Adoration of the Joint

Investigation and Translated Application of Jointing Methods

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Abstract

This research project is an investigation into the aesthetics and craft of traditional timber jointing techniques. It is an endeavour to grasp the essence of the timber joint and the craft by which it is produced and to develop it architecturally in the form of a pavilion for the general public in a national park.

Traditional timber jointing techniques were productions of culture; wrote learned, copied, and gradually refined over time. They have been widely used both structurally and decoratively and predominantly carry a high sense of craftsmanship and romanticism. Due to the need for highly skilled craftsmen and a rather time consuming production method this process has become largely attenuated through time. Nowadays, buildings with finely detailed timber joints are very rare because of the high cost involved in terms of time and labour; there are much quicker production methods that are generally more favoured.

This thesis will explore the joint and discuss the merits of the discourse with craft in the wider context and considers the relevance of this, not just as a way of tradition. This will be outworked through the synthesise of this methodology with a design for a timber pavilion that translates some of the concepts of jointing that Mies van der Rohe used in the Farnsworth House with steel. An investigation of different joints through physically crafting them is a fundamental aspect of this process.

The performance of the outcome can be marked by a successful integration of craft into the architectural design, which conveys the attitude of thoughtful correspondence between craft and design. Moreover, it completes the narrative of architecture as an edificatory process.
# Table of Contents

Acknowledgements........................................................................... ii  
Abstract................................................................................................. iii  
Table of Contents..................................................................................... iv  
1.0 Introduction...................................................................................... 1  
   1.1 Overview.................................................................................. 2  
   1.1 Objectives............................................................................... 3  
   1.1 Scope & Limitations............................................................... 3  
   1.2 Methodological Approach..................................................... 4  
2.0 Background..................................................................................... 6  
   2.1 The Joint: Beginnings............................................................... 7  
   2.1 Joint as Ornament................................................................. 13  
   2.2 Jointing Techniques............................................................... 14  
   2.2 The Craft of Architecture..................................................... 17  
   2.3 Building with timber............................................................. 20  
3.0 Precedent Analysis....................................................................... 23  
   3.1 Log Houses............................................................................ 24  
   3.2 Lockwood.............................................................................. 26  
   3.3 Carlo Scarpa......................................................................... 27  
   3.4 Gamble House................................................................. 28  
   3.5 Farnsworth House............................................................... 32  
   3.6 Pavilion Architecture.......................................................... 39  
4.0 Site.................................................................................................. 42  
5.0 Design Process............................................................................ 50  
   5.1 Documentation of Modelling.............................................. 51  
   5.2 Development of the brief..................................................... 68  
   5.3 Design Development........................................................... 69  
5.0 Conclusion................................................................................... 80  
   5.1 Critical Appraisal.................................................................. 80  
   5.2 Further Applications........................................................... 80  
6.0 Bibliography................................................................................. 81  
7.0 List of Figures.............................................................................. 83  
8.0 Appendices.................................................................................. 86  
   Appendix 1: Tables for Wood Strength and Stiffness............. 87  
   Appendix 2: Torrent Bay History............................................. 87  
9.0 Final Presentation Images......................................................... 88
The joint is the beginning of ornament
And that must be distinguished from
decoration which is simply applied.
Ornament is the adoration of the joint.

-Louis Kahn
1.0 Introduction
1.1 Overview

Architecture is a vehicle that facilitates human function and needs. Whether it be working, playing, learning, meeting physical needs such as shelter and warmth, or emotional and spiritual needs like a place to retreat, think, imagine, grow & develop, and relate with others. It also serves as a narrative of how we live both past and present; the way we design; and the way we build as a response to situation and requirements. The narrative is not only the story behind the architecture; how it was constructed, by whom and under what defining context, but also the connections that it creates in and to humanity through aesthetic and emotional appeal and the captivation of the mind and even the spirit. Whether the building is large or small, important to many or few, architecturally designed or not, ordinary or unique, it is architecture. This is not to say that all buildings therefore are worthy to be studied and written in the annals of history, but rather that buildings are simply a production of the creativity of human culture as a result of the process of dwelling and defines us individually and collectively.

Essentially, a building is the sum of a number of elements brought together and joined in a cohesive and deliberate way with particular intentions. The binding together of these elements is just as important architecturally as the building as a whole. Emmitt states, in the book *Principles of Architectural Detailing*, that “the detail is all-important in ensuring high-quality buildings. Indeed, common sense would seem to suggest that the place and meaning of architectural details is paramount, for without the details there would be no building.”¹ It is perhaps obvious that the detail (joint) plays a vital role in the architectural design of the building as a whole, so the intention of this research project is an investigation into the types and uses of construction jointing methods, of particularly timber construction, in an endeavour to express and exploit the properties of the joint and develop a language that can be applied throughout an architectural project from the individual parts to the whole.

1.1 Objectives

The main objective is to gain an in depth tectonic understanding of various jointing methods of timber construction; of the process of realisation of the design through the means of craft. Ultimately the goal is to design a piece of architecture with an architectural language that expresses the process and tectonics of jointing in a holistic manner from the details to the entirety. An architecture that brings out material qualities, incorporates a discourse with craft, and provides interest and appeal through the thoughtfully considered composition of the joint. To use Louis Kahn's words, "Ornament is the adoration of the joint."

1.1 Scope & Limitations

This research project is in no way an exhaustive analysis of all jointing methods, nor is it intended simply as a descriptive overview of selected jointing methods. It is the analysis of selected jointing methods for the direct purpose of design. This entails performance criteria, build-ability, and aesthetic considerations. Craft is a specific focus for the purpose of explaining that it cannot be separated from architecture. Analysis of certain buildings, architects, architectural styles, and architectural literature is to gain understanding and inspiration from the principles that govern and drive them, rather than used as a means for direct replication. Throughout this document, as is the case with much literature on the subject, the terms ‘joint’ and ‘detail’ are sometimes used interchangeably in the context of being considered part of a whole; a specific focus where two physical or spatial elements join at any level of an architectural instance. In his paper *The Tell-The-Tale Detail*, Marco Frascari explains that an "architectural element defined as detail is always a joint", implying that a specific element of design –referred to as a detail, will invariably be made up of, or being a connection to other different elements either materially or formally as part of the larger whole. As well as the physical product, both terms can be seen as the method of developing and executing; of bringing into being. He explains that "the art of

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detailing is really the joining of materials, elements, components, and building parts in a functional and aesthetic manner.” In this particular instance he has construed ‘detailing’ as the process by which joints are designed and executed, as distinguished from the joint being the product of this process. Therefore, details (or detailing) are both the process and the product – construction being the means by which details are construed.

1.2 Methodological Approach
The project will address the issue of jointing by looking at past and present timber jointing techniques, constructing some of those joints, assessing their merits, and trialling developments thereof. It will also take inspiration from various architects and architecture. The final design will be approached from the perspective of Mies van der Rohe’s Farnsworth House in a sense that if Mies were to design the building in timber what would it look like? This is inspired by various architects that migrated to New Zealand from Europe during, or around, the time of WWII (the same time that Mies emigrated to the U.S.) and successfully produced architecture that was ‘of New Zealand’ eg. Earnst Plischke, Frederick Newman, and Henry Kulka. They had to adapt their choice of materials to those that were locally available – that is, a more timber based architecture. Therefore, the intention is not to design a timber Farnsworth House per se, rather to translate the principles and design ideas of the Farnsworth House from steel into a timber medium.

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God lies in the Detail

-Mies van der Rohe
2.0 Background
2.1 The Joint: Beginnings

"God lies in the detail." This infamous adage has been attributed to Mies van der Rohe. While he may not be the first one to express this idea and the origins are impossible to state, it carries the underlying implication that the detail carries weight and consequence. A more common form (at least in the English language) is the derivative idiom, "the devil is in the detail", possibly because of the catchiness of the alliteration and the slightly mischievous sense it conveys. Again, it expresses the same idea that the details should not be overlooked, and in them can be the means for success or failure, but has a distinct focus on getting it right because of the ramifications of the word ‘devil’. In regard to this Blaser states: “The solution applied to the detail is, so to speak, the weakest link in the chain: if something is wrong in the detail, then something is wrong with the whole.” While this applies at the physical level, in context this carries distinct overtones of the constructional process (especially in relation to Far Eastern building techniques), and at a wider level, of the architectural clarity of a building.

Using the analogy of nature, Emmitt, Olie and Schmid point out that the detail is created in a way that is made up of smaller parts being joined together to form a whole:

"If we look at the way nature is ‘constructed’ we see that time and time again there are ‘small parts’ arranged and structured in such a way that they form a ‘larger part’. Using various forms and dimensions of attraction and attachment the whole cosmos appears as a structure of architecture based on the *gestaltung* [design; arrangement] and composition of smaller particles.”

The integrity and character of each ‘larger part’ is reliant on the quality and composition of its individual smaller parts. Let us take the simple example of Lego bricks. Even if we limit the amount of singularly different bricks to one type, the possibilities of different

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end products are almost endless because of the various combinations and permutations that are available, and the concept of representation in various scales. When the same smaller parts are connected and arranged in a different way we understand how dramatically different the resulting larger part is. This fundamental concept can be observed in chemistry, music, literature: Chemical compounds are stable or perform as designed when the elemental structure is joined appropriately; music can be harmonious or have discord depending on how the notes and rhythmic phrases are arranged; the meaning of a piece of literature depends entirely on the language used and the way in which the words are linked. It follows that this is intrinsically obvious in architecture as an architectural object is also dependant on jointing techniques that combine those smaller parts to form larger parts, and ultimately the whole.

Gottfried Semper’s architectural theory includes the aspect of textiles being the class of technical arts that the other arts developed from. Precisely, that architecture borrowed and has retained various symbolic forms, systems and terminology from textile art. "Over the centuries, he believed, building types retained the symbolic forms of their earlier architectural predecessors: the geometric patterns produced in brick, for example, were an active memory of the ancient weavings from which they were derived." Semper points out that the language used for certain textile elements are akin to architectural symbols (of ornamentation), like ‘string’, ‘band’, ‘cover’, ‘seam’, and we can see this in more common terms like ‘skirting’. From this basis he continues that the knot, as the primary system of joining threads, is the ultimate symbol for the primordial joint.

“The knot is perhaps the oldest technical symbol and [...] the expression for the earliest cosmogonic ideas that sprung up among the nations.”

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In particular, Semper identifies the weaver's knot (or sheet bend) as possibly being the original knot form because of its usefulness and diversity of applications within textiles. It has in fact been synonymous with the textile industry to this day. It found a very important use in primary production for making nets with which to use for fishing or hunting. In the case of the net, its very essence is the array of knots; the joints that hold the string together. Semper points out that the net in particular, as an important and ancient product of the joining of threads, is used in the arts as a motif in ornamentation or surface treatment, as we can still see in some liquor bottles as a net-like structure is wrapped around the belly, albeit for protection from breakage.
There are three main categories that can be identified in which an architectural object's qualities can be affected by jointing, namely, physical, aesthetic, and function. *Physically*, a joint is designed to be structural. That is, it must resist the forces imposed upon it by elements of its parts acting under gravity, or horizontal forces like wind and earth movement. Any joint will always have a degree of resistance to some force, whether large or small. For example, screws that hold a sheet of non-bracing plasterboard lining to a ceiling are not considered vital to the integrity of the *structure* of the building per se, but are inherently resisting the force of gravity on the plasterboard, so are therefore vital to the structural integrity of the *lining* of the room. Structural integrity (or failure) also brings about ramifications to the aesthetics. *Aesthetically*, the form, experience, and reading of an architectural object are dependent on the arrangement and choice of joints and materials. Gottfried Semper's writings on tectonics allude to this particular aspect as he explains the types of motifs and symbolism (specifically for the formal means of ornamentation) that would give the architecture a richer tapestry of understanding. He points out that properly signifying ornament is added to indicate a resistance to the forces that are acting upon a particular frame, support, or structure.\(^9\)

Rather than a theory of necessarily justifying the use of ornamentation, his architectural theory supports it as a formal means that serves to build up a rich tectonic understanding of an architectural object that adds to the ultimate end of aesthetic satisfaction. To illustrate, Semper directs our attention to the upright, vertical framework of the triangle.

"As is well known, it [the triangle] is also statically and structurally the most important joint in carpentry, and in fact the theory of carpentry is based on it because of the rigidity of a tightly jointed triangle."\(^10\)

In the case of the upright triangle we note that the rigid integrity is reliant on the presence of a horizontal member that supports as a structural collar or tie preventing the base of the diagonals from slipping outwards. Therefore, we can see the importance of the jointing technique that is used to connect the horizontal support to

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\(^9\) Gottfried Semper, "Techtonics (Carpentry): General-Formal," in *Style in the Technical and Techtonic Arts; or, Practical Aesthetics*, intro by Harry Francis Mallgrave, translated by Harry Francis Mallgrave and Michael Robinson (Los Angeles: Getty Research Institute, 2004). Semper explains the main purposes of tectonics in the context of frame with corresponding filling; the lattice, which is a complicated frame; the supports; and the structure, which is an integration of the supports with the frame.

\(^10\) Semper, "Tectonics," 626.
the diagonals of the triangle. In line with Semper’s theory the
determination of these connections should convey this idea
formally; that it is “necessary to indicate somehow the horizontal
forces that resist the thrust” that the two diagonal sides impose.11
Furthermore, the proportions of the triangle will affect (or drive)
the choice for how this is indicated – whether a horizontal member
is suppressed, articulated boldly, expressed by means of
buttressing, replaced with multiple supporting vertical members
etc. Further on, Semper (still referring to the framework of the
upright triangle) also brings up the idea of the gable as being
visually representative of the underlying, unseen structure that
makes up the roof. This is a notion that Mies van der Rohe uses, to
famous acclaim, on the Seagram Building in New York. The internal
structural I-beam columns (encased in fireproofing concrete) are
referenced by means of exposed non-structural I-beams attached to
the façade as expressed glazing mullions (Figure 2.3).

11 Ibid., 626.
More to the point, the external I-beams also perform the aesthetic function of expressing a verticality that is inherent in the concealed structural columns, and the fact that they stop short of the corner, allows an allusion to the dimensions of the concealed structural column. Finally, *functionality* is dependent upon the formal joints between spaces being conducive to the way people use and interact with the architecture. This involves many aspects that translate from a physical example of a joint, like vicinity between spaces, objects that act as hinges between spaces, vertical and horizontal spatial arrangement, routes between spaces (hallways, stairs, spaces between spaces etc.), overlapping of spaces.

There can be many overlaps within these categories, for example, an exposed joint between a column and a ceiling that was designed as integral to the structure will have ramifications to the aesthetics properties and possibly the functional properties if it serves to divide or delineate architectural space. Also, a joint that fails physically due to structural, infestation, weather tight or atmospheric issues (shrinkage, rust etc.) will invariably affect the aesthetics of the architecture. Moreover, it tends to bring a renewed tectonic understanding to the particular joint, the materials used, and the particular arrangement.
2.1 Joint as Ornament

In his paper “The Tell-The-Tale Detail” Frascari states that the detail is the “attaching of meanings to man-produced objects.”\textsuperscript{12} Not to be misconstrued as simply attaching a meaning to a meaningless object as one might ‘tack on’ ornament after the fact to embellish, rather, the sense that the detail expresses meaning and connection with culture. Loos passionately viewed ornament as a crime – a traditional architectural device used for cultures to express identity, culture, craftsmanship, and way of life that he believed was no longer relevant in his day and age. His justification for this standpoint was the fact that modern culture had advanced from various individual communities with their own traditions and customs and the primitive means of the past and no longer needed to express this sort of diversification. However, it is this very argument of the need for expression that Moussavi and Kubo use in their book, \textit{The Function of Ornament}, where they justify the use of ornament as necessary through various case studies explaining that there is a specific function to every use of ornamentation (or details). Likewise, Scarpa justifies the “need for decoration in order to achieve a life of expression and meaning in architecture.”\textsuperscript{13}

Uniqueness and individuality is something that is intrinsic to humanity, and therefore is desired to be expressed. Not just regarding the particular cultural identity we have through participation in a particular group, race or religion, but also on a more individual level. Identity is what defines us. We all have different ideas, thought patterns and experiences, and therefore have nuanced understandings in what we read and the way we read it. Loos’ view might be attributed a product of the particular culture he was part of – of the stripping back of Modernism to make the function more readable, and the rise of an International Style that was accepted worldwide, hence his argument for the obsoleteness of cultural identity. However, his view was a product of that particular culture, albeit having widespread influence. Uniqueness, identity, and belonging are aspects we all desire, and after all Loos himself was expressing his own cultural identity.


2.2 Jointing Techniques

This research project was undertaken with nothing particular in mind for either program or site, with the intention to let the research outcomes guide the development of the brief. This made it extremely difficult to envisage possibilities of an ultimate end goal, but was beneficial in that it forced the research and design development to drive the project. As per the research proposal, the general area of design was the joint: its expression, intentions, materiality, context within an architectural setting and the fundamental role the joint plays in telling the story of the architectural edifice. As there are a multitude of different types of jointing methods and categories, and it is simply not possible (practically or otherwise) to look at an exhaustive catalogue of every type existing, the subject was narrowed down to the realm of timber, in particular, the subcategory of mortise & tenon jointing methods. The mortise and tenon joint (in its various forms) is a very traditional method of fixing two perpendicular pieces of timber together without the use of nails as it predates the invention of smelting for the production of iron (and later steel) connectors.

Figure 2.4: Mortise & Tenon joint
Figure 2.5: Sample of different types of Mortise & Tenon Joints
Mortise and tenon jointing is an ancient technique that utilises the process of hewing a tenon in one end of the member to be joined that is smaller than the diameter of the member itself and a mortise, or hole for the tenon to be let into, in the other member. In this way one member literally passes through the other to form a strong connection between the two. It was discovered to have been used in the construction of the ship belonging to Kufu (King Cheops), an Egyptian pharaoh of the Old Kingdom (2650 – 2134 B.C.), and can be found in traditional Chinese and Japanese architecture.

Also, it is not limited to timberwork, and is seen as the method for jointing in edifices like Stonehenge (ca. 3000 – 1500 B.C.), where it is used to connect the lintels to the columns. Used in timber it can be used in a variety of situations from structural frames and trusses to windows, doors, furniture and fences. It is mainly used to maintain structural integrity between the connected members but has an aesthetic appeal as it reveals the tectonics of the joint, that is the nature and characteristics of timber and how it is assembled, embodying the inherent allusion to a discourse with craft.

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2.2 The Craft of Architecture

A very important focus to this research project is the outworking of architectural design ideas by means of craft, for it is the very means by which architecture is made manifest. For any designer there must be a discourse with craft that completes the understanding of detailing.

'Edification', from the Latin word 'aedification', is literally the process of building. It is made up two parts: 'aedis' or 'aedes' = 'dwelling' or 'temple'; and the combining form of 'facere' = 'to make'. Although it has the literal meaning of building a dwelling or a temple, it is synonymous with a building up spiritually; that of building up the church and the soul in faith and holiness.

'So Christ himself gave the apostles, the prophets, the evangelists, the pastors and teachers, to equip his people for works of service, so that the body of Christ may be built up until we all reach unity in the faith and in the knowledge of the Son of God and become mature, attaining to the whole measure of the fullness of Christ. Then we will no longer be infants, tossed back and forth by the waves, and blown here and there by every wind of teaching and by the cunning and craftiness of people in their deceitful scheming. Instead, speaking the truth in love, we will grow to become in every respect the mature body of him who is the head, that is, Christ. From him the whole body, joined and held together by every supporting ligament, grows and builds itself up in love, as each part does its work.'

This excerpt uses the same sort of language that relates to building to describe the process of building up requiring the unity of parts to make a whole, emphasising the process of the joining of these parts being key to success as a body, that being the Body of Christ. It is also interesting to note the derivation of the word 'temple' (aedes), as this is a term used in the Bible regarding the human spirit being the temple for the Holy Spirit as analogous to the physical temple of God in the Old Testament. "Do you not know that your body is a temple of the Holy Spirit, who is in you, whom you have received from God? You are not your own."

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16 Eph 4:11-16 (NIV).

17 1 Cor 6:19 (NIV).
Spirit from God then the human spirit is where the Holy Spirit dwells; therefore, edifying our human spirit establishes and builds up the temple, enabling and allowing the Holy Spirit to dwell within.

In his paper, *Building Dwelling Thinking*, Heidegger describes building as dwelling; living; being; that dwelling is the purpose to our lives and in building we construct meaning. The continual search for meaning is the process of edification. For in building we live and breathe and have our being. We are body, soul and spirit. As created beings we are all individual, we all look different to the next person, have our own dreams and desires, and have the ability to express the creative nature that is inside of our spirit. Gregotti too, states that the "application of construction can be a source of meaning. It reflects a phenomenological interest in the 'thingness' of architecture, and its ability to gather." If building is dwelling then as we build up physical edifices through the means of culture or design, we foster relationships, emotions and edify our society and the culture within which we dwell. Take for instance the building of a gothic cathedral. The construction process, which would span several decades, employed an army of craftsman and labourers. Over the years the skills and knowledge of the masters (masons, stonecutters, carpenters etc.) would be passed down, edifying the following generations so that they would become the masters themselves one day – working on the same cathedral in some cases. Furthermore, the building of a cathedral was the building of a community. Not only during the construction, where the cathedral builders became a community of like minded individuals edifying toward the same goal, but the community of believers that the cathedral served. Many of the great gothic cathedrals have become icons that are visited by Christian and non-Christian alike, on pilgrimages, sightseeing tours, and people in search of more intimate connections, creating a worldwide community of admirers of the ability of united human endeavour of edification unto a greater cause. If we allow it to, there is therefore potential for spiritual edification to take place as we go through this process that defines us as a culture and engages with our humanity. In many and varied ways the exercise and the result of edification serves to gather. Edification reveals creativity and desire that God

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has placed within our spirit, and cultivates the spirit as we open our hearts to what it truly means to be edified.

Where does design stop and craft begin: Do those involved in design need any concern with craft; similarly should the craftsman have any part in design?

The Arts and Crafts movement was a celebration of craft and the work of the hand with moralistic overtones of honesty that came out of the current social conditions. “It was about respecting your materials, and the way you used them. It was about showing how things were constructed, so they never looked different to what they really were. Equally it was about respecting the maker.”19 As a result the detail was instrumental in the liberation of the oppressed working class. Since the workers had the skill and knowledge with which to produce the details it empowered workers as they were not only an integral part of society, but the very means by which building custom was cultured.20 Indeed the process of constructing details throughout the Arts and Crafts movement needed to be understood by architects alike:

“The knowledge of details and of the related skills was the necessary means for the architect to practice his profession, since it was his task to select the appropriate workers for the appropriate details.”21

Both a thorough tectonic understanding of details and their fashioning was the key to ensuring quality of production and result. A relationship between architecture and craft can be a very powerful tool for design. The more a designer learns about the tectonic art of construction, the greater the potential for informed design decisions that result in detailing that tells a more comprehensive narrative.

Perhaps Mies’ usage of the term ‘God’ in the infamous adage “God lies in the Detail” (refer to 2.1 The Joint: Beginnings, page 7) was not intended to be merely metaphorical. The phrase is not as idiomatic as what we have attributed, for in details the creative aspect of human nature is expressed, which is, fundamentally, a reflection of the creative nature of God. Therefore, God truly is in the detail.


2.3 Building with timber

Timber is an elemental building material. The primitive aspect to the process of cutting down a tree, milling it and working it into conjoining elements of a greater architectural body is part of what gives timber an intrinsic connection with humanity. Timber jointing, especially that of traditional culture, carries a particular sense of 'integrity'; that someone has dedicated their time to carefully crafting the joint. Regardless of whether the joint was actually 'lovingly' crafted by hand or whether it was a more mechanised process, it inevitably insinuates human contact. Furthermore, the properties of the tree are still evident in the naturalness and rawness of sawn timber. Although it can be chemically treated to prolong durability; painted; or heat treated for bending, the elemental makeup of timber has not been altered. Other manufactured products use a process of melting and/or combining with other materials, as is the case with the production of steel, glass, plastic, concrete, or even brick (though brick still retains a sense of the raw clay from which it was formed.) A beam, plank, column, or stick of timber is precisely a cutting from a tree; it is fundamentally part of the tree and therefore retains all the characteristics that define it as thus like grain, colour, texture, strength, directionality (linearity), ability to absorb and expel moisture etc. It remains a natural and raw material. Even plywood, which is a slightly more contrived building material than simply sawn timber, is still made up of layers of the raw material itself that are rotationally peeled from the tree. Plywood retains (even exploits) the natural properties of the grain of timber. The strength and stability of plywood as a panel type product utilises the strength of the grain in both directions by each layer of veneer being laid across the grain to the last, resulting in a panel with a more isotropic strength.22 Furthermore, in terms of aesthetics, Patterson states that Frank Lloyd Wright believed “flatness […] exhibited grain characteristics better than surfaces that were not flat.”23 Flatness is an inherent property of the result of the milling process, both in sawn timber stock and rotary cut veneers. Both reveal different qualities of the grain that Wright readily employed, despite the anisotropic strength of natural timber.

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22 Refer to section 5.1 Documentation of Modelling, page 43 for information regarding the anisotropic strength properties of natural timber.
for “he was more sensitive to the grain of wood than any other property.” Linearity is a characteristic that is a combination of the grain direction and the manner in which a tree grows tall and narrow, and hence the way it is sawn for use in a building. Wright often applied the natural aspect of wood’s linearity into his designs, particularly to emphasise horizontality. Like his siding that was composed of stacked rows of butted horizontal boards with projecting battens every first, second or third row, or the lines of butted roofing shingles that produce many parallel lines along the roof. He even exhibited a plastic-like quality to the linearity in some instances with multiple accentuated horizontal lines wrapping around different surfaces. For example the long runs of lapped facia boards which continue around more than one side, dispersed layers of projecting battens on horizontal siding, and the interior plywood ceilings with projecting battens running along the grain and around different surface planes. While combining to achieve linearity these methods also isolate the individual members to reveal board widths (and often thickness) and the grain.

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But Patterson also asserts that the linearity of timber also relates to the human scale in terms of physical dimension, handling ability, and therefore workability. Hence why he cites Wright as saying wood is “the most humanly intimate of all materials.”

Like Wright, Meyhöfer is in high regard of wood as a construction material. His book, *Touch Wood*, is full of case studies of exemplary buildings from various architects worldwide, providing a brief insight into the way in which they used timber, other materials, structure, and design. He writes a fairly compelling introduction of the benefits of timber architecture including its healthiness, completeness and diversity as a building product, its simplicity, sustainability, and warmth. He even states that it is the “most sensible and responsible material one can use.” He points out at the very beginning the city of Hamburg’s recent issued requirement for all children’s day care centres to be made of wood. “Children are the most sensitive users of architecture, and wood is a material with child-like characteristics; it is natural, captivating and emotional.” From a very young age children absorb new information through all their senses like sponges. This involves touching; feeling and interacting with architecture in an intrinsic way. Whether it is the texture of the grain, the inherent warmth, or the enticement of the colour variations, wood is one of those products that offers the allure of touch, which, especially for a child is all too tantalising.

Indeed, our connection with the tree itself is fundamentally understood as a relationship of provision for humanity. Trees gives us oxygen and absorb the carbon dioxide we produce; they can be a source of heat when burned; shade from the sun; and focal landmarks and vital components that make up the glorious vistas we enjoy. Due to the fact that all of these aspects are for the provision of our primary needs, it is no wonder the crafting of timber for shelter has such a psychological appeal.

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3.0 Precedent Analysis
3.1 Log Houses

Log house construction is a historic form of building that has its origins in Eastern Europe and Scandinavia. It was much used due to the local, readily available source of materials in surrounding woodlands and the relative ease and speed of construction in comparison to contemporary building vernaculars (stone and earth.) Despite the advent of more developed, cheaper, and quicker timber building techniques the log house (or cabin) remains a popular romantic notion, particularly in North America. There are many different ways of joining the logs that make up a log house, but essentially the technique consists of roughly hewn round logs stacked vertically so as to become the completed walls of the house. This technique was traditionally used because of the sole reliance on hand operated tools. With no mechanised milling process available retaining the entire round trunk was a lot less time and work involved than ripping rectilinear profiles. Also, the benefits of thicker walls for insulation were well utilised. The arrival of saw mills enabled more accurately machined round logs and a definite increase in the speed of construction or the option for milled rectilinear profiled logs.

Figure 3.1: Log house jointing technique: Round notch with a tongue & groove
The jointing method between each log layer in a wall is crucial, as is the walls that interconnect with it, to ensure the logs don’t fall down. As one can imagine, stacking round logs on top of one another is not very stable without a way of interlocking. Round logs can be stacked up relying on the overlapping corners to hold the structure together and chinking the gaps between; logs can have a V-notch cut along the entire length of the underside to fit snugly with the rounded top of the layer below; the logs can be milled so as to have flat tops and bottoms where they mate; in traditional Scandinavian style the entire underside can be formed (scribed) to match the log that it sits on; or the mating logs can be tongue and grooved. Typically the corners of the walls will help to hold the structure together with each layer extending beyond the corner and through interlocking corner notches that prevents lateral movement. Especially in its typical round profile it remains a quintessential wood construction system.

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28 Chinking is simply blocking the gaps (chinks) between the logs to keep out the wind and help prevent heat escaping from the building. Traditionally these gaps were filled with mud and any larger gaps could have smaller pieces of wood inserted to take up space and then filled around with the mud. Contemporary chinking uses cement based mortars and modern flexible caulking compounds.
3.2 Lockwood

Lockwood is a firmly established New Zealand company with show homes and franchises throughout the country and built projects worldwide. It has been operating since 1951 when Jo La Grouw Snr created the proprietary construction system that makes Lockwood unique. The system has various different types of wall arrangements depending on specific requirements within the particular area of the building. Lockwood is built on the log cabin framework: All the wall arrangements comprise of horizontally laid pieces of tongue & grooved timber (with or without cladding and insulation) that are vertically stacked to form a completely finished structural wall. Each wall is interlocked to, and braced by, corresponding transverse walls that form the plan of the building. Laterally, the interlocking is by a specially designed dovetailed aluminium profile that slides into machined slots in the timber (Figure 3.3). Each aluminium section is the same height as each piece of timber and is inserted as each layer is placed.

In addition, tensioned vertical tie rods within the walls help to hold the entire building together, by compressing all the tongue & grooved joints of the timber. The complete system is designed to be easily buildable from the ground up in layers that one or two people can manhandle with ease. The differentiation from regular timber buildings in New Zealand, other than the way the timber is joined, is that Lockwood consists of solid timber walls (heavy timber construction) that serves as the finished product (for interior walls at least), rather than light timber framed walls that are then lined.

Figure 3.3: Lockwood system
3.3  Carlo Scarpa

Carlo Scarpa’s architecture has an astute connection with context through the reuse of materials in different ways. He was also the master of the joint and its relationship to the whole. Frampton tells us how the stone revetment in Fondazione Querini Stampalia main exhibition hall is used in a way so as to appear like “petrified cabinetwork” which links to the wood used on the handrail and deck of the entry bridge by way of the brass connectors employed at the joints to each.29

Albertini states that “his declared aim was to overlook nothing.”30 This meant not only that there would be a thematic encapsulation to the entire project, but it allowed the development of the details that has become so defining of his architecture.

Scarpa readily employed the use of traditional cultural methods, if not to produce a traditional result. He fostered strong working relationships with specialised craftsman that in turn help develop his architectural language. He respected their work and relied upon their unique abilities and understanding, always using them for his commissions:

“Scarpa did not restrict himself to using the available skills, but cultivated communication with the people who were to implement his drawings, developing both their skills and their creativity. He thus revived an artisan culture which had been threatened with disappearance. He enhanced it by designs which made the culture relevant, integrating it with contemporary architecture. [...] Scarpa emphasised that one reaches the truth through manual constructional work, a thought akin to the logic of dialectical reasoning.”31

31 Los, Carlo Scarpa, 22.
3.4 Gamble House

The Gamble House, in Pasadena, California, was designed by Henry and Charles Greene. They were trained architects but had also been previously schooled in woodwork and metalwork. The house (and as is common with much of the Greene's works) was a synthesis of the Arts and Crafts and oriental building styles. Outdoor rooms, exposed timbers, and the low pitched roof with large eaves are some of the features that they borrowed off the Japanese style. The brothers subscribed to The Craftsman, a monthly periodical promoting Arts and Crafts style and ideas, of which the first two issues were focused on Morris and Ruskin. So combined with their manual training background the Arts and Crafts Movement became an ideal for the Greene brothers. Although they sometimes used premium timber veneer strips in a decorative way and hid the lower cost structural timbers (and encased steel beams in timber in some later buildings), the Greene’s expressed a craftsman’s approach to construction. For, as Tinniswood states, “the Greenses were sometimes carried away with the idea of honest construction as decoration in a way that would have had English Arts and Crafts architects reaching for their Ruskin.” The Gamble House is a holistic approach to design. One of the reasons why it is so highly valued and admired is “in the quality of care in which the tiniest detail receives as much attention as the greatest.” The Gamble House is all the more an architectural icon because of the Greene brothers’ thorough understanding of the details they used and adapted and their appropriate use, and the means of craft they employed.

Figure 3.4: Gamble House

33 Tinniswood, The Arts & Crafts House, 84.
Architecture begins when two bricks are put carefully together

-Mies van der Rohe
Figure 3.5: (previous page) Farnsworth House as approached from the Fox River

Figure 3.6: Farnsworth House Plan
3.5 Farnsworth House

The Farnsworth House is an architectural icon that is highly representative of the design principals of Modernism – in particular, the International Style. It stands as a testament to Mies’ work and his principals. It is wrought of a craft that culminates in elegant simplicity creating a clarity of both whole and parts; epitomic of his infamous axiom ‘less is more’.

It was designed as a weekend retreat for the original owner, and namesake, Edith Farnsworth. It consists of a steel framed skeleton with full height glass between the floor and roof slabs. Although the floor and roof slabs are an intricate combination of steel grids, concrete, and travertine, they read as simply two monolithic slabs between eight wide-flange columns with a complete sense of structural ambiguity. Though no welds are apparent, the Farnsworth House is in fact a celebration of the craft of welded steel construction.

To get the pure, elemental look that he was after Mies spend a lot of time designing and developing the details. According to Cadwell it is these details that are the “governing logic” to the construction of the house.34 The joint where each of the main wide-flange columns connect to the roof and floor plate uses a welding technique called plug welding, which is more common in automotive manufacturing than in structural engineering. It is particularly useful to join two pieces of lapped steel flush together without using any other type of fastener that would protrude from either face. The process, shown by the sequence of pictures overleaf, is as thus: In the case of the Farnsworth house the wide-flange columns were set in place and holes were drilled at the connection points. A temporary steel seat was welded to the columns in order to accurately place and shim the perimeter beams into the correct position.

Michael Cadwell, Strange Details (Cambridge, Mass.: MIT Press, 2007), 113
Figure 3.7: Sequence of operations for plug welding Farnsworth House structure

Figure 3.8: Plug Weld – Clamped

Figure 3.9: Plug Weld – Welding to fill the holes

Figure 3.10: Plug Weld – Welding finished ready to be sanded
The channel-section perimeter beams of both the roof and the floor slab are clamped to the inside of the columns with flat faces together. Welders then fill the drilled holes, which fuses the two elements and the weld is ground flush. To complete the disappearing connection act the seats are removed and the whole structure is painted the same white colour. Thus, the two elements remain visually distinct, appearing to simply run past each other with no trace of a connection at all. The effect is even more than the slabs being 'slung' from the columns. Rather, they seem to float – defying gravity and revealing nothing of how they are joined. “The mechanical craft of the seated connection disappears with the industrial craft of welding, the industrial craft of welding disappears with the handcraft of sanding, and the handcraft of sanding disappears with its own operation. There is no glorification of technology in this curious sequence, just as there is no remnant of craft.” In the end the pursuit of the architectural ideal of simplicity belies the complexity of the craft that facilitates it. However, even though craft is suppressed, it is only by virtue of its exacting nature that the essence of the architecture is brought forth.

Figure 3.11: Seamless joint at main column

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35 Michael Cadwell, Strange Details (Cambridge, Mass.: MIT Press, 2007), 113
From the structure to the window frame details Mies designed the Farnsworth House with standard off-the-shelf steel sections. Figure 3.14 shows the details and the different steel sections Mies used at three different locations along the window frames. The wide flange column is given special consideration on the interior as well as the exterior. The flat section of the column is exposed to become the only ‘wall’ area in the house. This is emphasised by the gap between the windows with the steel angles wrapping into the column to form a recess. The intermediate steel window mullions between the columns have the same type of recessed detail and have also unsuspectingly been designed to offer tensile structural stability between the floor and the roof\textsuperscript{36}.

The corner detail of the window frames is unmistakably Mies. This configuration is reminiscent of many of his works, especially with respect to curtain wall systems like that of the latter Seagram building\textsuperscript{37} – albeit the main structural columns in the Farnsworth house are pulled back from the corners.

Mies designed the floor to float 1.2m above the ground; a further two feet above the level of the highest recorded floods in the previous hundred years. However, as a sign of things to come, the site was flooded during the houses construction up to the level of the lower deck. And despite the high level of the main floor, heavy seasonal rain has caused flooding on more than one occasion that has seen the building’s wooden core and primavera panels destroyed and completely replaced.

\textsuperscript{36} See Cadwell, \textit{Strange Details}, 112.

\textsuperscript{37} See Figure 2.3: \textit{Seagram Building corner} detail, page 11.
Figure 3.14: Farnsworth House - Isometric Section of Window Frame Details
Figure 3.15: Exploded view of Farnsworth House showing individually perceived parts
3.6 Pavilion Architecture

As defined by Blaser, “the pavilion – in late Latin “papilio”, the
pleasure tent– is a free-standing building, open to many sides and
as a rule linked to nature or a landscaped garden.” In its purity,
the pavilion exists for relaxation, pleasure, withdrawal, and the
adoration of nature. The pavilion can take on many forms from
classic architectural follies and small garden outbuildings, to those
built for nobility like the various pavilions within the Royal palace
complex in Phnom Penh. The idea of ‘pavilion’ permeates Mies’
arquitectura, especially the example of the ancient Chinese pavilion.

In a comparison with the Barcelona pavilion:

“[…] These buildings again show us the lost correspondence
between life and “existence within space”, as well as the
involvement of exterior space, and a reverential relationship to
nature.”

The Farnsworth House is epitomic of pavilion architecture: The fact
that it was designed as a weekend retreat, the open plan, a seamless
visual connection to the landscape, and the physical positioning all
speak of retreat and an embrace with nature. There are gradual
formal transitions as one journeys from outdoors to indoors: From
the grass of the open meadow up to the floor of the open deck; then
up again to the open (on three sides), but covered deck; a 90° turn
and then a horizontal move into the glass enclosed space; finally,
into the heart of the building, which is completely enclosed. Every
degree of enclosure is staged, “each stage pulling us deeper into the
play of frame and landscape.”

There are further graduations that
respond to the natural environment like the mosquito nets that can
be installed on the covered deck to enclose the walls, the sheer
curtains that can be drawn, and the doors and window that can be
opened or closed. The ‘less is more’ attitude that Mies took towards
the architecture emphasises the elegance of these different spaces
and the transitions between them. In its positioning on the flat near
the river “the Farnsworth house relinquishes its grasp on the
landscape and opens like a hand in a river” as it is gently
embraced by the giant sugar maple nearby: One with nature.

38 Werner Blaser, West Meets East: Mies Van der Rohe, (Basel; Boston; Berlin:
Birkhäuser, 1996), 90.
39 Werner Blaser, West Meets East: Mies Van der Rohe, (Basel; Boston; Berlin:
Birkhäuser, 1996), 90.
Figure 3.16: Sketch of Japanese pavilion

Figure 3.17: Sketch of Farnsworth house
Figure 3.18: Series of sketches that show the graduations of enclosure
4.0 Site

Site is an attribute that has arguably the most influence on design. Physical location, environmental and ground conditions, availability of building materials or labour, history, amenities, proximity to places/objects etc: All of these aspects can have an impact on design, whether they serve to constrain or expand. The initial focus on detail meant that the site was not something to be considered until the later stages of design.

This drew attention to the considerable influence that a location can have on the design - particularly planning, orientation, and geography. However, the site was chosen with specific intentions in mind that came as the result of initial and conceptual design. The chosen site is Torrent Bay within the Tasman region, in particular the lagoon-type estuary that lies inland to the bay itself.
Figure 4.3: Site at Torrent Bay showing walking tracks and rivers
The estuary is a unique site in many ways. It lies within the Abel Tasman National Park and is visited by many people year round who stroll the walking track or kayak around the different bays, exploring the area. The village of Torrent Bay is situated on the northern edge of the estuary between the bay and the beach. It marks a pickup point for water taxis that operate in the area and a significant milestone in the walking track that runs through it. The estuary is very responsive to tidal changes, filling up every high tide and emptying out every low tide. Notably, tidal differences in the Nelson/Tasman region are particularly large. The range of spring tides (around new moon and full moon) can often be up to 4.5m between low and high tide. The tides also determine the path of the walking track: The estuary can be crossed within two hours either side of low tide, otherwise, an all-tide track leads around it to Torrent Bay village. The difference in time is one hour between the two routes. It was this tidal feature that was attractive about the site as it echoes the flooding that has happened at the Farnsworth house on more than one occasion when the Fox River breaks its banks. It was an opportunity to respond to the tidal changes.

42 Source: http://tides.mobilegeographics.com/calendar/year/4097.html
Figure 4.6: Dramatic change: Satellite view of high tide (above) and low tide (below)
Figure 4.7: Torrent Bay at high tide

Figure 4.8: Torrent Bay at low tide
Moreover, a defining factor in site selection is that the estuary is the confluence of the sea and the waters that flow from the mountains; it is the joint, in the wider context, between ocean and tributary. The brackish water of the estuary is neither ocean nor river; it is both. The two main tributaries are the Torrent River from the south east and Tregidga Creek from the northern tip, while a minor one flows in from the southern point. It was French explorer Jules Dumont d’Urville, who was instrumental in charting the area and naming many of its features, who named Torrent Bay Anse des Torrents (Bay of Torrents) because he saw three torrents flow into it⁴³. The estuary is partially enclosed to the sea between a prominent hilltop on the south and a sand bar that stretches from Torrent Bay village on the north.

The specific site will be on a prominent headland at the south end of the estuary (see Figure 4.3). This has quite a slope and is covered in dense bush that runs right down to the estuary, which in contrast is flat and sandy. It is a very sharp transition between the two terrains. This is a desirable point as it is a place that the walking track nears as it runs around the hill and is a junction where one can choose the high tide or low tide route. Also, from here one can explore Cleopatras Pool, another notable feature along the track, just up the Torrent River to the east. This will be especially beneficial for kayakers at high tide as they can kayak right into the estuary and leave their kayaks at the pavilion to explore up the river further. The pavilion will need to be able to respond to the tides, which is an integral aspect of the site.

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⁴³ Dumont D’Urville, “III The Passage from Port Jackson to Tasman Bay and visit to Astrolabe Bight” in New Zealand 1826-1827: From the French of Dumont D’Urville, edited by Olive Wright, 60-84. (Wingfield Press, 1950), 78-79.
Figure 4.9: Cross section of site running north-south
5.0  Design Process

The design process did not start out, as one might expect, with intensive site investigations and research into various precedents of the program. There was no site and no program. This might leave the question begging, what do we design? However, it meant an initial focus on detail and an inside-out design approach with the intention that a brief would develop from those initial investigations; that the details would be a generator for the architecture as pretexts for text.44

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5.1 Documentation of Modelling

The design process began with an investigation into various types of timber joints. As there are numerous different ways in which timber can be joined, and indeed numerous variations and complexities within, the predominant focus was on the mortise and tenon joint. Within this type alone, there exists a myriad of variations and possibilities, so a selection was made of some typical traditional joints and some perhaps not so mainstream.

The commencement of the research involved physically modelling different mortise & tenon joints to gain greater understanding of both the three dimensional look & feel, the process of crafting, and an idea of the performance of the joint. No extra fixings (glue, nails, screws etc.) were used in the process of crafting so the performance of the joint can be determined by the inherent properties of the jointing method. Needles to say, the quality of execution is a major factor in the joint making process and can lead to varying degrees of success or failure depending on a specific joint’s tolerances. Also there is the assessment of how much time is taken getting the joint to fit precisely.

The simple through tenon was the first to be crafted. Though it is the most basic, it is still a difficult and time consuming joint to build. From previous experience (and through various research sources) the process of crafting a tight fitting and neat joint requires an understanding of the final pieces that mate and how it can be ensured that the visible edges are tight to their mating counterparts. Care must be taken in the marking out, cutting and chiselling.45

Figure 5.1: Extended through tenon

45 All of the examples of joints have been created using hand tools for the most part. In doing this I found myself constantly checking and sharpening the various chisels used to ensure clean cuts and ease of use (for example, smoothing down the final surface of the tenon cheeks to fit tightly into the mortise).
This joint can rely entirely on friction (if no other fixing elements are used) therefore it is essential to get a tight fit. However, as is the case with all mortise and tenon joints, the tolerances are critical: If the fit is too tight the mortised piece may split apart when the tenon is inserted, especially if the side walls are too thin (tenon is too thick). Likewise, the joint will fail if the fit is too loose. The first iteration of modelling is an example of the tolerances being overstepped. In an effort to achieve a tight fitting and secure through-tenon joint, the insertion of the tenon caused the mortised piece to split (Figure 5.1). When the tenon is inserted it asserts stress on the mortised piece that causes a reactive tension which helps to hold the joint tightly together, but the case in point shows that there is a point at which the internal structural integrity of the timber itself will fail when tensioned too much. This is fundamental to the nature of a timber joint in which the solidity depends principally on the nature of friction, but it is important to know that the reactive tension does not have the same result in every direction. The anisotropic nature of timber deems that any tension along the length of the grain (in the same direction as the fibres) has a greater ability for resistance than tension perpendicular to the grain. For example a piece of timber will split along its grain far easier than breaking across its grain due to the innate nature of the direction of the fibres within timber that hold it together.\footnote{Timber is also anisotropic in both directions across the grain, typically splitting more readily normal to the growth rings (radial) than tangentially as the growth rings are defined lines on which to split along.} Naturally, the same goes for the compressive strength of timber. Typically the compressive strength of timber parallel to the grain is between 2 and 4 times the strength in the perpendicular direction the tensile strength parallel to the grain can be as much as 20 to 40 times the strength in the perpendicular (It varies with grading and species.)\footnote{See Appendices} It is also worthy of noting that imposed loads can result in both tension and compression on different parts of particular timber members depending on the situation. For instance, loading a spanning structural beam with floor joists running perpendicular; the floor joists will impose a compressive load on the top of the

\[\text{Appendix 1: Tables for Wood Strength and Stiffness, page 72. It is also interesting to note from this table that the tensile strength of timber parallel to the grain is between 2 and 4 times greater than its compressive strength, while the opposite is generally the case in the perpendicular; depending on the grading and species it can be up to 1.5 times the strength in compression than in tension.}\]
load bearing beam, resulting in a reactive tensioning of the lower part of the beam.

The pinned tenon joint is very common in timber framing. In the constructed model in Figure 5.2 two offset, tight fitting pins (wooden dowels) were bored into a through mortise & tenon joint after it was assembled. Sometimes the holes in the mortise can be predrilled slightly offset (foreshortened) to the holes in the tenon, resulting in a drawing together of the joint as the pins are struck in. This process is a form of pre tensioning called draw boring. The pins assist in holding the joint together should the timber shrink as it adjusts to ambient moisture conditions and/or to resist any movement. They directly assist in the structural integrity of the joint as they work in shear to prevent the joint separating. The pins themselves are reliant on friction to remain fixed but this is secondary to the performance of the joint. Greater shear loads also create more friction to help hold the pins in (until the limit of shear strength has been reached of course.) The presence of the pins gives the joint a tectonic expression of rigidity and permanence in comparison to the simple through mortise and tenon.

They also emphasise the expressed aspect of different members passing through each other to fix the joint (especially if seen from both sides as is the case in the model), in addition to the visible end of the tenon, which was flushed like the pins to obtain a consistent appearance.
A slight variation is the open through mortise & tenon, sometimes referred to as a bridle joint, which is used in a corner situation rather than a ‘T’ joint. The joint isn’t as strong on a corner as the mortised piece has no timber beyond the mortise itself to hold the open end together, thus the mortised timber must be very strong so as not to split open when the tenon is inserted or if there are loads imposed on the joint that would cause it to twist. Also, it has a greater predisposition to hinging if any loads force the members off the perpendicular because of the lack of the other mortise side wall which helps to stabilise the joint. Pins would aid in preventing any hinging. Albeit, in terms of a corner joint it is far superior to that of a simple mitre in terms of performance albeit they are both suited to different applications. The mitre emphasising a visual continuity, of wrapping or folding around and displaying a clear profile as seen in Figure 5.4, while the bridle giving a sense of both overlapping and immersion. One linear direction is seen as the more dominant one, which can be emphasised by thicker widths of timber or darker coloured species as is in the picture where the darker, richer colour of the Douglas fir overshadows the lighter pine.
The pegged, or keyed, tenon joint, as the name suggests, has a peg through the tenon. The peg acts in much the same way as pins (ie. locking the tenon in place) but in a different position, but it also draws the tenon tighter against the mortised piece when inserted due to its wedged shape. It is wonderfully simple in theory but of course extremely time consuming and difficult to craft, not only because it has extra parts that need to be fashioned, but a measure of awareness is needed to ensure the peg will work correctly to pull the joint together as it is inserted. It is a very visually engaging joint as its workings are clear to see and understand, but it also physically engaging as it can be assembled and disassembled as needed. This has particular use in large or bulky furniture that can easily be broken down into smaller parts for portability or storage when not in use.

Figure 5.5: Pegged, or Keyed tenon
The foxtail wedged tenon is perhaps one of the most unpretentious and unassuming joints. On face value it looks exactly the same as a butt joint and on closer inspection could easily be supposed a tight-fitting blind mortise and tenon. The later would essentially not be wrong but the slight differentiation is the wedged or dovetail shape that the tenon assumes when inserted into the mortise. This is due to wedges in saw kerfs at end of the tenon (in the end grain) that are forced further in when the tenon is inserted into the mortise. This splays the tenon to fill the shape of the dovetailed mortise as the joint is brought together. It is a mechanically bound joint that has extremely fine tolerances and gives no room for error; it is by nature single-staged - requiring no secondary means of fixing; single sided – being worked and fit together from one side only in relation to the mortised piece; also, it is a joint that will not come apart - even if assembly goes wrong. Its main use is when a mortised member is already in place and there is no way in which to fit wedges to the tenon from the reverse side or to gain easy access to the sides to drill fixing pegs, for example remedial work.48

The foxtail wedged tenon can also be used to conceal any fixings in joinery and furniture, for example, when a clean look is desired that does not compromise strength. All of the previous mortise & tenon joints have an architectural expression that coincides with the method of assembly. Although his joint exemplifies a dialogue with the process of construction very well, the architectural expression of this is masked. Much like the plug welds used on the Farnsworth House the craft hides itself. Two sectioned models were constructed to reveal the fixings that are vital to the integrity of the joint. The sectioned model, as it was executed by ‘splitting’ both members in half, revealed that the structural integrity of the joint was compromised. While the tenoned member did not pull out along its length away from the mortised piece due to the wedges preventing movement in that direction, the tendency was to slide out sideways if there were any residual movement due to the joint not being completely tight. In the first attempt (Figure 5.8) large gaps can be seen between the two members as the wedges did not splay the tenon enough to ensure tight fitment. It will not pull out completely longitudinally to the tenon member, but can easily slip out sideways.

Figure 5.8: ‘Sectioned’ foxtail wedged tenon

Figure 5.9: Second attempt at a ‘sectioned’ foxtail wedged tenon
The second attempt redressed this problem, but the joint tended to open sideways during insertion resulting in the need to belt it back together, of which one can observe the hammer marks on the face in Figure 5.10. A possible solution to this would be to adapt the joint so the mortise was dovetailed not only in the direction that can be seen (on the visible side), but on the side that faces the tenoned member. In turn, the wedges would need to be angled so as to open the tenon more on the hidden part of the join. However, this only adds further complexities in construction to an already difficult joint, and doesn’t actually align with what the motive behind sectioning the joint sought to achieve; it only creates more detail that cannot be perceived in the end outcome – which may or may not be desirable. Figure 5.9 and 5.10 both clearly show the effect that the wedges have on the tenon, splitting the timber along the grain. This demonstrates the timber revealing its limits of cross-grain tensile strength. However, the direction and short length of the splits will not overly compromise the joint along the length of the tenoned member.
All of the joints thus far have been between members that are perpendicular to each other. It was therefore decided to investigate whether or not members could be expressively joined in parallel. One method that came to mind because of the dovetail shape of the previously modelled foxtail wedged tenons was to incorporate a butterfly key that spans between the two parallel members to bind them together in a similar way. This method is particularly synonymous with the Lockwood system and its use of aluminium keys, albeit at right angles (See section 3.2 Lockwood, page 26). Butterfly keys are sometimes used in joinery as a (mostly decorative) way of expressing a connection between two corresponding members. They are usually set partway (very rarely the full depth) into the face of the already glued timbers with a dovetail in each member (Figure 5.11). This expresses a delineation of both the individual members that are joined and the reinforcement for an otherwise seemingly unconvincing butted connection. Practically, because of the double dovetail shape the butterfly keys will prevent the two corresponding members from separating. Due to this, it is can also be used over a crack in a piece of timber to prevent it from separating more.

![Figure 5.11: Bench top with butterfly key jointers](image)
How well could the butterfly key hold two parallel members together without glue?

A model was constructed with two butterfly keys made with Eucalyptus Saligna hardwood across two pieces of pine. Even when complete this joint clearly demonstrates the mechanical process of its connection. It was also possible to express a tension between the two parallel members by physically separating them slightly (about 2mm) knowing that they would remain in that position because of the keys’ shape. The connection between the two is expressed by the obvious orthogonal intervention. This enables the individual elements to be read in their own right, but also as parts of the whole.

Figure 5.12: Butterfly key joint
A second attempt was made at the butterfly key jointer, this time in an effort to draw the two members together tightly as the key was driven in – much like the process of draw boring (see page 53.) This was done by tapering the butterfly key so as to form a wedge, and adjusting the position of the rebates. In this way, the further the key was hit in the closer the two members would become. This worked very well until the final blow when the key cracked down the middle due to excessive tension. It may not have cracked had the grain of the key been aligned correctly – so as to run across the connection rather than normal to it. The reason for the grain direction of the key was for ease of manufacturing. An entire length of timber could be shaped with the profile and desired key lengths then cut. This still leaves a wedge to be formed, but it is still faster than forming each key individually. However, this exemplifies the thought that needs to be taken regarding grain direction; not only for strength, but also in the way we read the join. The way it is modelled reveals end grain – a hint that the key travels a distance into both timbers. But if the grain runs transverse to the two joined members we get a sense of crossing and interconnecting that is also aligned with the tensile strength of the key. In principle this method works well but the tolerances are very fine and there are many variables – the angle of the key, the position of the key rebate and how that pulls the two members together, and the wedged shape of the key that causes it to get tighter as it is driven in. Therefore, the craft has to be exacting in execution.

Figure 5.13: Cracked butterfly key connection
The illustrations on this page and the following two show a series of different configurations of butterfly keys to join two parallel timber members. The first illustration shows the butterfly key going the full depth of both members, as in the physical model in Figure 5.12, while the second displays the key on one side only – being rebated part way in. The third illustration shows the two members tongue and grooved so as to prevent sideways movement, a factor not allowed for in the first two.

*Figure 5.14: Different configurations of butterfly key – Top view: Plan. Bottom view: 3D*
These illustrations further develop the idea of the rebated members, using different proportioned members, key positions and rebate positions in an effort to design a join that is both structurally sound and relatively easy to construct. The last development shows a separation of the butterfly key and the tongue and groove allowing a longer key connecting for all of its length to both members rather than the previous two, and the third illustration in Figure 5.14, connecting by a smaller amount of key due to the interruption of the tongue and groove. This therefore requires a larger width of timber to fit the two systems.
This sequence of illustrations shows the addition of a smaller PVC (or similar) baffle rebated into both members as a floating tongue to alleviate the complications of the tongue and grooved system getting in the way of the keys and to get rid of the need to machine the members so much. It is not a problem to create a rebate down the side of a piece of timber, but machining a tongue down the face takes a considerable amount of work and reduces the size of the timber. The floating tongue solves that problem, meaning the same simple groove can be cut into both members. The last illustration incorporates a weather groove to create a pressure equalised chamber for use if the member was part of an exterior wall. However, note the need for wider pieces of timber to incorporate both the vertical and horizontal systems.

Figure 5.16: Further development to resist lateral movement with an inserted baffle
Figure 5.17: Development of the linear joint into a wall system
This is an attempt to provide a jointing solution for a situation like prefabricated wall elements that have linear joints rather than a node. "Architecturally speaking, the technologically complex linear joint supplants the node." The butterfly key used in this way is a node on a linear joint. To form a complete linear joint the foxtail wedged tenon was adapted so as to run the full length of one timber member, being inserted parallel into a corresponding full length dovetailed member, the sequence of which is outlined in Figure 5.18 overleaf. In this way, the ends clearly express the method of jointing and the process. Because of the 90 x 45mm timber stock used it was chosen to run the tenon down the edge of the member and the receiving dovetail down the side to form a T-shaped profile. This was due to the amount of timber being used for the tenon itself and to ensure the remaining amount of the tenoned member was still substantial and the full thickness. For the rebated piece it meant there was plenty of timber left width-wise to resist the force of the tenon’s splay. This resulting T profile was a (surprisingly) pleasant combination as it served to outline the two pieces strongly, because of the rotated axis, while still retaining a sense of wholeness. Though, in this form the joint presented its own problem in that the amount of force required to engage the two members was too great for one (or more) to assemble with any real precision for larger sections – rather, a great amount of precision would be required due to the amount of force needed. Albeit, the entire joint does not need to fit together at once (it can be angled in), but the mortised element needs to be sufficiently braced so as to apply a decent force to engage the tenon. The foxtail wedged tenon jointing method certainly encapsulates the process of construction; of the two pieces coming together and interlocking – one of the central reasons why the foxtail tenon was investigated.

Figure 5.18: Sequence of insertion of foxtail wedged tenon running lengthwise
5.2 Development of the brief

For the reason that this project is primarily concentrated on detailed aspects, it makes sense to express this within a small scale architectural setting. Not that the joints would necessarily lose their focus within a large context, rather the more practical matter of time constraints would restrict an intensely detailed large-scale project. A brief that involved the process of craft would be the most fitting way to present the research and design investigations. While constructing and analysing the various joints it became clear that certain joints expressed a degree of "put-togetherness", namely the foxtail tenon and the pegged tenon. That is, one has to understand the physical process of the construction of the joint in order to construe the tectonics of the joint. There is one fundamental difference between the two joints in that while the pegged tenon can be disassembled, the foxtail tenon cannot.

The foxtail tenon has a strong relationship to the principles of the plug welded joins on the Farnsworth House; it is ambiguous but refined, it involves a high degree of craft to be precise and is about process, and the craft covers itself up in the end product. Therefore, a timber pavilion that closely follows and translates Mies' intentions, themes and design principles of the Farnsworth House was fitting.

The program is to offer a specific place of retreat within the national park for the adoration of nature. It will mark the junction of the two alternate pathways across to Torrent Bay village and the pathway up the river to Cleopatras Pool. It will provide a floating jetty for kayaks that explore the area at high tide and a sheltered place to stay overnight.
5.3 Design Development

In order for the building to read as a series of parts joining to form a whole, the next stage was to develop the modelling of individual joints to form larger parts, and to investigate how these larger parts could be in turn joined together.

Column-Floor Junction

The intention is for this junction to be read as a simple slab with a tenuous connection to the column. As we know, like all modernist designs simple appearances are never as they seem...

The column will utilise the T-profile with a foxtail wedge connection that was developed through modelling (see Figure 5.18, page 67 and the previous page). This was chosen for its simplicity of aesthetic and it can utilise standard timber stock. It also offers good structural stiffness in both lateral directions. The intention for the floor to appear as a fine timber box with joinery-type qualities was rather difficult, and it involved a lot more work beneath the surface. The perimeter will be read as a slender border to which the flooring is laid flush with.

Figure 5.19: Sketch of corner joint development

Figure 5.20: Further corner joint development
The only joints to be seen from the outside will be butterfly keys at each corner to hold the junction. This will reinforce the impression of fine joinery. The important connection between slab and column will introduce a delineation of the two parts by incorporating an additional separator element. It was chosen to separate slab and column (in a deviation from the Farnsworth House) as a development of designs revealed this to be more expressive of both the two parts and the jointer. This is in the form of a floating tenon that references the plug welds on the Farnsworth House by way of a pinned connection at the column. The floating tenon was structurally developed to introduce a positive connection between the two parts, as they do not run into each other.
Figure 5.23: Slab & column connections together

Figure 5.24: Slab & column connections apart
The idea of a floating jetty is an extension of the floor onto the estuary, regardless of the tide. It was chosen to retain the same floor structure but slightly modify the edge connection so as to provide for raising and lowering. One of the earlier models of the linear foxtail tenon joints provided the inspiration for this (see Figure 5.18). The first model that was constructed was actually too loose, but it had a certain characteristic of being able to slide lengthwise. Therefore, this was seen to be an interesting take on the same joint used in the main columns.

Figure 5.25: Perspective sketch of jetty

Figure 5.26: Plan and elevation of connection to piers
Roof

To begin, there was a struggle to ensure that a design that used Mies’ architectural principles and intentions did not merely replicate the Farnsworth House.

An early design for the roof structure was both an expression of Semper’s theories on the framework of an upright triangle (see page 10) and a response to the context – essentially in a valley between two large mountains. It was an investigation into how this might be shown through the strength of the singular node that connects the two upright members together, by removing the horizontal member. This emphasises the junction itself and its integrity as an inescapably essential part of the whole. This notion could indeed be adapted to a perceived triangle at any angle, hence the application of a butterfly roof.
Figure 5.28: Early design with butterfly roof

Figure 5.29: Central node of butterfly roof viewed from inside
Figure 5.30: Development of crossing purlins connection

Figure 5.31: Structure of butterfly roof
The central connection was then modelled with various iterations of a floating butterfly key being the only connecting element for two passing angled members to test the strength of such an unconvincing joint. The eventual result was the need to let the two members slightly into each other to prevent twisting. It also highlighted the need to orient the saw kerf and wedges of the tenon in the direction most favourable to the strongest part of the grain in the receiving member.

However, this design focused too much on individual elements and steered away from the original design intentions. The belief in designing something completely different to the origin proved misleading as differences in detail are inevitable with a material translation. Furthermore, since our main objective is the translation of material it is perceivably allowable to be closer to the origin in terms of a holistic design. Hence, it was decided to adapt a flat slab roof with a jointing system that matched the floor.

Figure 5.32: Series of different models to test the strength of the connection
Plan

Mies’ careful crafting of different spaces is very elegant. He uses level changes and different degrees of enclosure to differentiate between them. Essentially the pavilion will have two entries: One from the track to the south and one from the estuary to the north. The entry from the track will take on a more varied level approach as the ground slopes quite steeply before the estuary, with a series of different height platforms leading to a main space. From the estuary the approach will be a long flat floating jetty that responds to the tidal changes, a pathway that leads out over the water or the flat sand, depending on tide, in the direction of Torrent Bay Village. The immediate difference to the Farnsworth House is that of a double ended entry. The interior of the Farnsworth House is the final destination, while there is the possibility of a transitional reverse to take place in the pavilion. The views to the east and west are also of high importance as they both provide distinct long views. The main part of the pavilion is proposed to be positioned partly on the hillside and partly over the estuary.

Figure 5.33: Earlier sketch of plan

Figure 5.34: Developed plan


*Curtain walls*

The main space will be enclosed in a timber framed glass curtain wall. Mies’ use of the curtain wall at the Farnsworth House is particularly interesting at the corner where the system of uprights seems to wrap around the building like a mitre. It forms a very symmetrical pattern and retains all the dimensions of the intermediate columns albeit by using different sized members. Moreover, it is very simple. (See cutaway isometric, Figure 3.14, on page 37.) Some design iterations focused on a solid wall of timber, rather than glass, to visually enclose the space as an antithesis to a glass wall, while others used a system that used more closely followed the model of the Farnsworth House.

*Figure 3.35: plan view of wall system*

*Figure 5.36: 3D view of wall*
Figure 5.37: Development of glazing system

Figure 5.38: Development of corner
5.0 Conclusion

5.1 Critical Appraisal
Regardless of the building architectural edifices are monuments to human dwelling: Endeavour, community, relationship and edification. Over the course of the research project it has become more evident, and indeed solidified the importance of craft in an architectural design, as it portrays a distinct human connection in the making of architecture and tells the complete narrative. If we are to concern ourselves with the cost of labour then we must consider the more valuable: The value of an architecture that reflects people’s time, effort, craftsmanship and a narrative of human edification; or an architecture that stands for economy of production that limits this narrative. While steel jointing cannot obviously be directly replicated in timber, the translation of the principles of the jointing techniques Mies used was successful in portraying a similar architectural idea. The use of timber rather than steel (predominantly) provides a nuance in the way we interpret that idea. While white steel, travertine and smooth plastered ceilings represent the structured, fineness and exquisite qualities of nature, timber presents the more rough-hewn, varied, physical aspect.

5.2 Further Applications
The design principles explored here could be applicable to any timber structural system that has a specific emphasis on craft. The translation of jointing techniques into other materials works to convey allusions to, and different readings to than the original material.
6.0 Bibliography


7.0 List of Figures

Figure 2.1: *Weaver's Knot*, Gottfried Semper, "Textiles: Technical – Historical," in *Style in the Technical and Techtonic Arts; or, Practical Aesthetics*, intro by Harry Francis Mallgrave, translated by Harry Francis Mallgrave and Michael Robinson (Los Angeles: Getty Research Institute, 2004), 220.

Figure 2.2: Fish net made from weaver's knots, http://en.wikipedia.org/wiki/Sheet_bend

Figure 2.3: Seagram Building corner detail, Farshid Moussavi and Michael Kubo, ed. *The Function of Ornament*, (Mass: Harvard University Graduate School of Design, 2006), 60.

Figure 2.4: Mortise & Tenon joint, http://blog.brazos-walking-sticks.com/2012/02/15/mortise-and-tenon


Figure 2.6: Plastic configuration of linear wood grain on a ceiling at the Carlton Wall Residence - FLW, Terry L. Patterson, *Frank Lloyd Wright and the Meaning of Materials* (New York: Van Nostrand Rienhold, 1994), 23.

Figure 3.1: Log house jointing technique: Round notch with a tongue & groove, http://www.expertthow.com/how-to-connect-wood-with-simple-joints-in-woodworking


Figure 3.3: Lockwood system, http://www.lockwood.co.nz/Why-Lockwood/Innovation

Figure 3.4: Gamble House, Peter Davey, *Arts and Crafts Architecture*, (London: Phaidon, 1995), 199.

Figure 3.5: (previous page) Farnsworth House as approached from the Fox River, Franz Schulze, *The Farnsworth House*, (Chicago: Lohan Associates, 1997), 6.

Figure 3.6: Farnsworth House Plan

Figure 3.7: Sequence of operations for plug welding Farnsworth House structure, Michael Cadwell, *Strange Details*, (Cambridge, Mass.: MIT Press, 2007), 114.

Figure 3.8: Plug Weld – Clamped, http://www.mig-welding.co.uk/plug-weld.htm

Figure 3.9: Plug Weld – Welding to fill the holes, http://www.mig-welding.co.uk/plug-weld.htm

Figure 3.10: Plug Weld – Welding finished ready to be sanded, http://www.mig-welding.co.uk/plug-weld.htm

Figure 3.11: Seamless joint at main column, Franz Schulze, *The Farnsworth House*, (Chicago: Lohan Associates, 1997), 17.
Figure 3.12: *Farnsworth House - Horizontal Section*, Werner Blaser, *Mies van der Rohe: The Art of Structure*, (Basel; Boston; Berlin: Birkhäuser, 1993), 114.

Figure 3.13: *Farnsworth House - Vertical Section*, Werner Blaser, *Mies van der Rohe: The Art of Structure*, (Basel; Boston; Berlin: Birkhäuser, 1993), 118.

Figure 3.14: *Farnsworth House - Isometric Section of Window Frame Details*

Figure 3.15: Exploded view of Farnsworth House showing individually perceived parts

Figure 3.16: Sketch of Japanese pavilion

Figure 3.17: Sketch of Farnsworth house

Figure 4.1: Location of Abel Tasman National Park

Figure 4.2: Torrent Bay Location

Figure 4.3: Site at Torrent Bay showing walking tracks and rivers

Figure 4.4: Trampers crossing the estuary

Figure 4.5: Kayaks on the Abel Tasman, http://www.abeltasman.co.nz/assets/Uploads/_resampled/lightboximage-Abel-Tasman-Nat-park-Kayak-7.jpg

Figure 4.6: Dramatic change: Satellite view of high tide (above) and low tide (below)

Figure 4.7: Torrent Bay at high tide, http://thekiwikronicles.blogspot.co.nz/2010/11/day-55-56-kaiteriteri-sea-shuttle-abel.html

Figure 4.8: Torrent Bay at low tide, http://ontarions.travellerspoint.com/43/

Figure 4.9: Cross section of site running north-south

Figure 5.1: Extended through tenon

Figure 5.2: Pinned Tenon

Figure 5.3: Open through mortise & tenon (Bridle)

Figure 5.4: Mitred corner

Figure 5.5: Pegged, or Keyed tenon

Figure 5.6: Foxtail wedged tenon

Figure 5.7: Inner workings of foxtail wedged tenon

Figure 5.8: ‘Sectioned’ foxtail wedged tenon

Figure 5.9: Second attempt at a ‘sectioned’ foxtail wedged tenon

Figure 5.10: Hammer marks: evidence of the joint not conforming to expectations

Figure 5.11: Bench top with butterfly key jointers

Figure 5.12: Butterfly key joint

Figure 5.13: Cracked butterfly key connection

Figure 5.14: Different configurations of butterfly key – Top view: Plan. Bottom view: 3D

Figure 5.15: Development of butterfly key join

Figure 5.16: Further development to resist lateral movement with an inserted baffle

Figure 5.17: Development of the linear joint into a wall system

Figure 5.18: Sequence of insertion of foxtail wedged tenon running lengthwise

Figure 5.19: Sketch of corner joint development
Figure 5.20: Further corner joint development
Figure 5.21: Sequence of development of slab joints
Figure 5.22: Junction - Column to slab (not shown)
Figure 5.23: Slab & column connections together
Figure 5.24: Slab & column connections apart
Figure 5.25: Perspective sketch of jetty
Figure 5.26: Plan and elevation of connection to piers
Figure 5.27: Sketch of triangle with missing member showing forces imposed on the joint
Figure 5.28: Early design with butterfly roof

Figure 5.29: Central node of butterfly roof viewed from inside
Figure 5.30: Development of crossing purlins connection
Figure 5.31: Structure of butterfly roof
Figure 5.32: Series of different models to test the strength of the connection
Figure 5.33: Earlier sketch of plan
Figure 5.34: Developed plan
Figure 5.35: Plan view of wall system
Figure 5.36: 3D view of wall
Figure 5.37: Development of glazing system
Figure 5.38: Development of corner
8.0 Appendices
Appendix 1: Tables for Wood Strength and Stiffness

Table 1
Major elastic constants for five wood species at 12% moisture content.†

<table>
<thead>
<tr>
<th>Property</th>
<th>Loblolly pine</th>
<th>Sitka spruce</th>
<th>Red oak</th>
<th>Yellow poplar</th>
<th>Balsa</th>
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</thead>
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<tr>
<td>$E_z/E_L$</td>
<td>0.078</td>
<td>0.043</td>
<td>0.082</td>
<td>0.043</td>
<td>0.015</td>
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<td>$E_{cd}/E_L$</td>
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<td>$\mu_{zt}$</td>
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<td>0.372</td>
<td>0.350</td>
<td>0.318</td>
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<td>$\mu_{zt}$</td>
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<td>$\mu_{zt}$</td>
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<td>0.245</td>
<td>0.292</td>
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† Values for $\mu_{zt}$ and $\mu_{zt}$ are small, seldom used, and often not available. Values of $E_L$ may be estimated by multiplying the modulus of elasticity in static bending given in Table 2 by 1.10.

Table 2
Mechanical properties for five wood species at 12% moisture content.†

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<th>Shear</th>
<th>Tension</th>
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<td></td>
<td>Modulus of rupture (MPa)</td>
<td>Modulus of elasticity (GPa)</td>
<td>Parallel to grain (MPa)</td>
<td>Perpendicular to grain (MPa)</td>
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<td>Sitka spruce</td>
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<td>38.7</td>
<td>4.0</td>
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<tr>
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<td>7.0</td>
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<tr>
<td>Balsa</td>
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<td>3.4</td>
<td>14.9</td>
<td>—</td>
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† Force at 5.6mm indentation.

Appendix 2: Torrent Bay History

Torrent Bay has a rich history of occupation. According to archaeological records it was occupied by Maori for at least 800 years prior to European settlement. When Dutch explorer Abel Tasman arrived in the area in 1642 he found them to be altogether unwelcoming after four of his crew were killed by the local Maori in a bloody encounter. Nearly 200 years later, D’Urville however, managed to trade and even developed cordial relations with them. Some of his sketches record the huts of the Maori, including one at Torrent Bay, as seen in figure 4.4. The earliest settlers began to live in Torrent Bay as early as 1857, and there were enough people living there in the early 1900’s to warrant a school. During the 1870’s a Quarry Reserve was set up at Torrent Bay and the granite was used for the construction of the mole at Nelson Harbour entrance. The bay was synonymous with boating, for that was the sole means of transportation in and out of the area. Among other bays in the area Torrent Bay was used for boat building; the largest ship recorded being built there was a 22 ton ketch called the Comet. In the early 1900’s a family who lived at Torrent Bay organised a New Year regatta because of the great number of Christmas visitors to the area. This was held in the lagoon itself and was continued for some later years. When the national park was established in 1942, the 300th anniversary of Tasman’s visit, Torrent Bay was left as privately owned land, fully surrounded by the park. Today the Abel Tasman is the most frequented national park and attracts visitors from all over the world, who all have the privilege of stepping into and exploring part of the region’s local history at Torrent Bay.
9.0 Final Presentation Images
Adoration of the Joint

Design component in the requirements for the degree of Master of Architecture professional.

UniTE Institute of Architecture 2013

Location: Torrent Bay Estuary
Abel Tasman National Park
Tasman

Plan 1:50