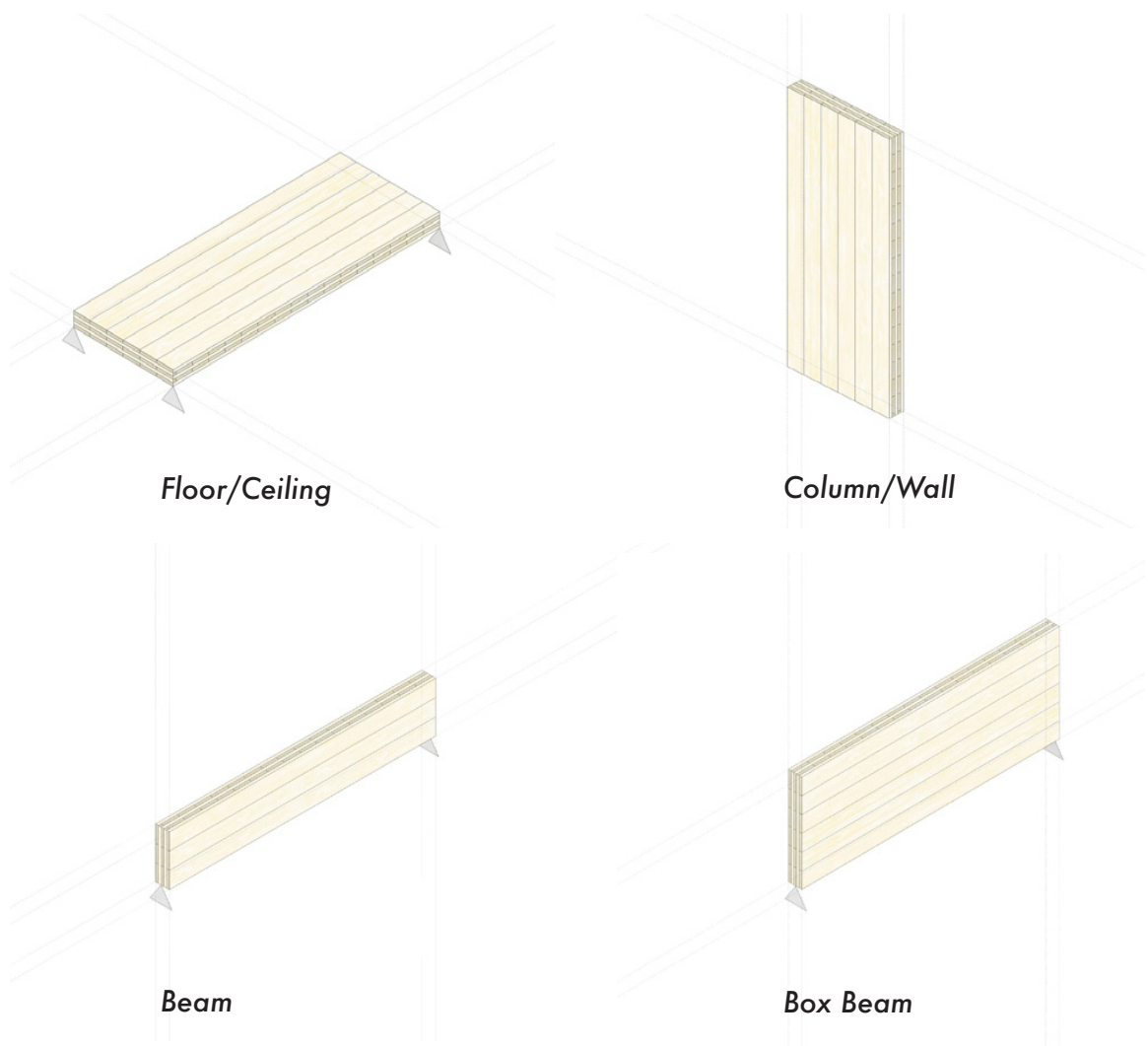


Figure 6. Diagram illustrating the primary structural CLT applications.

## Shortcomings/Opportunities

While the benefits of CLT have been well documented, the development and exploration of CLT as part of a fully integrated building system have been limited. As a promising new building product, CLT deserves detailing and connection systems specifically designed and tailored to it. Currently, CLTs are fastened together with many screws or simple and basic clips. The opportunities for CLT could be enhanced and expressed further with a counterpart system providing connections and systems integration to form a complete building assembly. The critical junctures in architecture, where floor, wall and roof come together are also the place where building systems and services need to be and function best. Can the design of a custom connection system hold the building services, connect and simplify to express and enhance the nature of CLT.

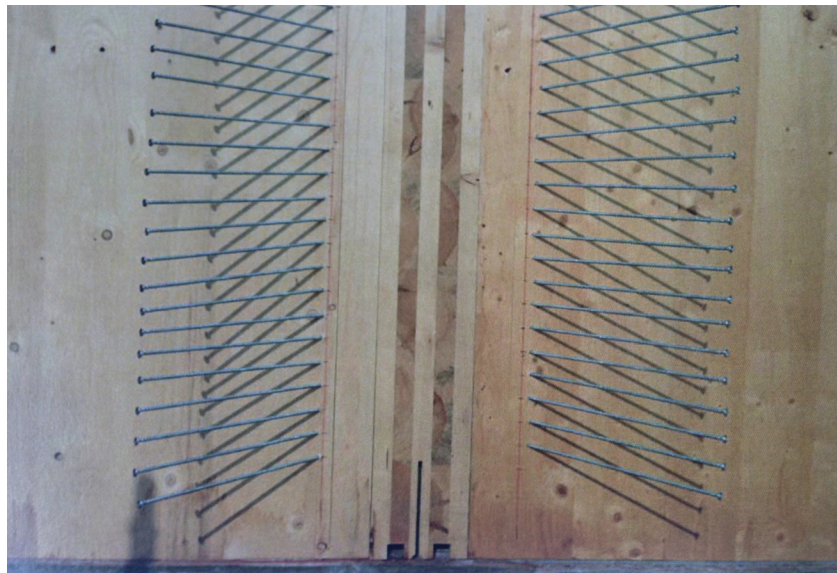


Figure 7. Image showing screw connections at CLT walls, 2015, photograph by Simone De Menis (Mayo 2015).

The above (fig. 7) shows a typical CLT connection, where the panels butt up to one another and are screwed numerous times to achieve a structural joint. This type of connection has no ideas about integration and is a tedious and monotonous job.

## **Steel**

### **Material Properties**

Steel is the perfect counterpart to CLT because it is durable, thin and malleable (Farrelly 2009, Johnson et al 2008). Steel sections will be used to fasten, wrap and integrate CLT seams. Steel has been considered for this project because of my knowledge and experience working with steel in construction, welding and erecting buildings. There is great potential for 'The Idea' of steel sections matching in thickness with the CLT, having the ability to connect and host building services simultaneously within the steel section. The use of stainless steel will complete CLT providing connection, fit and finish. Stainless steel requires next to no maintenance and achieves unmatched precision and resolve (Aperam, 2012, Johnson et al 2008). Currently, steel is the principal construction material in regards to sustainability (Rossi, 2014); it offers exceptional environmental, social, energy and economic benefit, 100% of stainless steel can be multicycled endlessly with no detriments to its properties (Houska 2002). One of the most notable features of stainless steel is the life span which, "usually varies between 80-infinity years depending on the environment and its uses, for our purpose, stainless steel is expected to last about 1200 years" (Narahari and Narayana 2013). Essentially stainless steel is a wonder material, maintenance free, durable, recyclable and aesthetically pleasing.

Steel parts and profiles can be screwed/bolted anywhere along the face and edge of a CLT panel serving as critical junctures or as additional smaller details. Designed steel parts will be used in as many ways possible to enhance, complete and complement CLT.

### **Thesis Question**

How can a multi-functioning steel system complete CLT?

## CHAPTER 2: DESIGN

### Exploring CLT & Steel

#### Structure

#### *Wrapping & Passing*

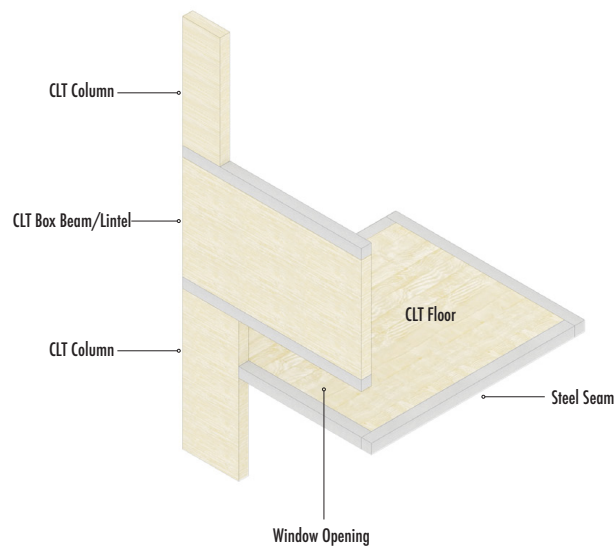


Figure 8. Diagram showing how CLT panels and steel can integrate to make unified structure and space.

(Fig. 8) is a structural diagram describing how CLT panels can be used with steel seam connections. The CLT panels are structural slabs of wood that act as shear panels in any orientation or application. The use of steel seams wrapping the panels serves as moment connections, where the forces on the CLT panels are framed. The steel transfers and stabilizes loads and forces between CLT shear panels; hence, creating an integrated and integral composite structural system. The ability to mould and shape spaces becomes a direct relationship to the structural scheme. The idea of wrapping the seams and edges of the CLT panels with steel connectors makes it possible to slide and pass CLT elements by one another to form unique and exciting architectural conditions. The diagram illustrates how continuous columns can hold floors and reach up to support large horizontal box beams enabling expansive window openings, easily accommodating structural and spatial orientation changes in the building.

## Tapering

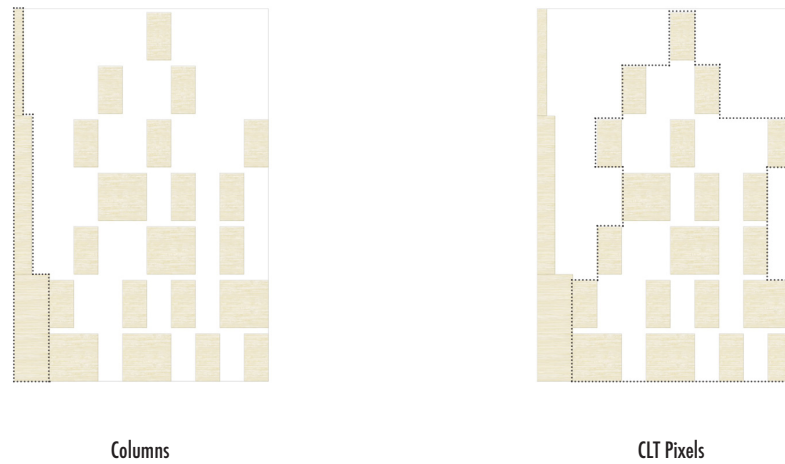


Figure 9. Diagram illustrating methods of structural tapering.

A major consideration and design intention was the idea of tapering building elements. When designing a tower, it is important to think about material efficiency; there is an inverse relationship between structure and height of a building. Toward the top of the building, there is less loading and accumulated weight compared to the bottom of the building, indicating that the structure can taper and diminish as it moves upward. This gesture is two-fold: reducing material usage, and allows for design variety and difference of building appearance and visual effects. It also makes a framework and provides legibility for the different program in the building. The tapering idea can be achieved with two defining elements of the building: the structural columns, and the facade CLT pixelated panels. The intention is to make the building lighter, more open and porous.

## Plan Components/Parts

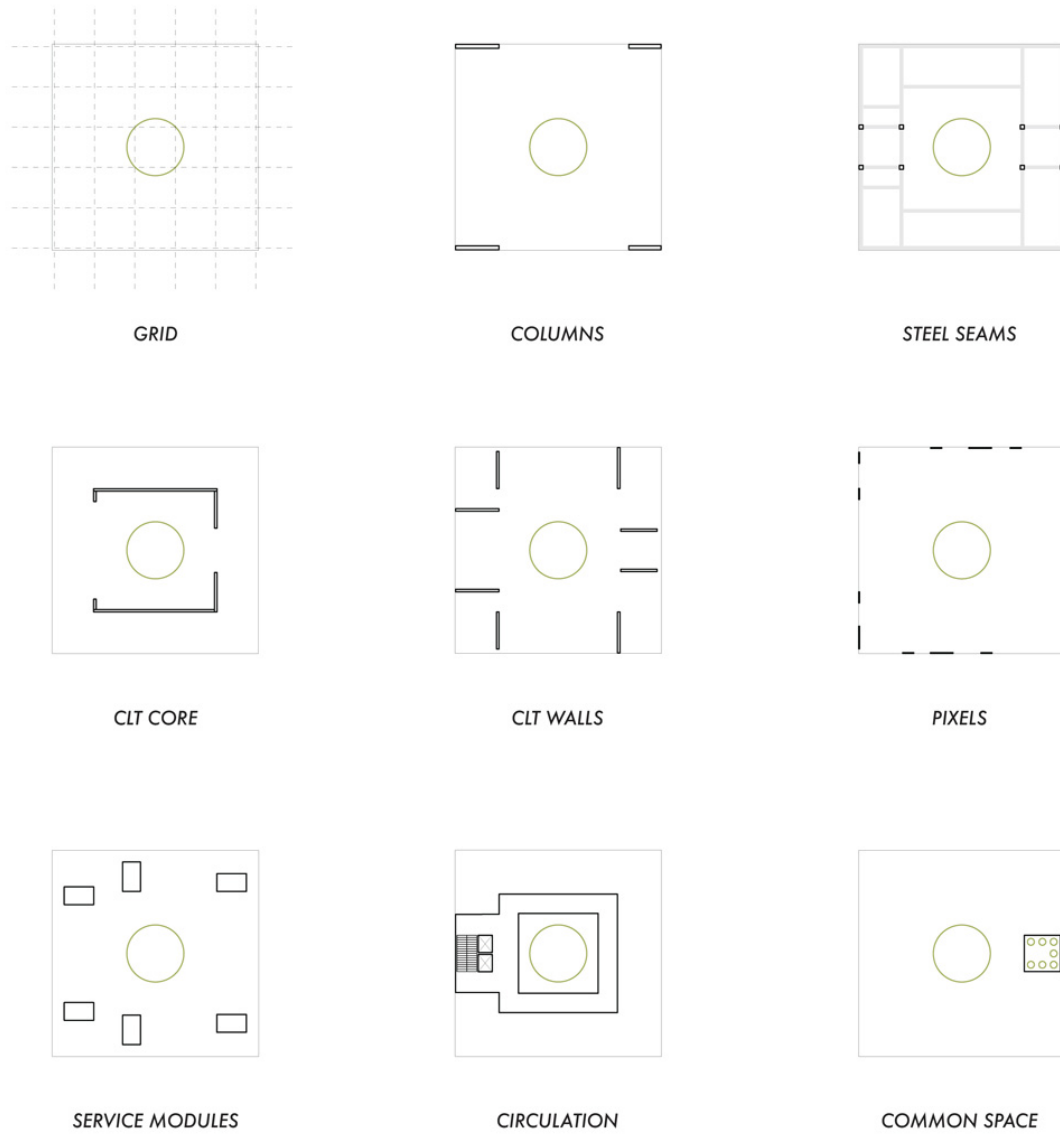


Figure 10. Series of diagrams showing the structural logic and parts of the building in plan.

## Systems

### CLT Tests

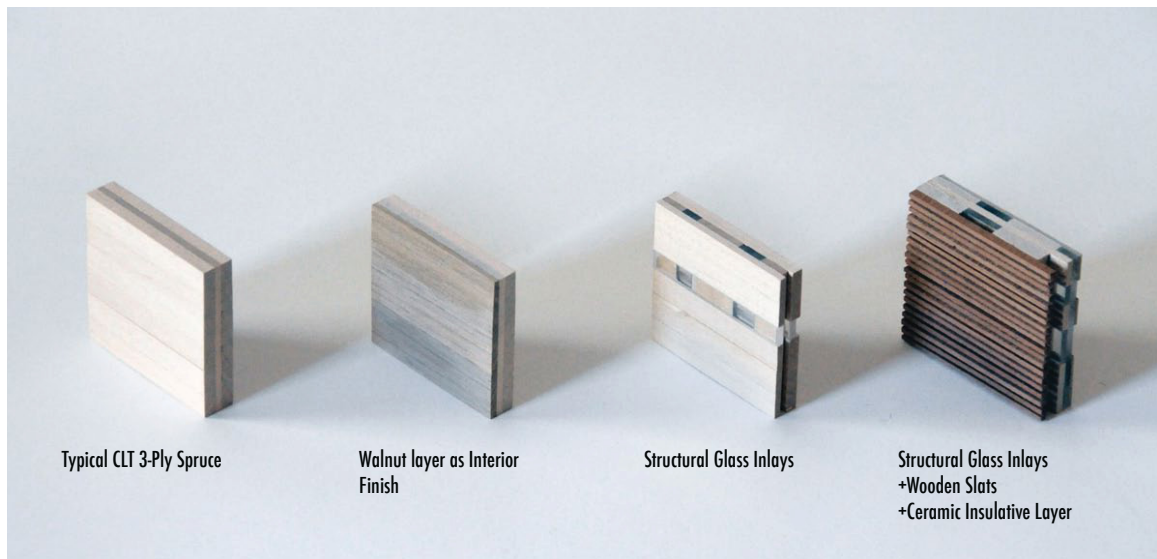


Figure 11. Image of models testing different types of materials added into CLT panels.

Upon completion, as shown in (fig. 11), it is evident that the integration of other materials for lamination, beautification and other added functionality is unnecessary. There is no need to complicate arrangements because the beauty is in the simplicity of the wood and the efficiency of the process. Therefore, integrated panels are not necessary as they are time-consuming, expensive and labour intensive. Plus, even with integrated panelized systems, there still lacks a connection system.

Experimenting with ideas of adding different materials to the CLT laminations and integration was an interesting exploration but quickly dissolved.

## Modes of Integration

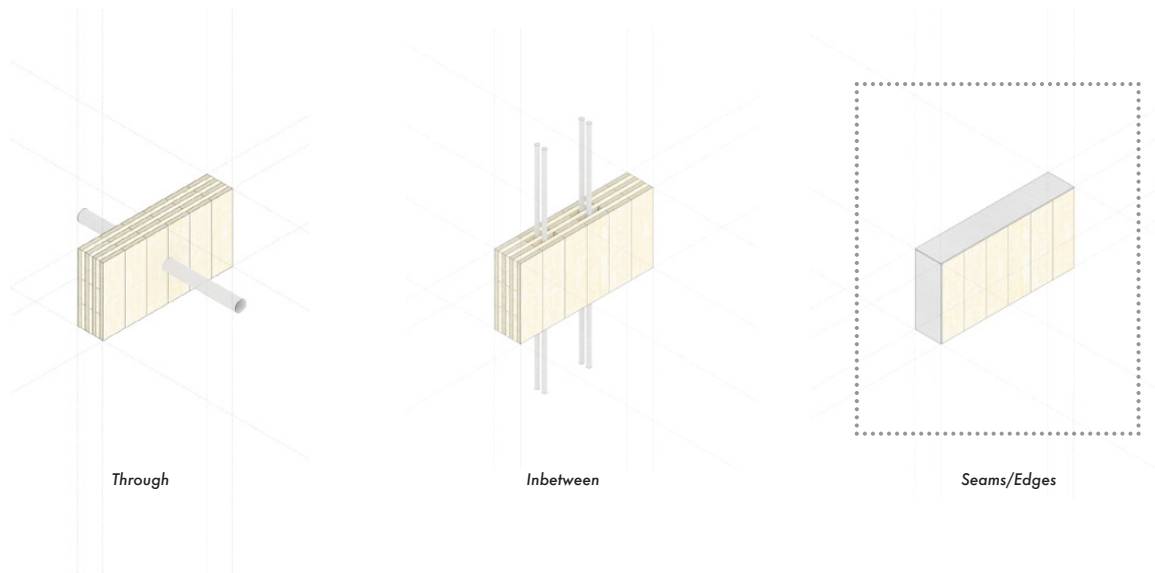


Figure 12a,b,c. Diagrams showing different ways of integrating systems with CLT.

The above (fig. 12) provides more detail on integrating systems into the CLT panels. Here, the idea of putting systems through and in between the panels was tested, and neither provided complete building service integration, and they both lack an entire connection system.

The previous test (fig. 12a,b) led to the idea of integrating steel connections around seams and edges, as illustrated in (fig. 12c), this can simultaneously provide CLT connection and systems services integration. Conclusions made from test observations led to the notion of CLT seams and edges being wrapped in steel as shown in (fig.13) below.

### The Idea



Figure 13. Diagram showing the basic concept of hollow steel sections integrating with CLT panels.

Here, the illustration shows how hollow steel sections can be truly integrated (Note the equal distribution of thickness) with CLT panels becoming an extension of the panel itself. It further provides the connections at the seams and edges as well as expressing the planar nature of CLT by condensing and concentrating systems and services into the steel conduit.



## Development

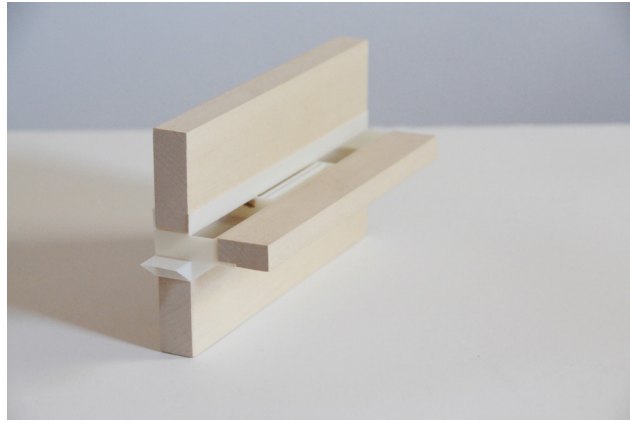


Figure 14. Image of 1:20 3D printed model developing the steel seam.

(Fig. 14) shows the preliminary 1:20 model based on further exploration and development of the steel connection seam. Ideas of incorporating ventilation and electrical systems at the critical juncture where the exterior wall meets the floor.

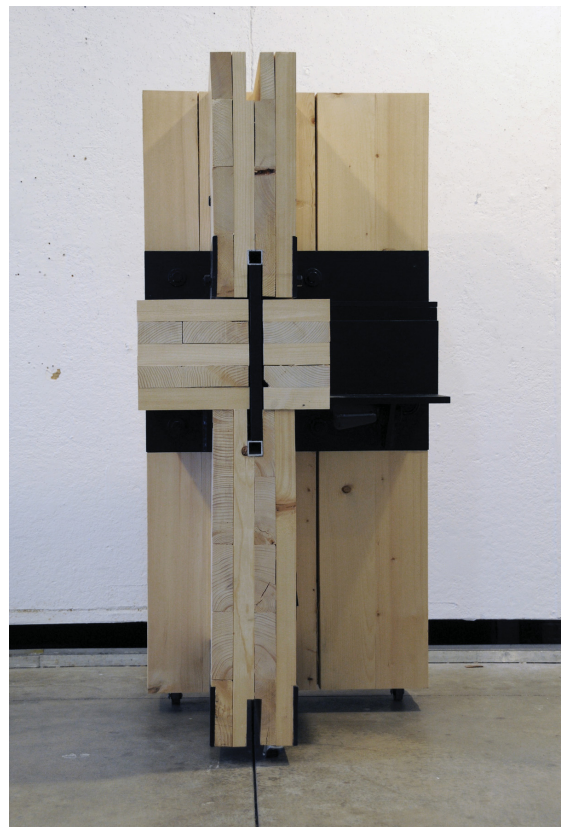


Figure 15a,b. Images taken of 1:1 model testing the practicalities and functionality of actually making a critical juncture.

1:1 model from (fig. 15a,b) delve into the tectonics dealing with the constructability of CLT and steel. This test models wiring and electronic installation in the steel-CLT model. This provides insight to the practicality of the design to understand in detail how utilities like electrical, and plumbing can be done along the framework.



Figure 16a,b. Detail images taken of the 1:1 model showing accessibility and connection to power through the steel system.

The above images show the functionality of the steel detail. (Fig. 16a) shows accessibility to installation and maintenance of system services. (Fig. 16b) shows the ability to connect to the power in the space; this allows for the generalisation of plumbing and other services required for 21st century buildings.

## Space

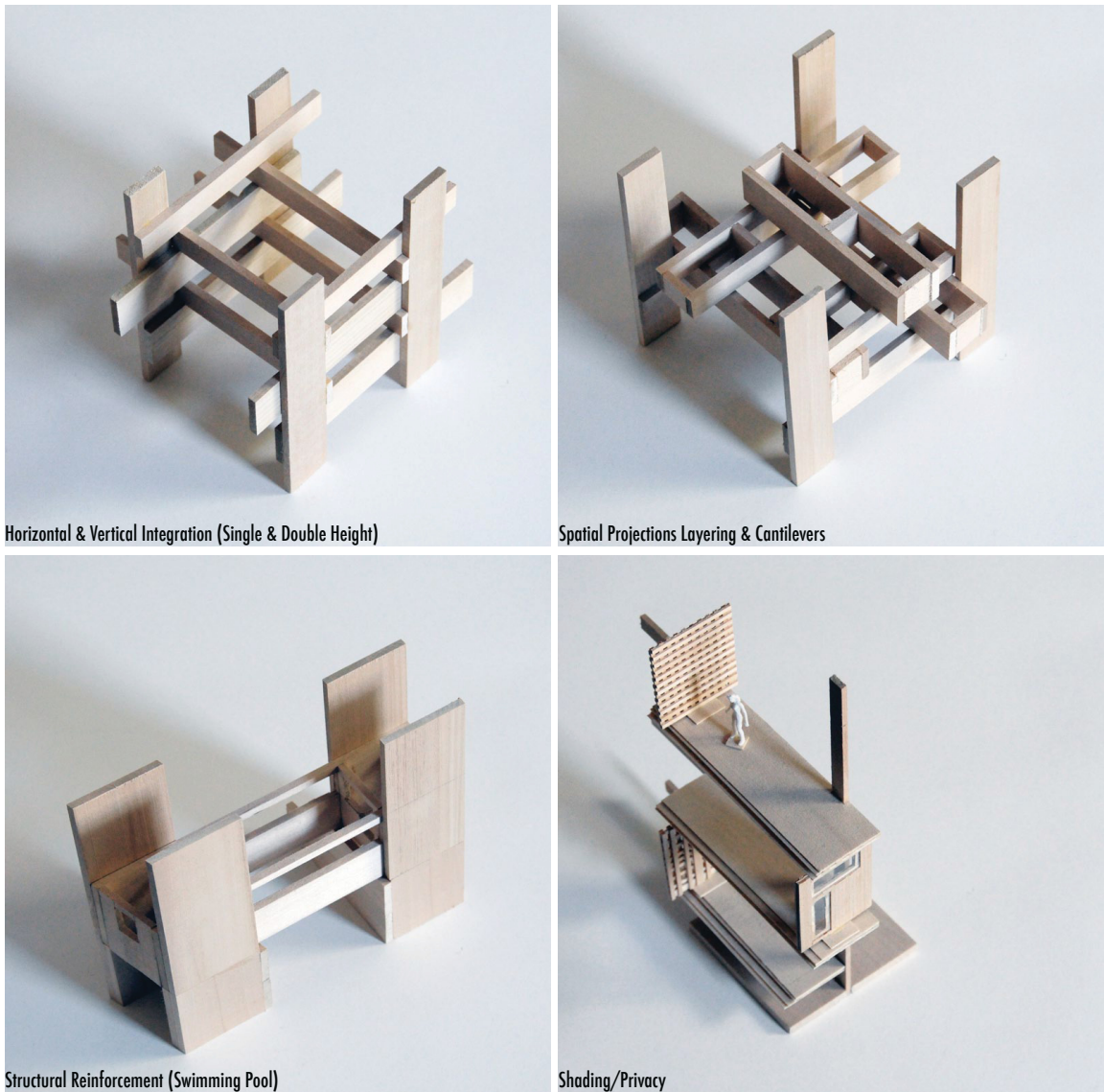


Figure 17. Series of images taken of study models exploring space & structure with CLT.

(Fig. 17) shows a series of study models exploring ideas of space and structure with CLT. The potential to cantilever spaces making projections that highlight certain parts/program of the building design. Doubling up CLT panels for unique circumstances, where additional support or structure is needed (i.e., the swimming pool). Ideas of wood slatted walls as movable sunscreens/shading devices for the perimeter or exposed areas of the building can provide protection and privacy.

## **Integration**

The following series of images (fig.18-22) show the developed idea of integrating steel seams at critical junctures in the building. Showcased are the five crucial building details: foundation, typical floor (corner), facade, interior (core) and the roof. The idea being that these set of details cover the fundamental parts of a building and can then be used as universal details adaptable and scalable to fit a range of building types. These features can be utilised as a toolkit for designing and conceiving buildings and spaces with CLT.



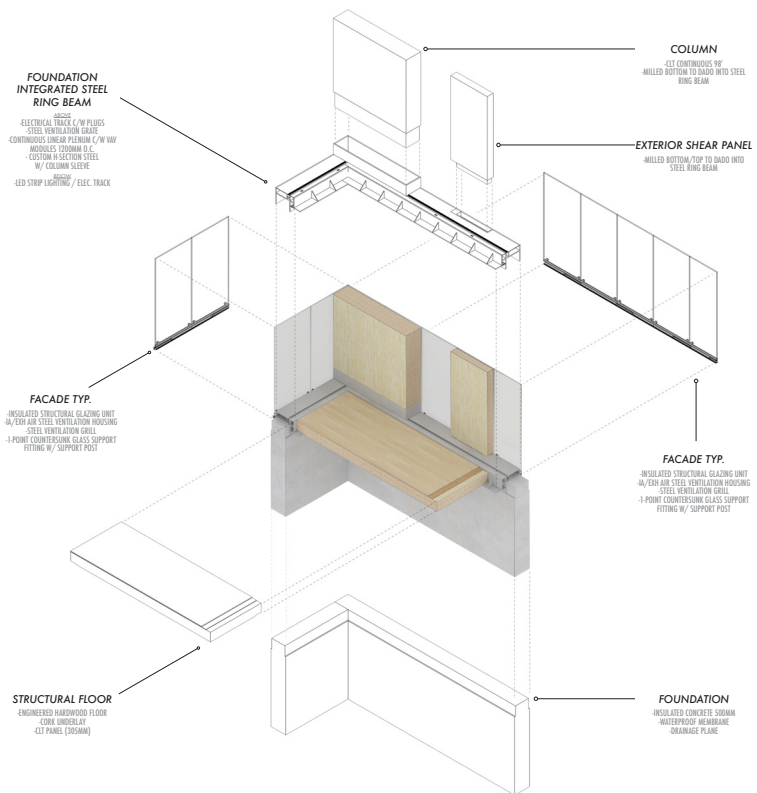
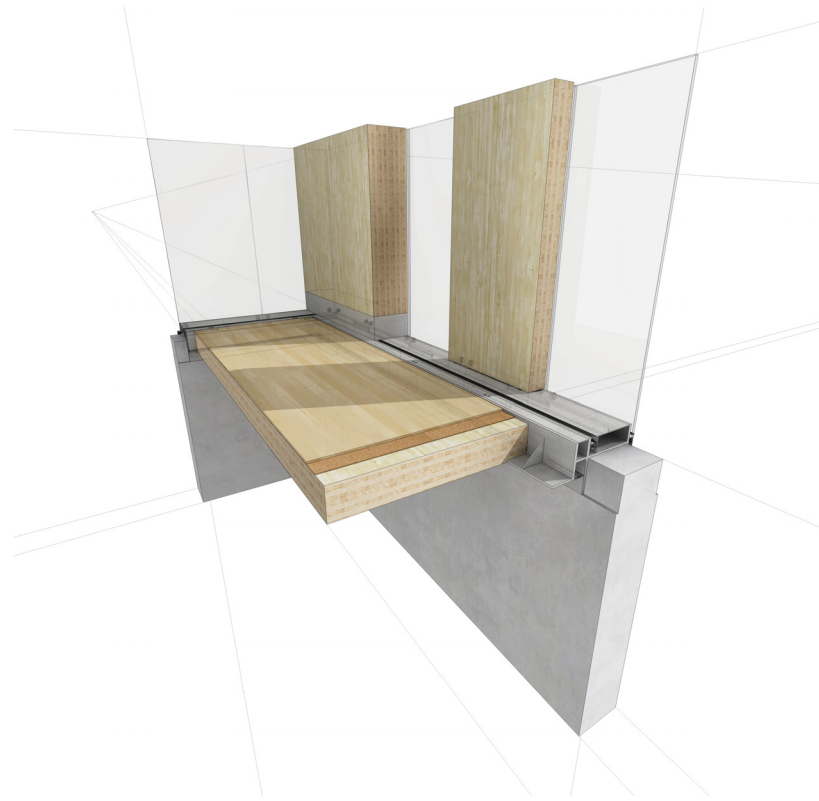


Figure 18. Drawing describing the foundation juncture.

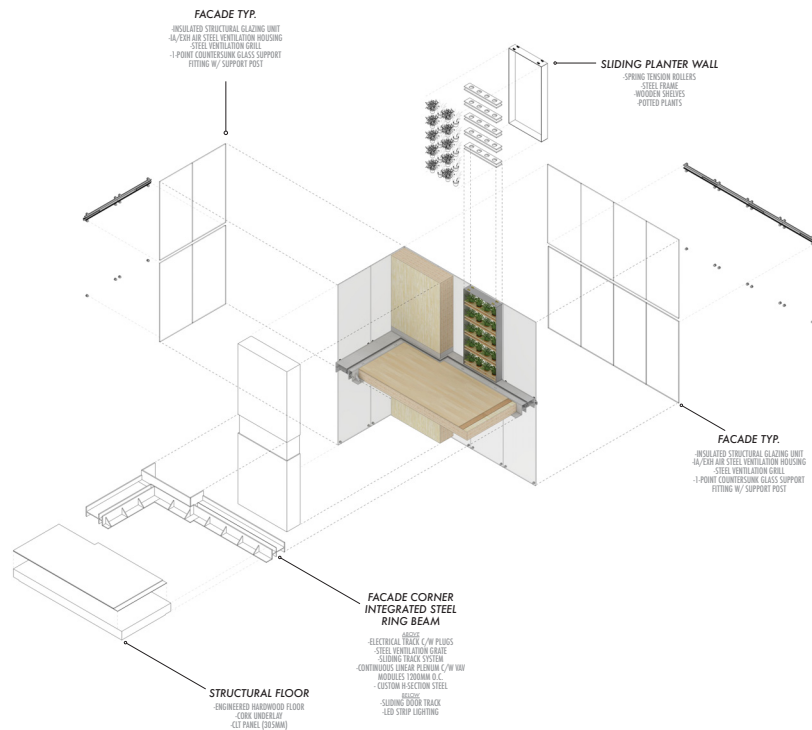


Figure 19. Drawing describing the corner juncture.

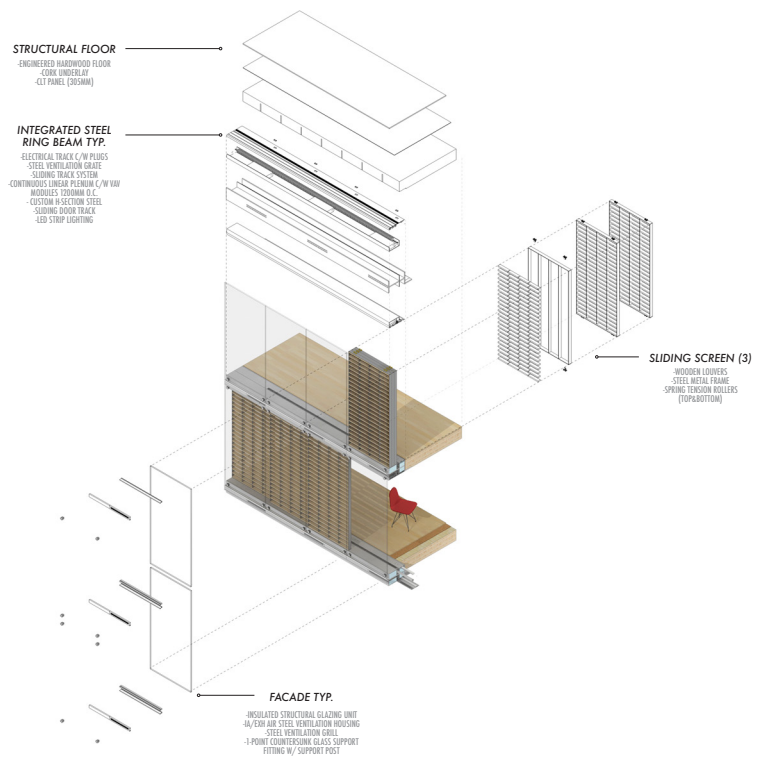


Figure 20. Drawing illustrating the facade juncture.

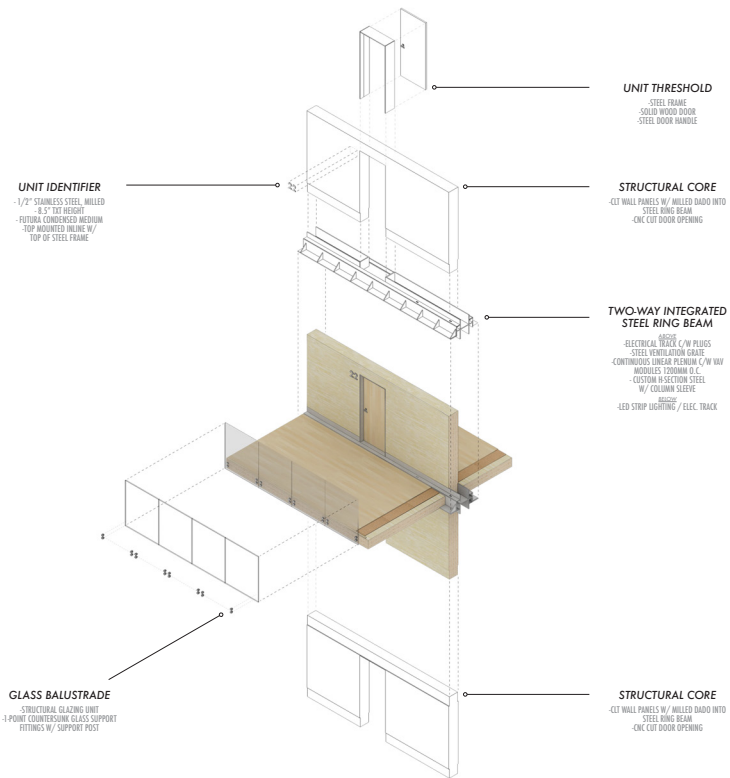
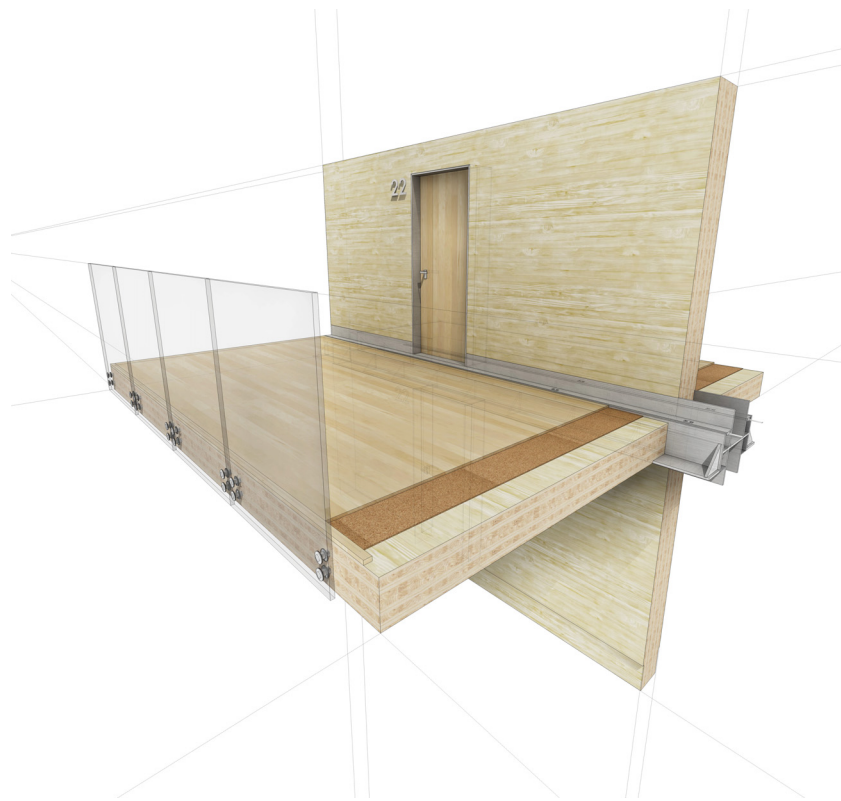


Figure 21. Drawing describing the core/circulation juncture.



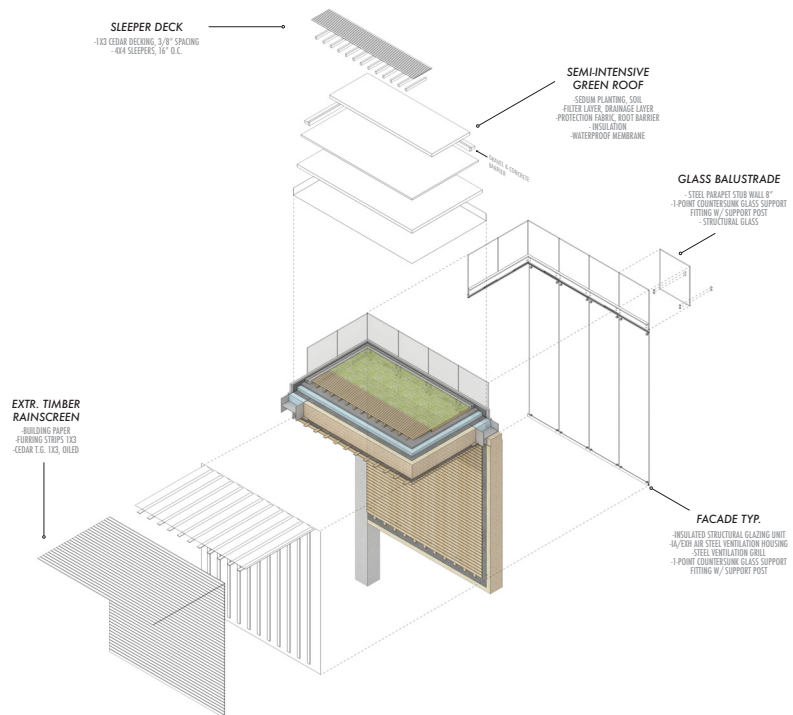
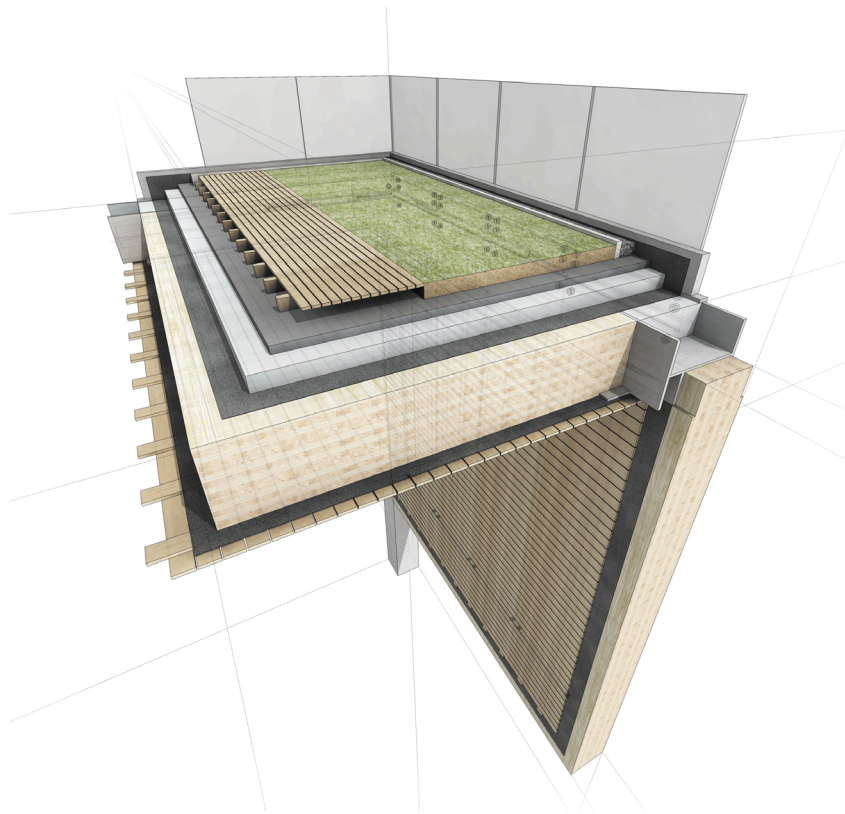


Figure 22. Drawing describing the roof juncture.

## Building as Test Site



Figure 23. Drawing showing the building roof plan and surrounding context, base image of Halifax (Google 2016)

### Site

The site for this thesis is an urban location situated in downtown Halifax, Nova Scotia, Canada. Currently, the vacant lot is framed by the Public Gardens and the Citadel Hill (historical fortified defence battery). The placement of the site is both urbanistic and natural, flanked by two parks, making it a suitable site to test and build a 21st century wood tower. The building will demonstrate the ability and suitability of building with wood in a dense urban site in contrast to the old outdated dull buildings surrounding it. Although the building is more about the idea of base building/structural skeleton, able to accommodate a variety of program transitioning or adapting to different needs over time, programmatically it is a condominium with a variety of bachelor, 1 bed, 2bed and 3 bedroom units with mixed use larger programme spaces woven into the building all



surrounding a central atrium. Additional program is a restaurant mid-way up the building overlooking the park, a swimming pool/gym and several double height large spaces for events/conferences situated at the top of the building taking advantage of the views of the harbour and surrounding parks.



Figure 24. Drawing showing the site in relation to the Halifax Peninsula and transportation of CLT panels, base image (Google 2016)

The above image (fig. 24) depicts a larger contextual plan of the Halifax Peninsula, showing the location of the site and how the CLT panels would be transported to the site via ship and transferred to truck on land to be delivered to the site.

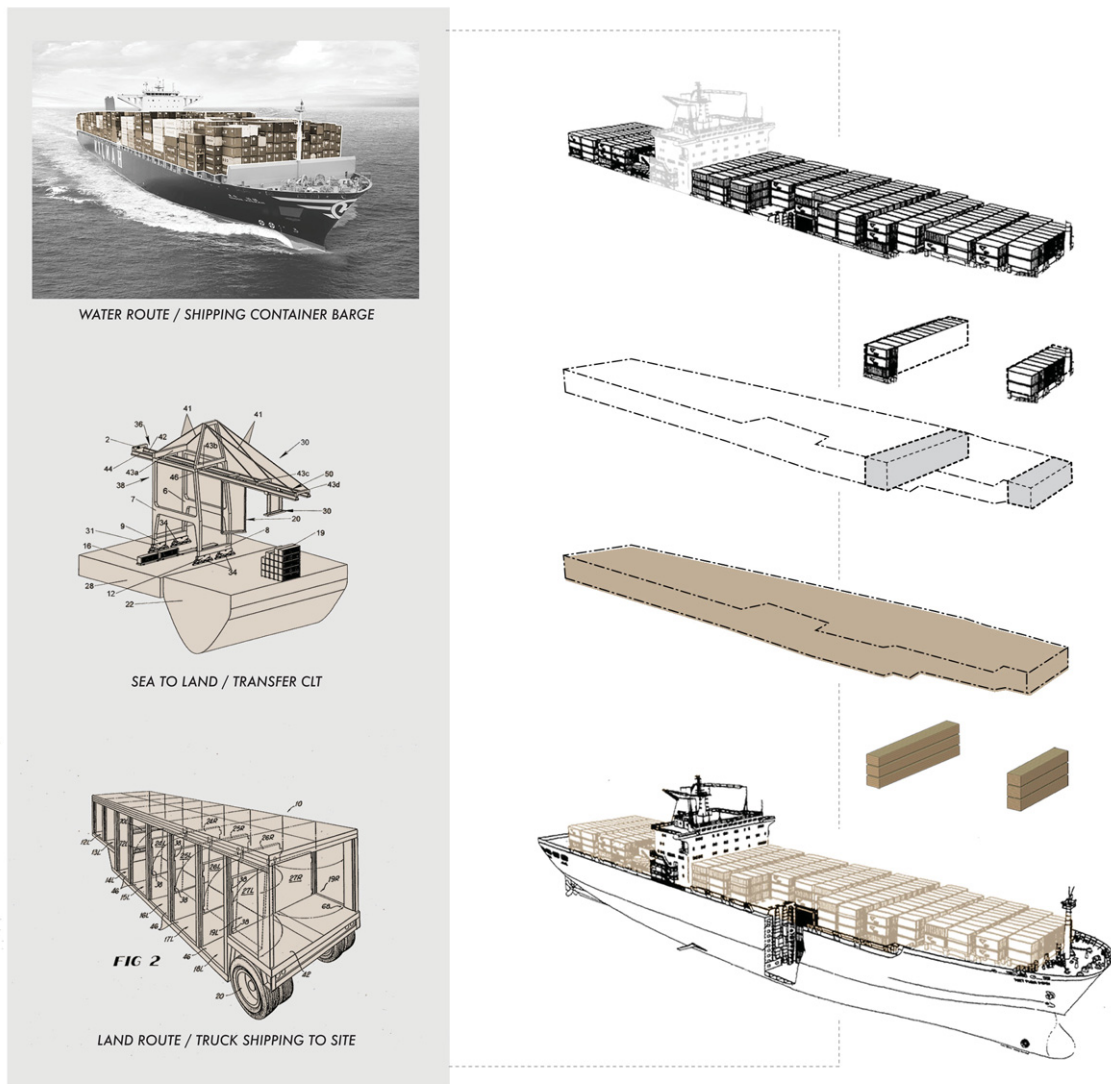


Figure 25. Drawing showing CLT transportation scheme.

The above image (fig. 25) highlights how CLT panels could easily be transported by ship making CLT an accessible building solution. Buildings could be designed and manufactured in one place and be sent to a location as a prefabricated kit. The diagram shows how stacks of varying lengths of CLT could replace shipping containers/freight. The 98' length panels can also be accommodated. With this notion, it is easy to image an entire building arriving on one ship.

## **Building**

To test the steel system with the CLT a host of different spaces and programmatic elements compose the wooden tower. Single, double and triple height large span volumes prove the versatility of the system. Below is a key plan (fig. 26) showing the locations of the integrated junctures and the different program elements of the building design.

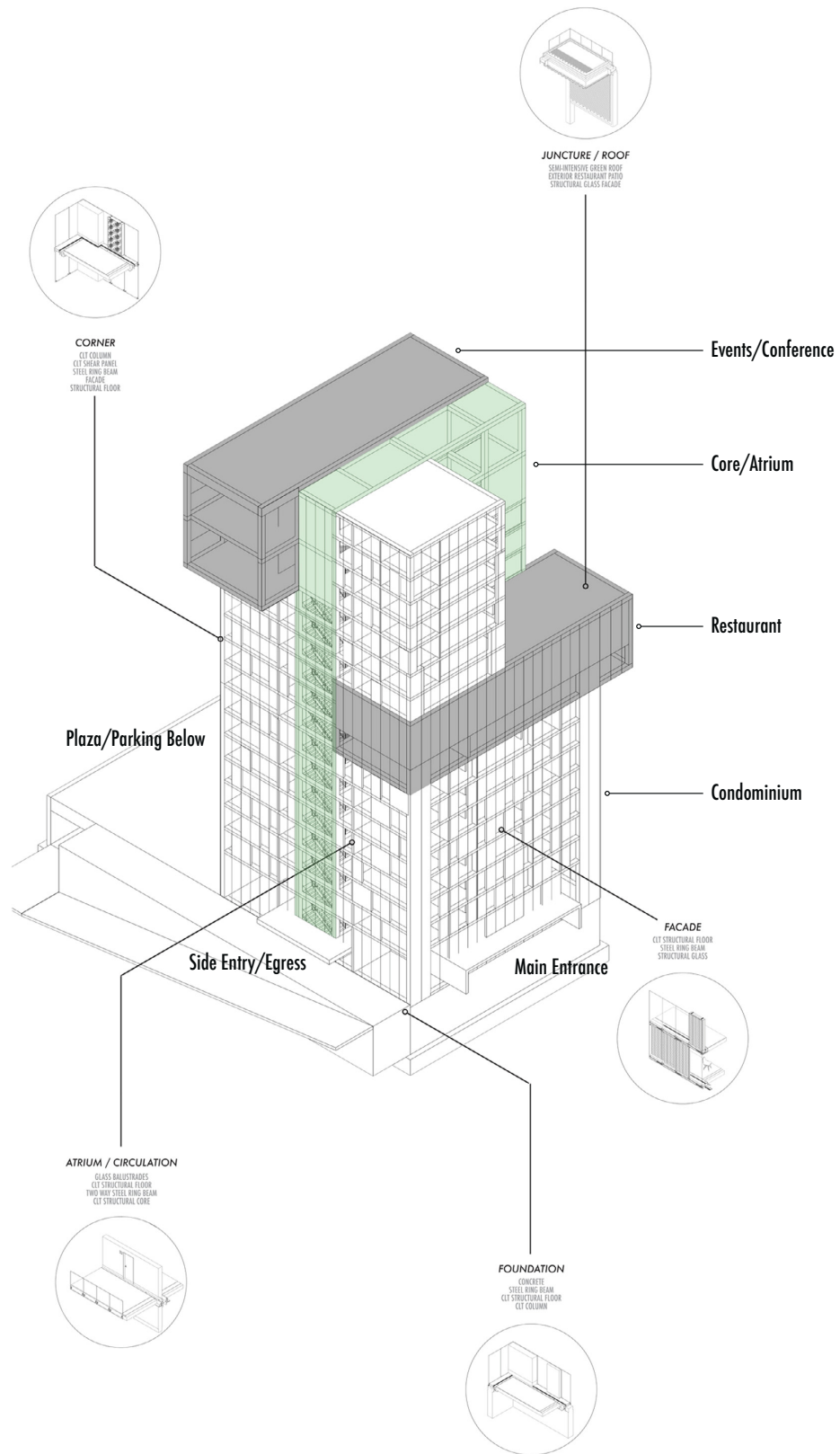


Figure 26. Building diagram illustrating critical juncture locations and building program.





Figure 27. Drawing of the building ground floor plan and immediate context (Public Gardens), base image Halifax (Google 2016)

The ground floor plan shows the building as an extension of the Public Gardens. The reduction of the building footprint created space for surrounding plazas and extended public green space servicing the ground floor program. Found on the ground floor are a cafe, several small shops and a central open space for gathering. Adjoining the atrium area is the main entry with concierge/help desk and building mail services.

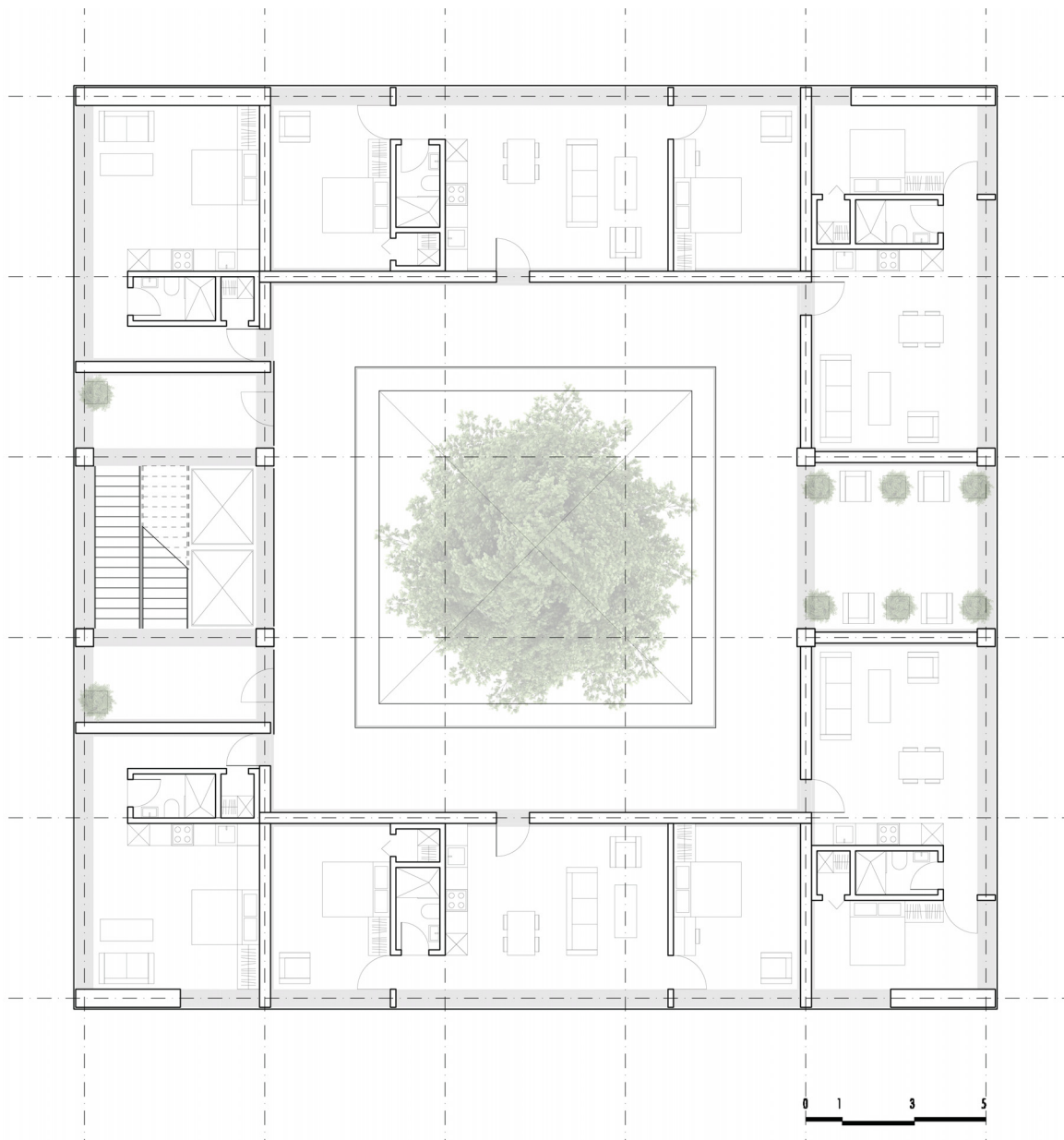
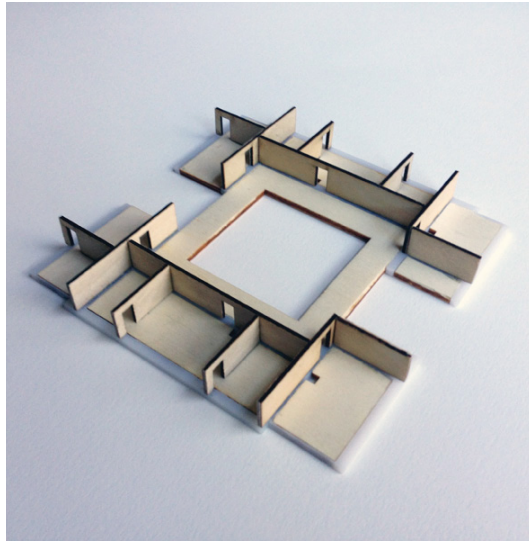


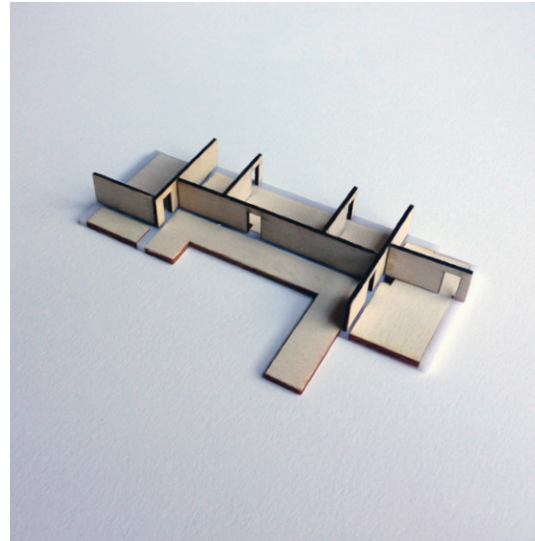
Figure 28. Drawing of floor plan unit layouts (Floors 2-8) (Scale in Meters)

Top left clockwise: Bachelor, 2 bed, 1 bed, Common Space (vertical garden), 1 bed, 2 bed, Bachelor and Circulation Core.

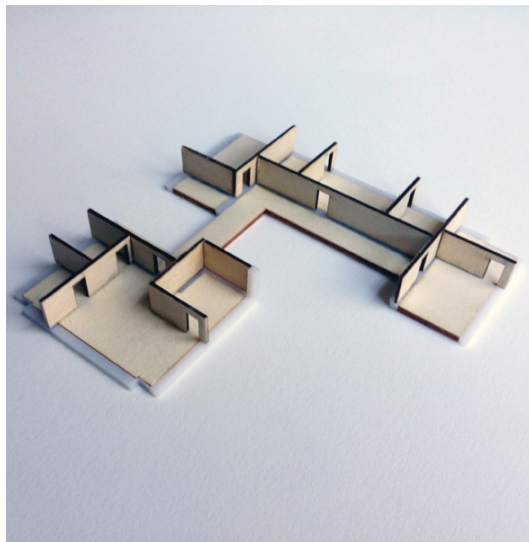




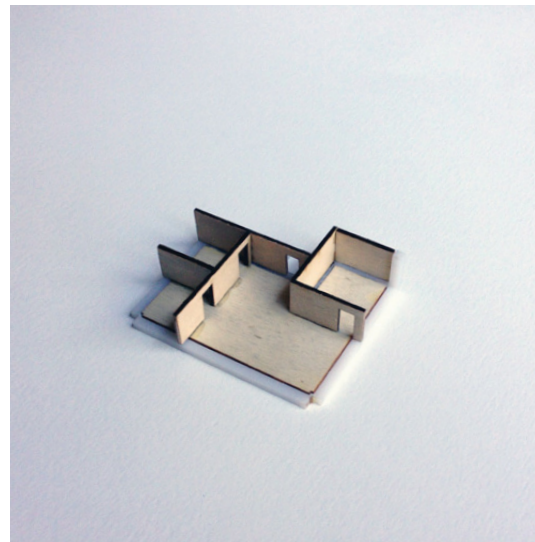
Full Circle



Half



Three quarters



Quarter

Figure 29a,b,c,d. Images 1:200 model parts showing other floor plan/unit types.

Above are the variety of different plan configurations through the building:

Fig. 29-a Full Circle, Floors 2-8 (bachlor/2bed/1bed) Fig. 29-b Half, Floors 9-11 (bachlor/2bed/1bed)

Fig. 29-c Three Quarters, Floors 12-14 (bachlor/2bed/1bed/3bed) Fig. 29-d Quarter, Floors 15-18 (3bed)

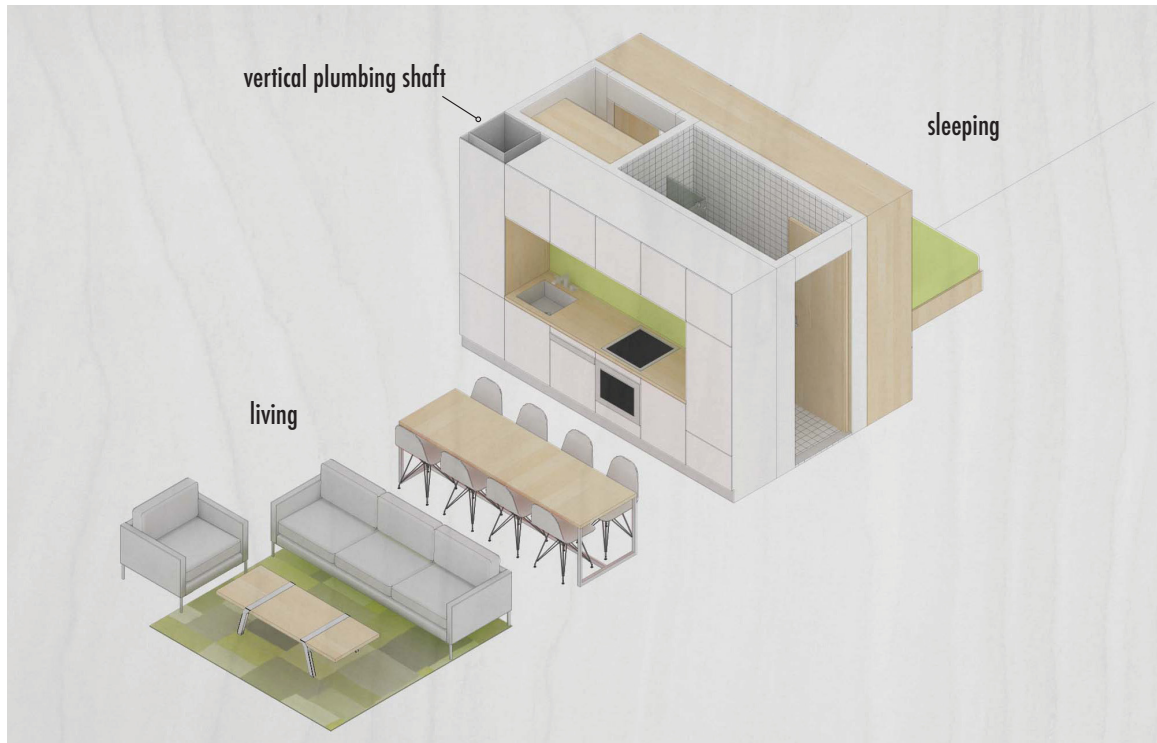


Figure 30. Drawing showing the living configuration of the units based around a service core module with kitchen/bathroom connected to a vertical plumbing shaft.

## Construction

The construction of this building is much faster and less disruptive to the site because of the prefabricated nature. All CLT and steel parts can be manufactured ahead of time in a controlled environment, creating building components that are precise, dependable and ready to put in place once on site. There is little to no preparation needed on site, and the building can be erected with a small team of workers.

The design of the double steel core atrium means that the two cores can first be assembled by crane and can then become the crane for the rest of the build. Reducing the space needed on site, street closures, allowing for a more efficient site delivery and building erection process. This is a powerful feature, with the crane incorporated into the design of the building it becomes part of the build and not an extra assemble and tear down. It saves time and money and promotes the ease of constructing a building on tight site conditions.

The entire building at each phase and every process is either screwed, bolted or clipped together. There are no permanent and or destructive connections. The building can be assembled with a small crew using few hand tools. The process is entirely

reversible.

The sequence of construction is shown on the following pages (fig. 31 a,b), depicting how the building goes together and the particular phases.

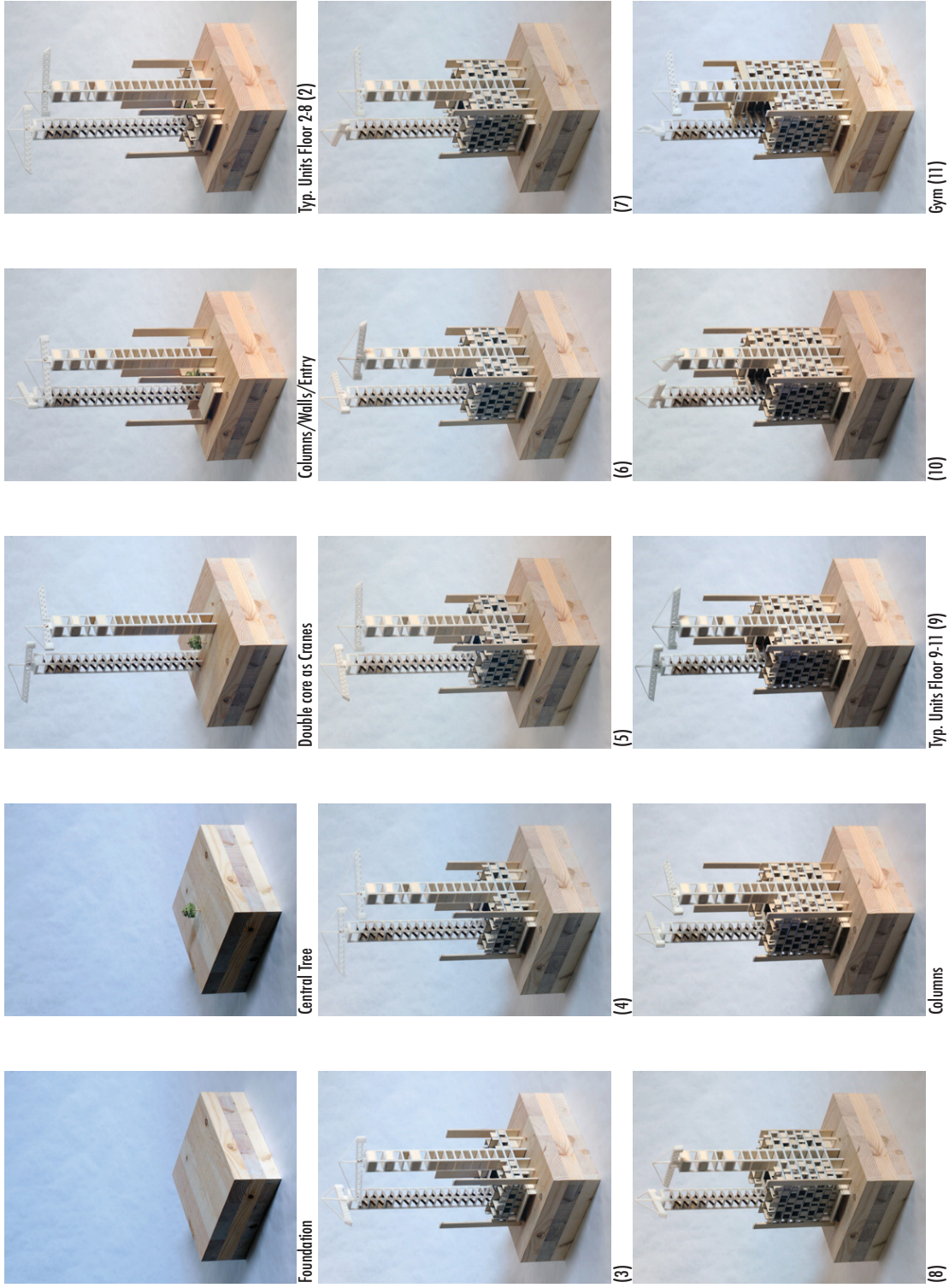


Figure 31a. Images of 1:200 model showing construction sequence.



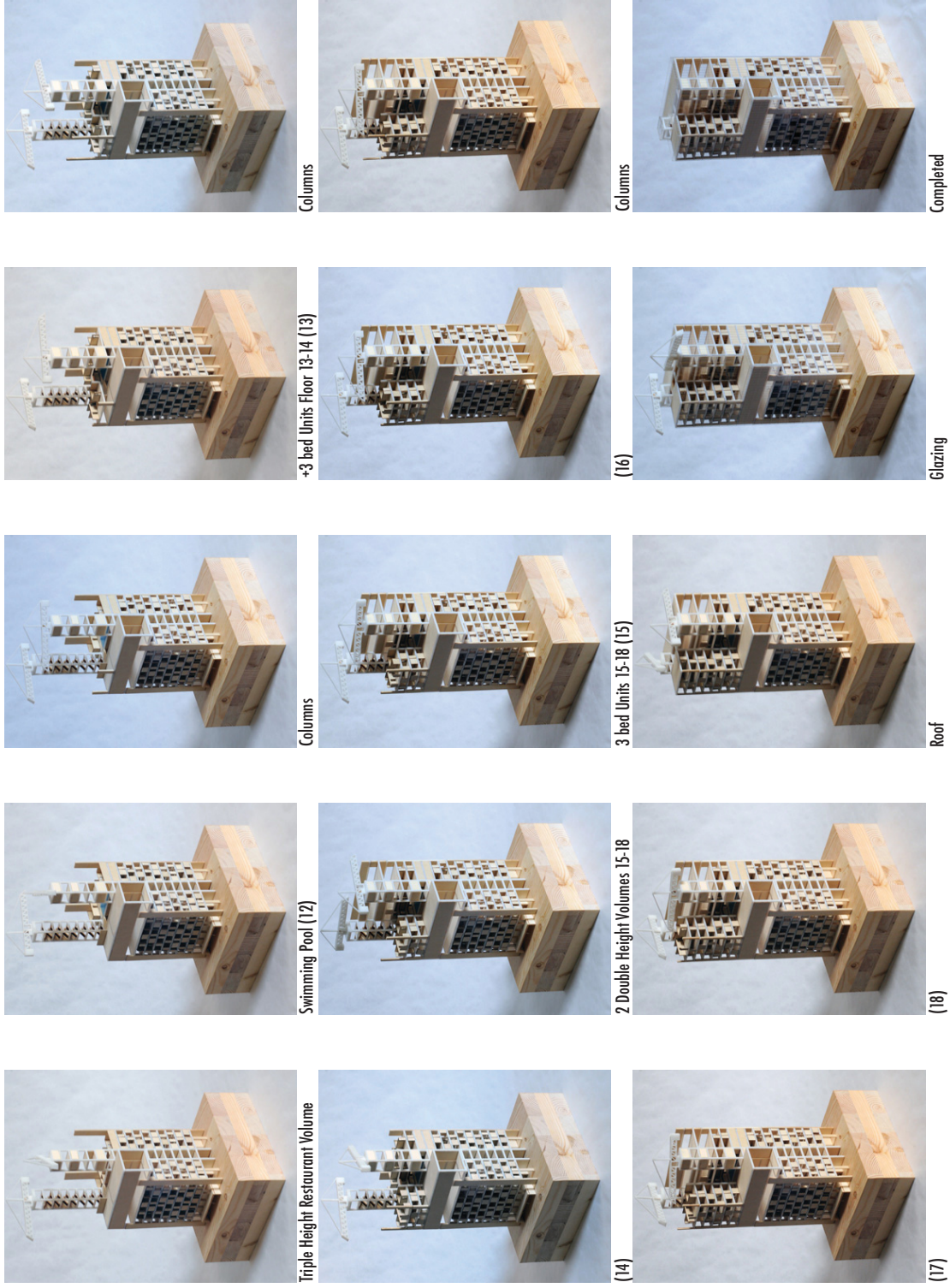


Figure 31b. Images of 1:200 model showing construction sequence.

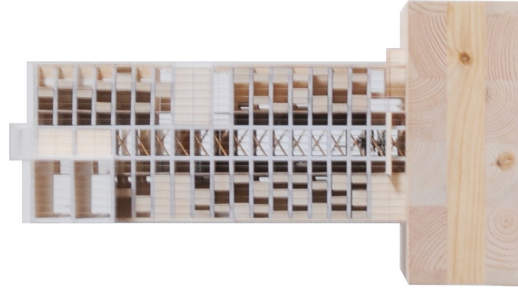


Figure 32. Image showing building structure and site context.

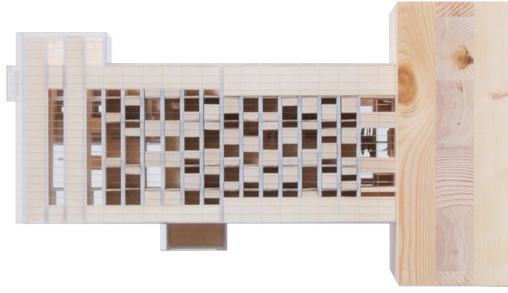




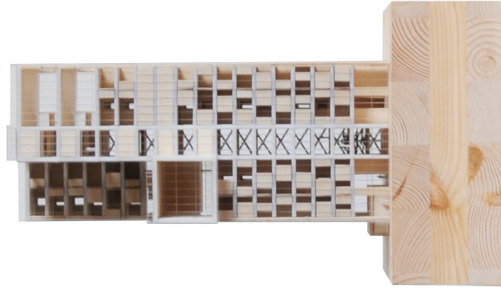
Figure 33. Sectional drawing of the building facing North.



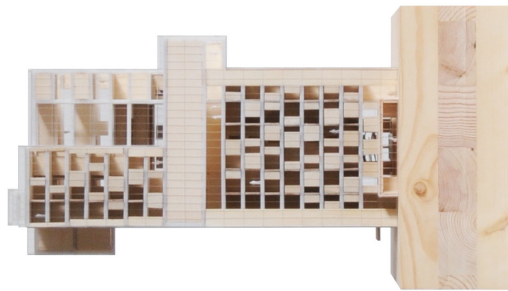
North



East



South



West

Figure 34. Images of 1:200 model showing building elevations.



**Enclosure**

The building is finished by wrapping the entire structure in glass. One single hardwearing multi-functional material. Glass is used to provide protection to the inner woodworkings of the building while allowing the wood to be expressed as a defining characteristic. This process creates a pure and genuine undressed wood building. The following images (fig. 35-36) show the building in its completed form enclosed in a glass shell.



Figure 35. Image showing the completed 1:200 model looking at the South-West corner.



Figure 36. Image showing the completed 1:200 model looking at the North-West corner.

## CHAPTER 3: CONCLUSION

A modern tower that is made primarily of wood is a good move forward. A building made of wood that can also be completely dismantled the same way it was assembled, is a new way of thinking about buildings entirely. Historically and still today buildings are conceived of as one-way vehicles, built for a particular purpose with a limited life span. These buildings are heavy, time-consuming to make, expensive, energy intensive, destructive, and they are torn down eventually. This creates a constant flow of resources being taken from the environment and then returned later as altered and foreign substances (i.e., waste). This process is causing significant and irreversible damage to our environment.

The proposed methodology of constructing buildings based on the entire life and function of the building could change the way we look at making everything. Free from the shackles of industry and corporate pressures, decisions and considerations formed around big picture holistic solutions have tremendous potentials to shape a better future and existence. This does not mean disregarding the economy, the economy can be shifted and is integral to any system we employ, it is more a matter of changing our views and our desires to meet the values we want and need.

The proposed building methodology hosts a slew of benefits:

### *Nature*

It is made mainly from wood, therefore; it sequesters CO<sub>2</sub> and offsets greenhouse gas emissions. Natural and renewable, accessible and versatile, wood is the best most suitable building material.

### *Time*

CLT panels are pre-fabricated precise and accurate building blocks delivered to site ready to be installed/erected with no on-site preparation. The process provides better quality control, better project delivery and minimal site disruption.

### *Weight*

Wood is a fraction of the weight compared to concrete or steel. Meaning it is easier to handle, process, manufacture, deliver and install. Associated with this is the reduction of energy usage. Plus a lighter building means less extensive footings and foundation and ultimately less concrete.

### *Height*

CLT as an engineered structural system makes it possible to build taller and more challenging structures with wood. The planar nature of CLT panels enables a single plane to act as both the floor and the ceiling to the level below. The design of the steel system eradicates the need for drop ceilings/plenum spaces, drastically reducing the overall height by limiting unnecessary, superfluous space. This makes a much tighter more efficient building.

### *Maintenance/Serviceability*

The steel seam connection gives the ability to access the building systems and services via top and bottom cavities. This not only makes it easier to maintain the building but makes it much simpler to install the services in the beginning, because the steel is designed to house them.

### *Scalable*

The CLT+STEEL system is completely scalable. CLT panels can be made in endless configurations of plies and lamination thicknesses, and the steel counterpart can be scaled to match. Meaning you can imagine making something using this system at the scale of plywood like a bird house for example, and on the other end, you can imagine mega-structures being made in the same way only at a different scale.

### *Health*

Using wood in buildings makes healthier living environments, improving inhabitants physical and psychological well-being. The use of wood creates a relatable and understandable manifestation of social values in building form. Wood buildings are buildings you can feel better in and better about.

### *Closed Loop*

Other than wood the building is comprised of steel and glass, both of which are highly recyclable materials. Therefore; when the building has reached the end of its life/use the CLT panels can be reused or adapted to suit another project, and the steel and glass can be recycled. Essentially, becoming a closed loop building system, where the parts and materials can be reused over and over.

### *Final Remarks*

So far, I have discussed the old, and new materials architects use in building. I have also shown an alternative way as well as provided a suitable methodology for improving current practices. It is well advised to review our past actions and learn from the good, while refining or refraining from the unfavourable practices to develop appropriate alternatives that are in agreement with best architectural values and principles.

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