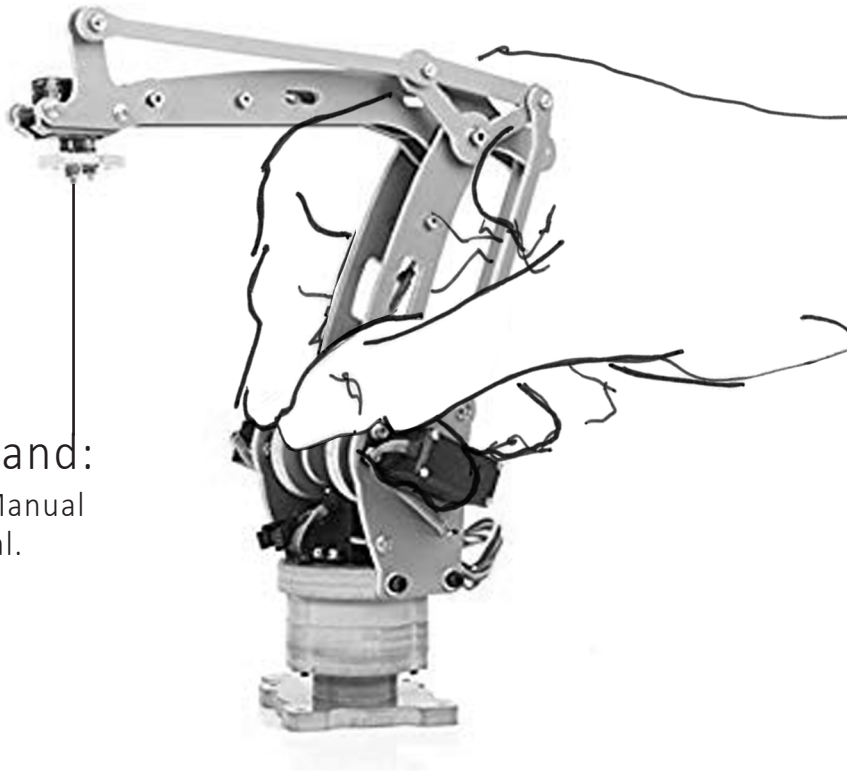
The Bionic Hand:

Augmenting the Manual
and the Digital.



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A 120-point research portfolio submitted to Victoria University of Wellington in partial fulfilment of the requirements for the degree of Masters of Architecture (Professional).

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School of Architecture.
2019.

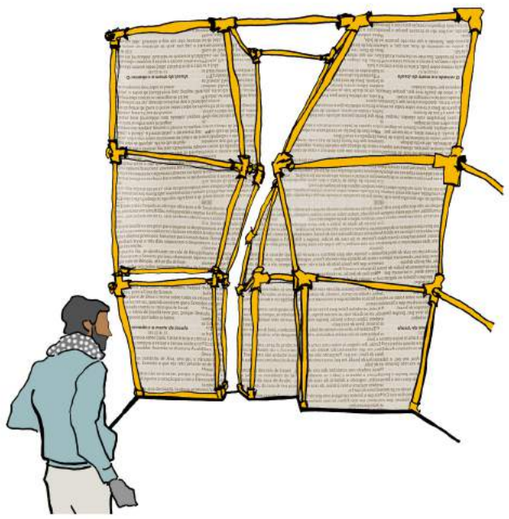
Thank you:

To my supervisor Dr Sam Kebbell for your knowledge, insight, and encouragement.

To my friends on campus for being so talented and pushing me to work harder.

To my friends off campus for sticking around.

But mainly to my parents, and Katherine, Justin and Abby for putting up with it all.



Abstract

The tension between the hand and machine is currently at the core of one of architecture's biggest debates. Pallasmaa and the firm Kieran Timberlake, for example, hold very different positions on this spectrum, both with a significant following.

Kieran Timberlake, who designed Loblolly House, use digital design and construction methods to discover new construction techniques for a globalised world. The capacity of parametric software, 3D printing, and robotic fabrication has been rapidly advancing in the last decade. They are opening the possibilities of new sculptural forms, more efficient construction processes, and alternative forms of detailing and ornamentation.

In contrast, Pallasmaa uses 'the thinking hand' to draw out intimacy: nooks, irregularities, material richness, and handcraft that invite the user into a closer relationship with architecture. Hand drawing and hand making are crucial to Pallasmaa's goals: intimacy exists in both the design process and the final form of architecture.

The design process is not as divisive as famous pillars at each end of the spectrum imply. In this work, I explore: how can emerging technologies and 'the thinking hand' complement each other? And how might the 'bionic hand' inform both intimacy and efficiency?

I explored this through designing a six-unit housing project in the Wellington suburb of Hataitai. The site is next to Roger Walker's maze of intimate moments, Park Mews. I approached design through hand and digital processes.

My main intention was to document a design process that integrates hand and digital techniques, showing one way an exchange between them could occur. I aimed to combine efficiency and intimacy, through exploring digital and hand techniques. This resulted in findings of the possibilities of the bionic hand in both the form and formation of architecture, the design's place in the context of New Zealand suburbia and its place in the discipline.

Contents

Introduction

The bionic hand is a process of working (the formation of architecture), and an approach to building (the form of architecture).

It combines:

Firstly, **the thinking hand**. This is the direct connection of brain to arm to tool for drawing and modelling to create intimate space, and in construction, to create hand crafted, materially rich space.

Secondly **digital tools**: which allow a more efficient design process through digital programmes augmenting manual techniques, and digital fabrication in construction decreases the labour associated with irregular design.

I have explored this in a suburban context through a six-unit housing project in Hataitai. The research stream is investigating the densification of Hataitai from its centre outwards, as a sub-centre for Wellington. I am using the bionic hand to generate intimate architecture, with moments of interest and spaces to dwell and inhabit.

The design of intimacy comes through complexity in the building, The site is adjacent to Park Mews, a building that contrasts the otherwise low-density stand alone dwellings of the area. Park Mews is an example of how many New Zealand architects of the 1980s understood 'complexity' and 'irregularity' in architecture, which carries a significant legacy today. In one thread of complexity through global architectural history, this has developed to include spatial irregularity, but also complexity and intimacy through craft and material, such as the work of the firm Miralles Tagliabue EMBT. This is exemplified by the main precedent of this research, Walmer Yard, a housing project in London by Peter Salter.

I position my research within this thread of history, using the bionic hand to achieve it. I also draw on Peggy Deamer's writing around the high levels of labour involved in both the design and construction of complex architecture. The digital side of the bionic hand aims to progress the understanding of complexity to address this.

I mainly designed through two orbiting processes.

1. Orbiting between hand processes and parametric digital models to augment the drawing and make it more efficient for testing.

2. I switched between perspective drawing of moments and planning and form of the full scheme aggregating the moments together. This used physical drawing to generate irregular imaginary worlds and the intimacy of the experience within them.

Discoveries within each side of the bionic hand, both in designing and prototyping pushed the research and understanding of this way of working forward.

Throughout this writing, I have used **intimacy** to mean closeness and familiarity with architecture through physical proximity to walls and furniture, ability to engage, and familiarity with the material and craft. It is what the Danish and Norwegians would call 'Hygge'. Gaston Bachelard writes in Poetics of Space,

"Indeed, in our houses we have nooks and corners in which we like to curl up comfortably. To curl up belongs to the phenomenology of the verb to inhabit, and only those who have learned to do so can inhabit with intensity" (Bachelard, 1957)

"Oh, but architects don't really draw now do they? I thought it was all computers these days."

Aims and Motivations

This was said to me by a friend during the year.

It is a common misconception outside of the discipline. A false dichotomy. This tension within my own process was the motivation of this research.

Thinking and creating imaginary spaces through drawing has been fundamental to my design process throughout my architectural education. To speak of only 'drawing with computers' does not begin to touch on the capabilities digital tools provide us. These are advancing capabilities designers must embrace. However, the value of hand drawing should not be disregarded in the digital age. My research question is:

How can emerging technologies and 'the thinking hand' augment each other in the design and construction of intimate architecture?

The key aims in this research are:

1. To contribute to the body of knowledge of how design process works. The specific aim in this project is to document a process of digital and hand techniques augmenting each other.

2. To use drawing to generate intimate, familiar spaces through complexity in space, craft and material.

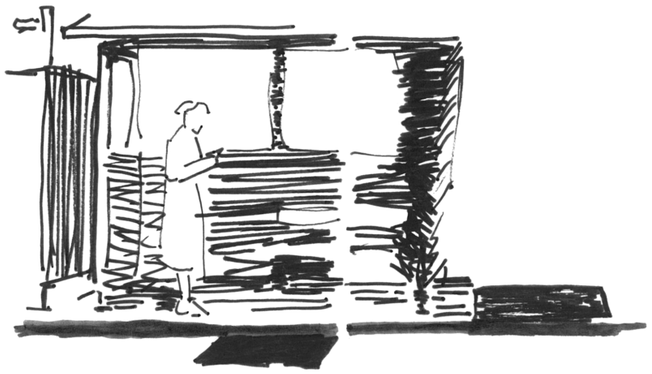
3. To use digital tools to mitigate the high levels of labour (in both the form and formation of architecture) associated with this style of bespoke design.

4. Designing a suburban architecture to engage with a densified street front.

The objective of the final design is to be an example of the bionic hand **form** of architecture.

The objective of the documented design process is one example of the bionic hand in the **formation** of architecture.

Overall this project addresses both these aspects of architecture, the form (the constructed building) and formation (the design process) of an intimate architecture.

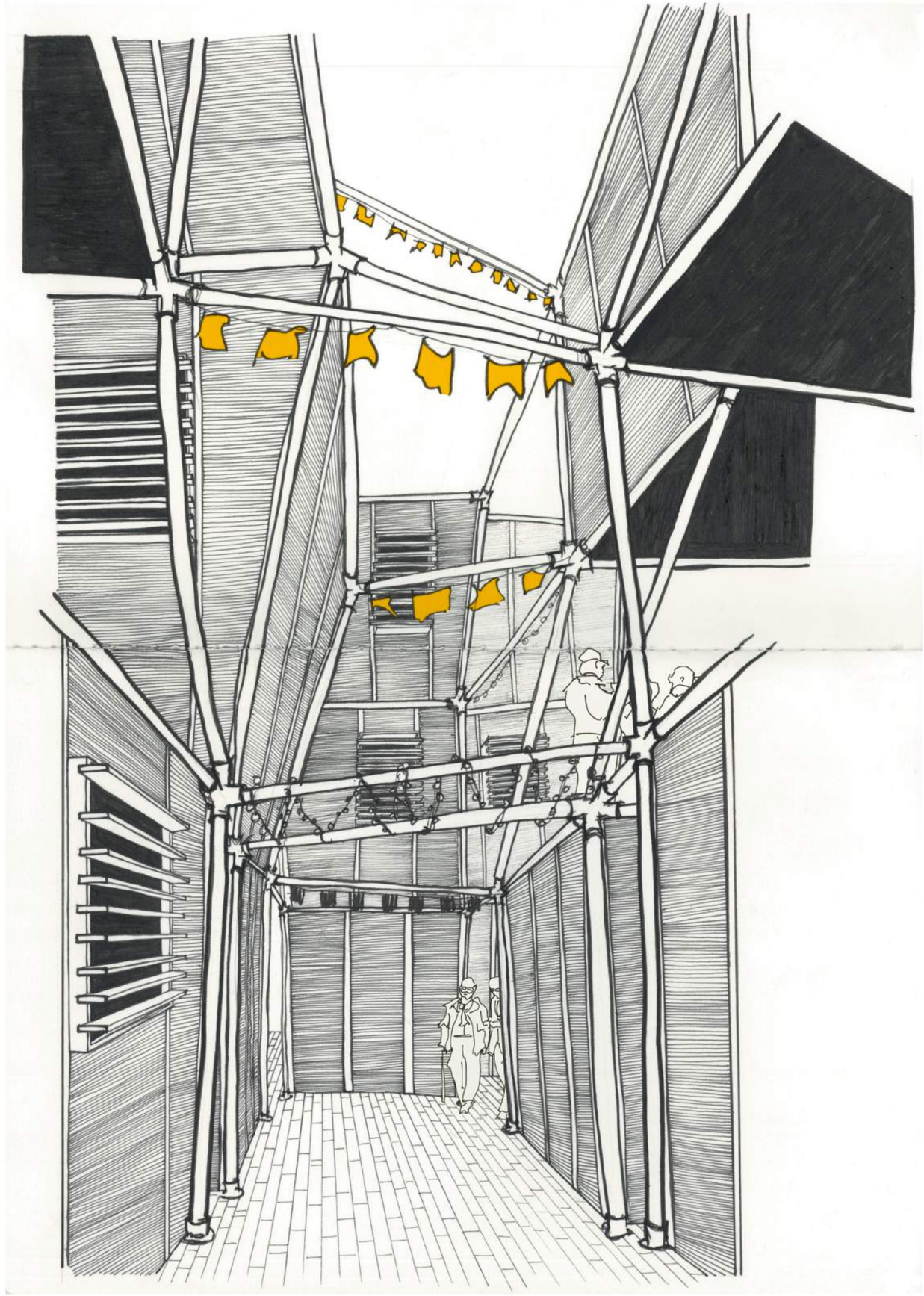


▲Fig 1.1. Early site sketch of a bus stop in Hataitai town centre.

01. The Design

50 Moxham Avenue. Hataitai

◀ Fig 1.2. Entrance cloak room space within stair case.



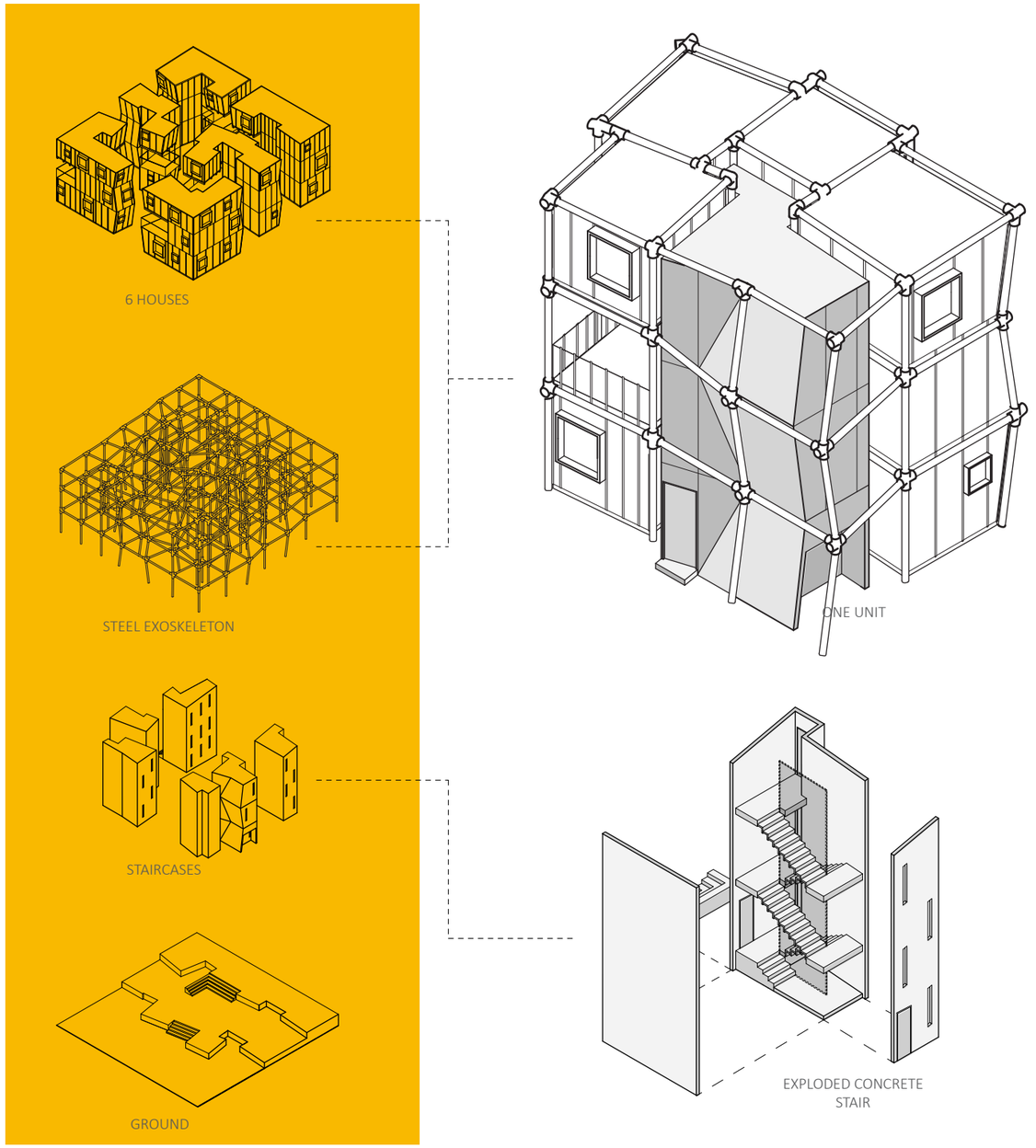
▶ Fig 1.3. Circulation space between buildings. Process sketch.

Overview

1.1

▲Fig 1.4. ‘Stoop’ space for socialising between houses.

Fig 1.5 shows the design is six houses within one site, and within one frame. The building is an irregular steel exoskeleton system, which acts as a structure to the houses within. Each house spans three storeys, including a private balcony on the first floor. The concrete staircases sit amongst the steel structure but are self-supporting. Their weight and solidity contrasts the lightness of the exoskeleton on the site. They are six pillars of the building with irregularly planned and formed houses wrapping themselves around them.

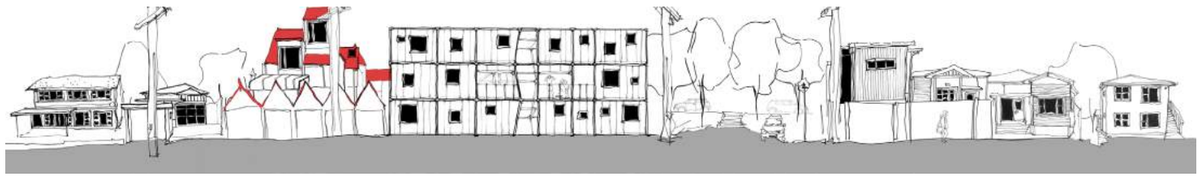


▲Fig 1.5. Tectonics of the six houses

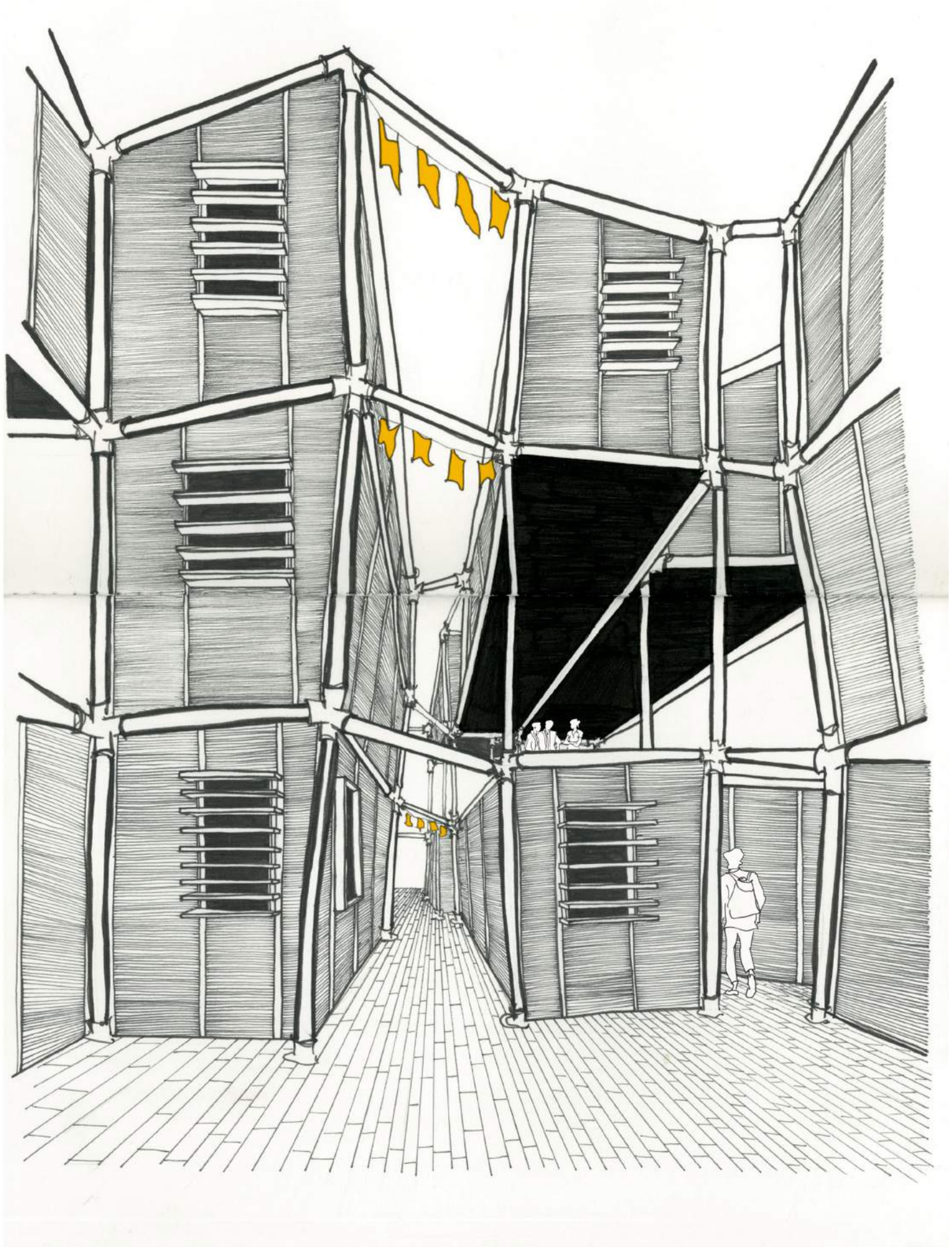
▲ Fig 1.6. Site Plan

▲ Fig 1.7. Moxham Ave Elevation 1:200

▲ Fig 1.8. Tapiri Street Elevation 1:200



▲ Fig 1.9. Moxham Ave Elevation



1.2 Narrative Through the Site

The main entrance to the site comes off Moxham Ave, a key street leading to the Hataitai Town centre. A straight façade abutting the footpath breaks into a kinked slit of an entrance, hinting at the complexity of form behind the Euclidian front (shown in fig 1.7). Fig 1.10 shows upon entrance exoskeleton beams criss-cross over the circulation spaces, walls lean over the walker, and corners poke out leaving nooks aside them. Stairs along the central axis drop down the site's contours, for both circulation and sitting (fig 1.4). Unique paths off the different levels lead to each house.

As seen on the ground floor plan on the following page the main entrance to each house is through the staircase, which acts as storage and a cloakroom. A second entrance/exit and utility space, drawn above, on the other side of each staircase leads off site. The concrete textures of the stairs act as a threshold to the warm dwelling spaces through the next door. The ground floor contains a bathroom and laundry, but the door opens into a kitchen, each bespoke in layout. A living area comes off the kitchen and dining space enclosed by richly crafted bamboo lined walls, shelving, a sloped wall for leaning against, and inbuilt furniture to fit the irregular angles.

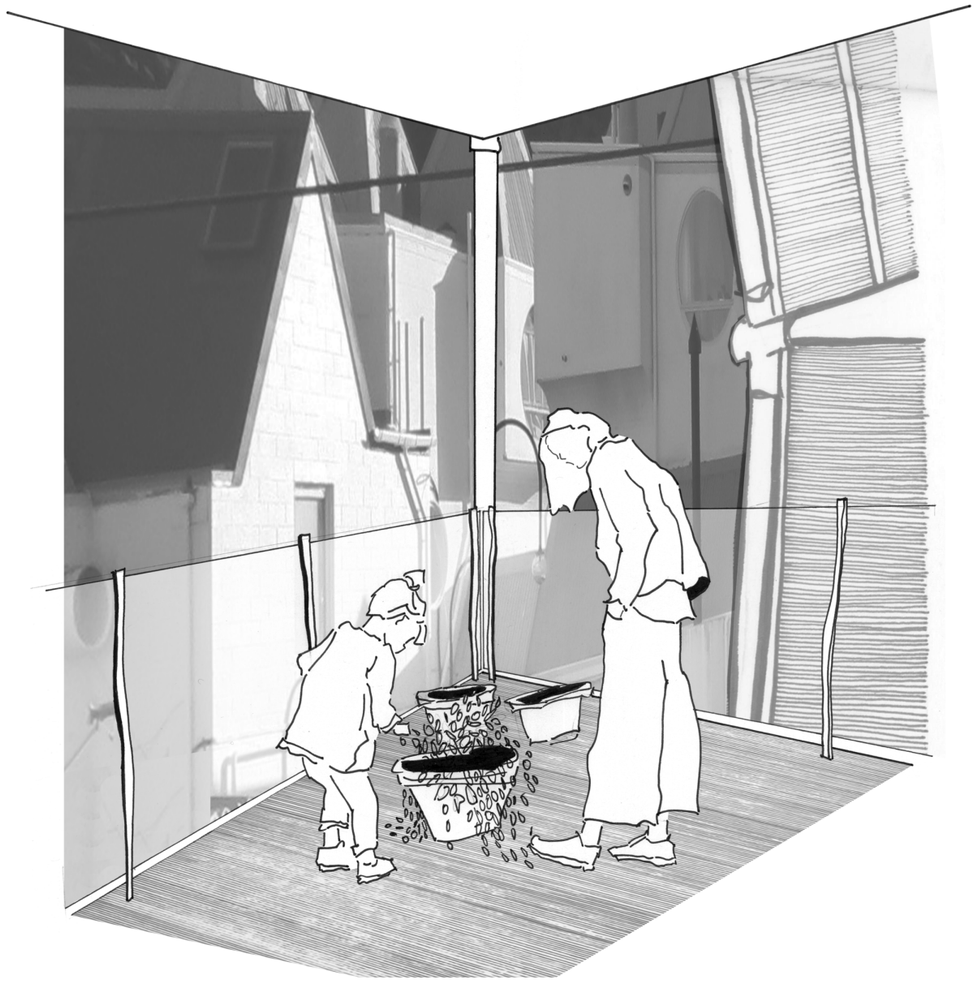
▲ Fig 1.11. Second entrance to one of the houses from Tapiri St. Provides bin and utility space.

◀ Fig 1.10. Circulation space between buildings. Process sketch.

▲Fig 1.12. Ground Floor Plan

▶Fig 1.13. Circulation space between buildings. Process sketch.

▼Fig 1.14. (next page) Ground floor interior dwelling space, lined by bamboo lining.



Level one provides the main living spaces. The interior of these also takes on the characteristics of rich material and inbuilt furniture to be a place to “inhabit with intensity” (Bachelard, 1957). The concrete staircase diversifies the material palette as a threshold between the levels. On the first floor is an open balcony looking over the maze of structural members below, out to Hataitai or back to Park Mews (as shown above).

▲Fig 1.15. Level 1 balcony looking towards Park Mews.

▼Fig 1.17. (next page) Level one balcony and interior dwelling area.

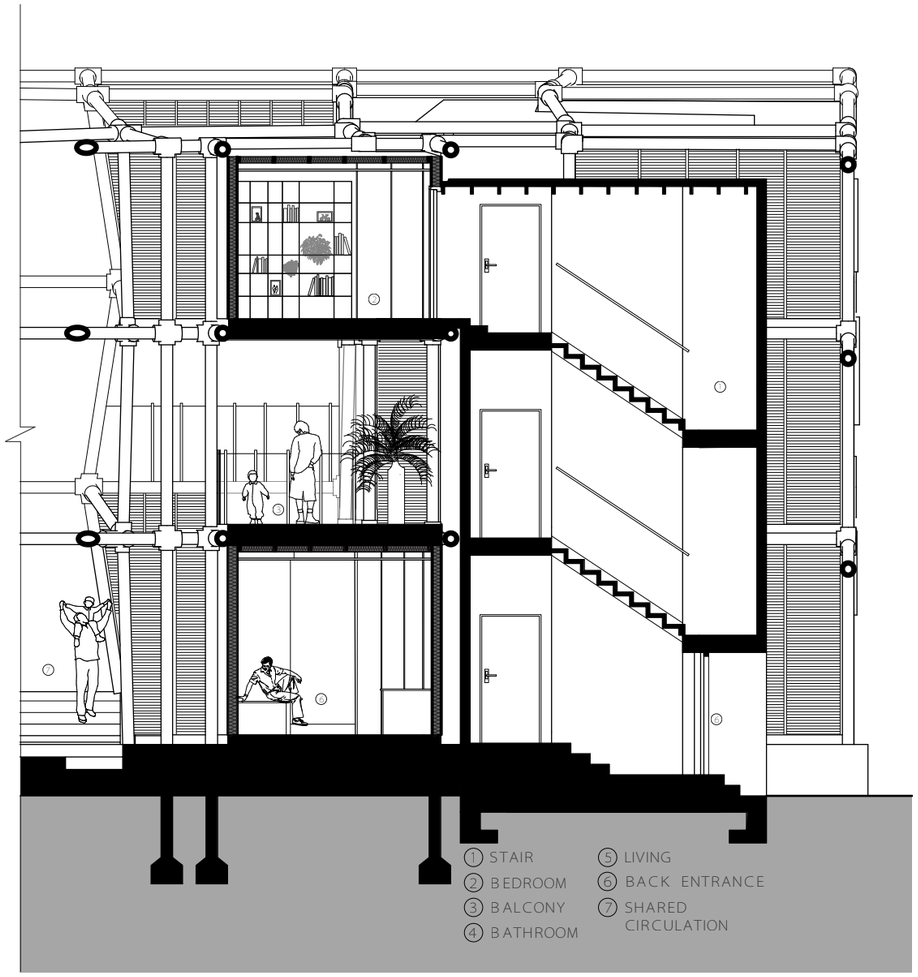
▲Fig 1.16. Level One Plan

▲Fig 1.18. Level Two Plan

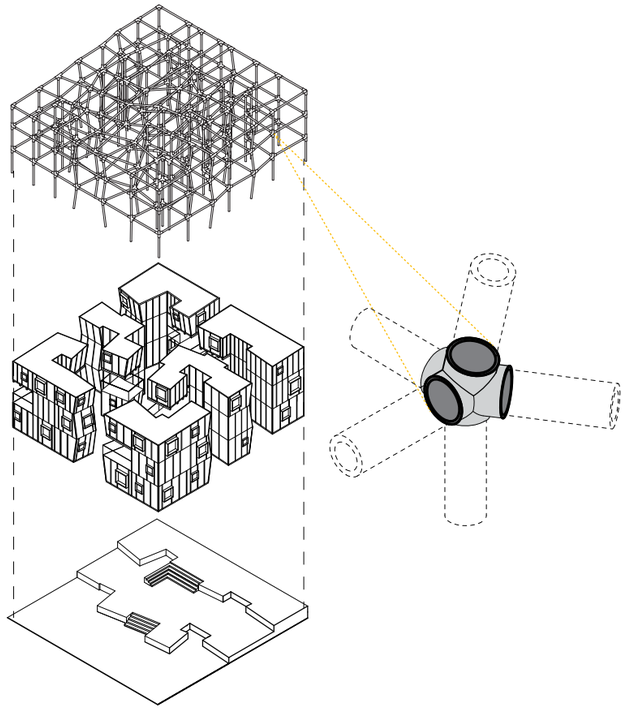
The top floor maintains irregular angles and sloping walls of the other storeys. It contains bedrooms, an office and another bathroom. While all storeys of the six houses have the same basic programme, each house has a unique arrangement due to the irregularity of the planning.

▲Fig 1.19. Staircase space with contrasting textures to interior dwelling.

▲▶ Fig 1.20. Section A A'. 1:100



1.3 Tectonics



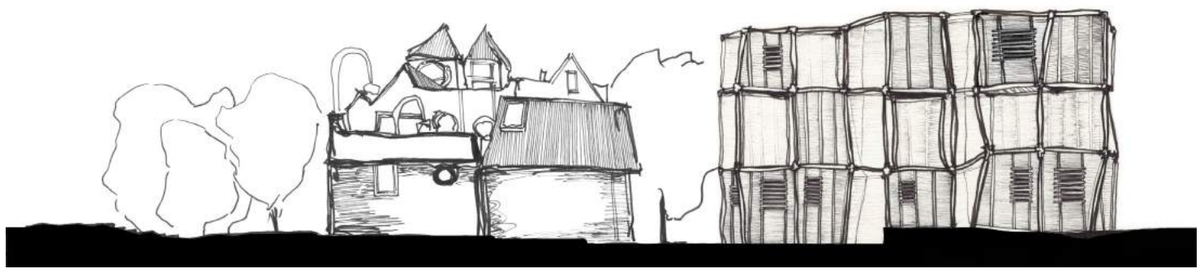
◀ Fig 1.21. Full building exploded axonometric.

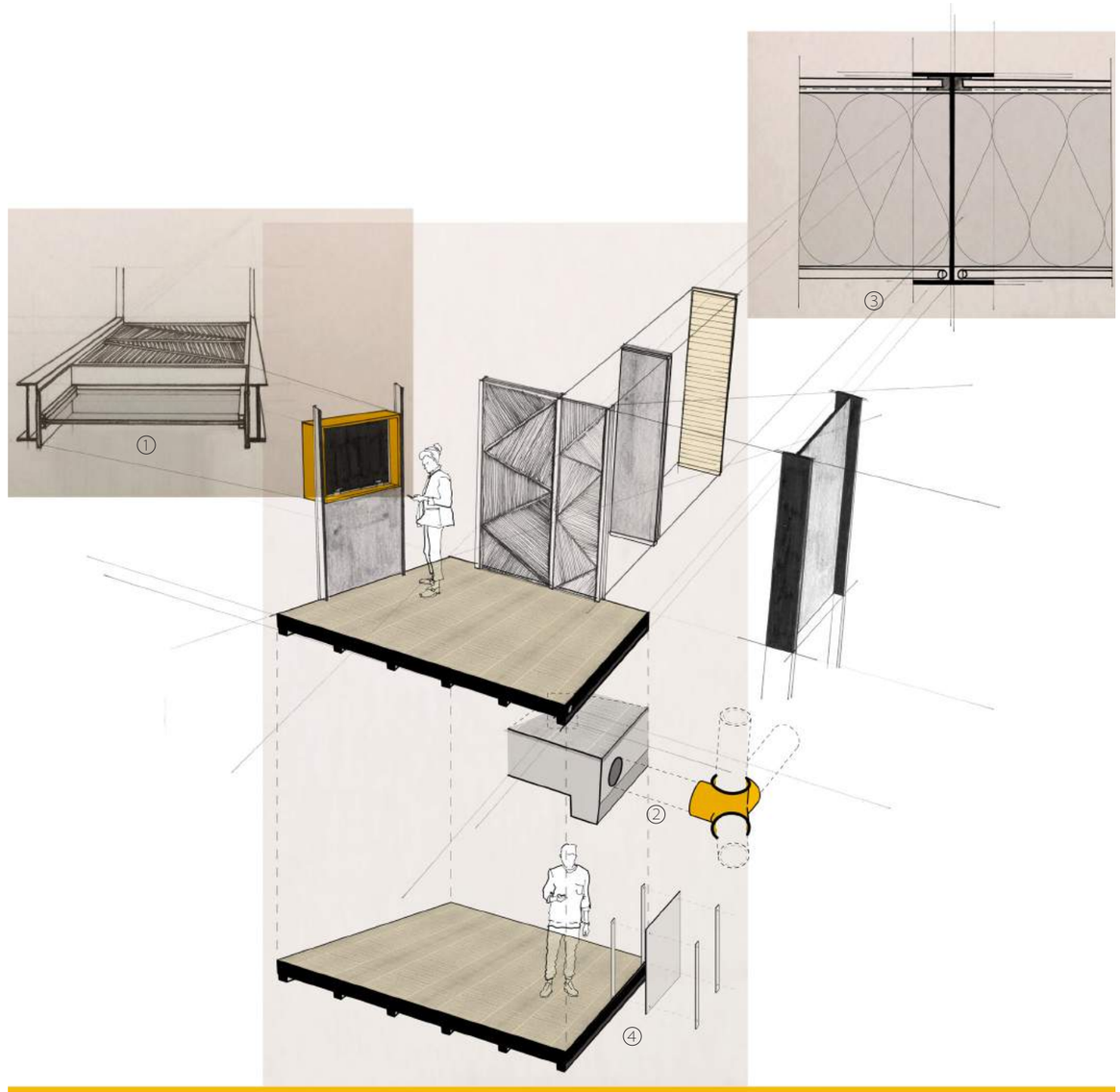
▶ Fig 1.23. Tectonics of the house structures.

▼ Fig 1.22. (below) Process sketch of Tapiri St elevation, a study in comparison to Park Mews.

▼▼ Fig 1.24. (next page) Level one interior dwelling area.

The exoskeleton system provides the structure for the building. Because the nodes and the structural system provide the irregular angles, corners and lengths, all other construction systems only have to fit into and around it, not accommodate the irregularity themselves. Ribs attaching to the structure and floor slabs make up the walls. These hold the windows, insulation and claddings, including the hand crafted bamboo interior linings. The exoskeleton takes the structural responsibility off the walls allowing them to angle creating spatial intimacy.



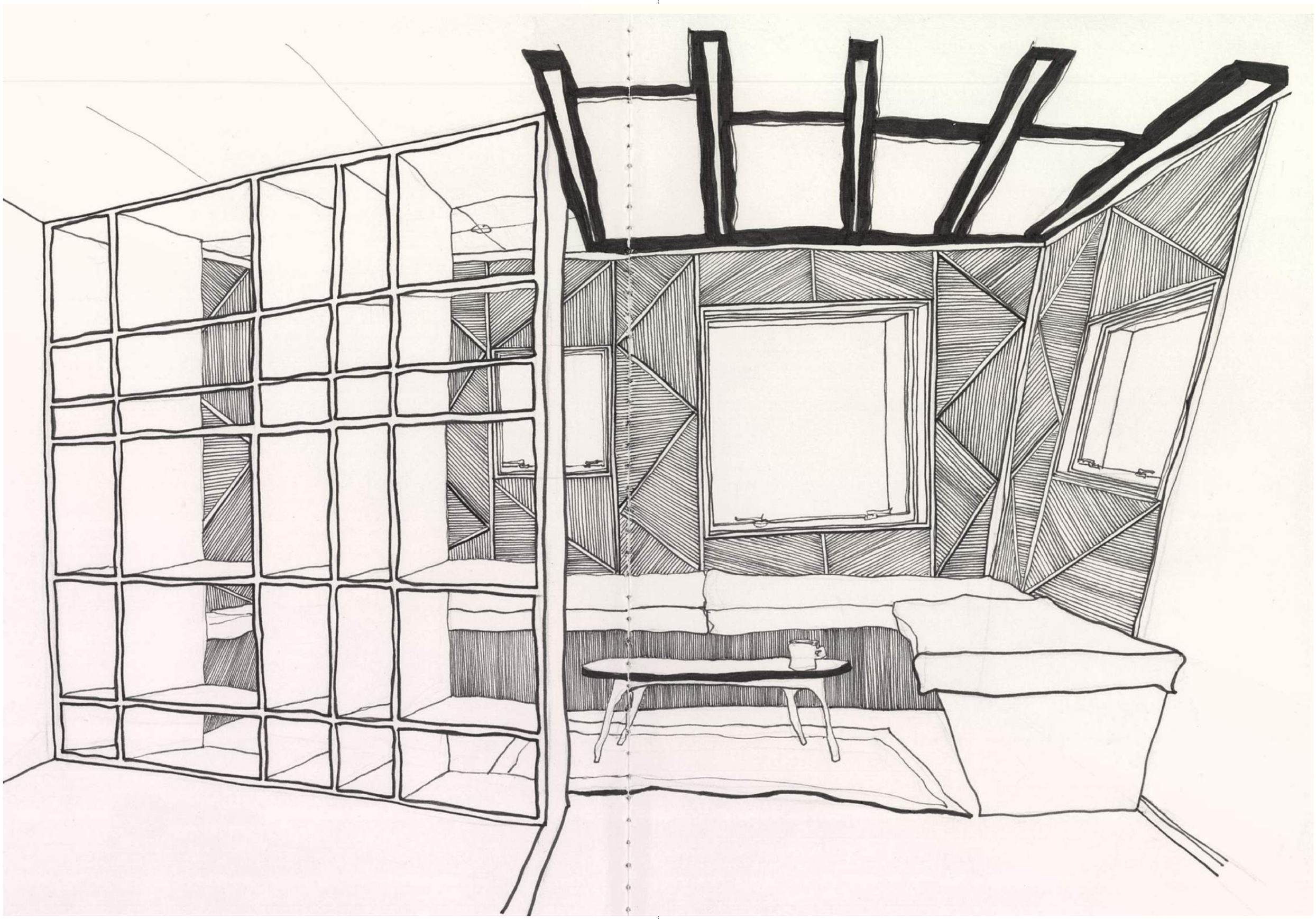


① Wooden box window detail.

② Beam through floor slab.

③ Exterior cladding- insulation- exterior cladding. Held together by the ribs.

④ Balustrade to floor slab bolted detail.



▲Fig 2.1. Early site sketch of an alley in Hataitai town centre.

Context and Processes 02.

Method

2.1

The design method is diagrammed and explained through annotation on the following pages.

As design led research, early work sparked my understanding of my own process. I was continually further enlightened by critical reflection of my process as I progressed. The bionic hand is the umbrella process that all of my work fits within. Processes fit either, on the hand side, or on the digital side. However, the most valuable and efficient work was when the two sides augmented each other.

The design process began with an analysis of Hataitai as a whole, and of my original site (Hataitai Park). Alongside this, I was developing concepts for that site through the brain to pen connection of the thinking hand. It was critical analysis of these drawings that uncovered a tendency toward the complex geometries in design. This discovery raised Peter Salter's Walmer Yard as a key precedent.

This reflection, along with the site analysis led to the final site choice. The site is adjacent to a case study (page 114), Roger Walker's icon of irregularity, Park Mews.

From further critical analysis of these drawings came the understanding of the value of the direct connection from brain to arm to tool: as Juhani Pallasmaa calls it, the thinking hand (Pallasmaa, 2017).

A plan designed through the thinking hand led to the development of a parametric script, which gave me a wire frame base for drawing formal, material, structural and tectonic tests over. This, in conjunction with photoshop drawing editing, was the point of understanding of the value of digital tools as a side of the bionic hand, bringing efficiency to the design process.

A main way I used the thinking hand was cartooning human eye level, perspective moments of the building, as I was designing it, such as in fig 2.2. A change in perception of my project developed into more detailed drawings to push my designing forward.

The final stages on the design method are annotated on the diagram on the following pages.

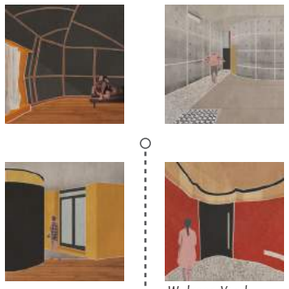
"The bionic hand" was my design method that included all of these processes, using the strengths of both the hand and digital sides. My process was at its strongest when I used the strengths of each side in conjunction.

▲Fig 2.2. Early concept cartoon.

The rest of this chapter is a broken down analysis of the contexts my work fits within, and relevant literature and case studies. These contexts are: the site, the bionic hand as a way of working, the placement in the discipline, interpretation of visual richness as ornamentation, and labour in the building's construction and design. In conjunction with this is written and visual explanations and analyses of the related processes in my work.

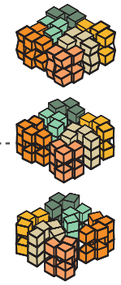
Vibe Cartooning

A main way I used the thinking hand was cartooning human eye level, perspective moments of the building, as I was designing it. A change in perception of my project developed into more detailed drawings to push my designing forward.

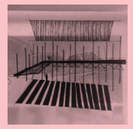


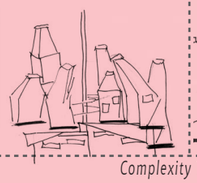
Walmer Yard Case Study

Testing Dynamo Model



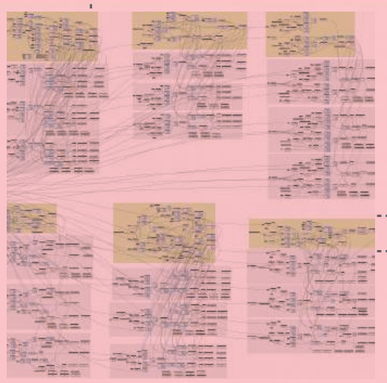
DESIGN METHOD



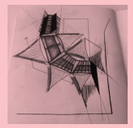


Initial Thinking Hand Work

Complexity Tendency



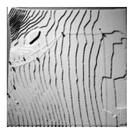
Generating Dynamo Script



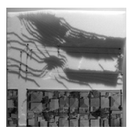
First Planning

Hataitai Site Analysis

Site Three. Final Site



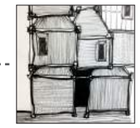
Site One

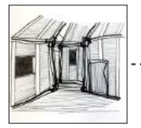


Site Two

Park Mews Case Study

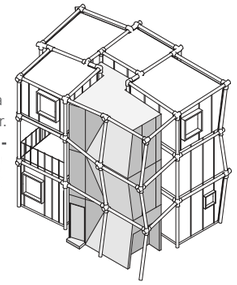
Drawing Detail into Cartoons



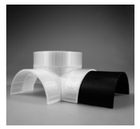


At the same time as developing ideas through drawing, I was adding detail to a digital model, from the original dynamo frame. This aided planning, and became a better base for tracing images over.

Digital Model Development



The final move in the design process was testing how the two sides of the bionic hand came into the built form of the building. This involved prototyping significant elements I had designed from each side: hand crafted bamboo interior linings and 3D printed node connector joints.



Digital 1:1 Prototypes

Thinking Hand Modelling

Thinking Hand Drawing

Thinking hand drawing development, with support from digital tools, also included model making to understand the building's placement on the site, layout and stair development in plan and section

Floor Planning and Staircase Detailing

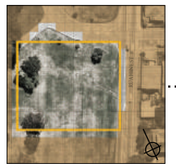
Thinking Hand 1:1 Prototypes

Park Mews Comparison

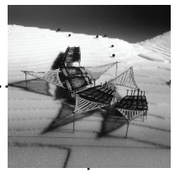
The Design

Development of Design

2.2

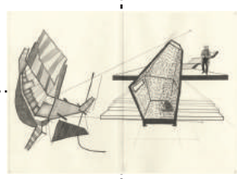


Site 1.
Hataitai Park



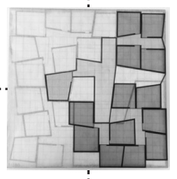
◀ Original site concept one: Individual accommodation units as one building stepping down a steep site.

Site 2.
Hataitai Park, Goa St

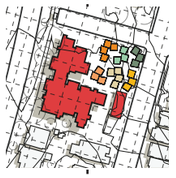


◀ Site two concept: After a site change I maintained individual housing units- but gave each its own form. Aggregating these together became structure for a pedestrian bridge.

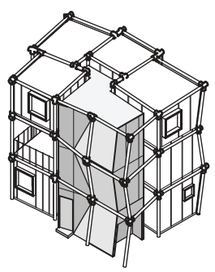
Final Site.
Moxham Ave/ Tapiri St

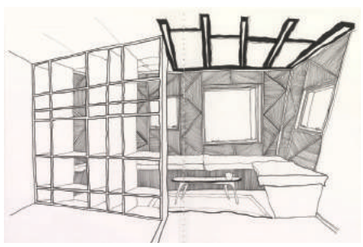


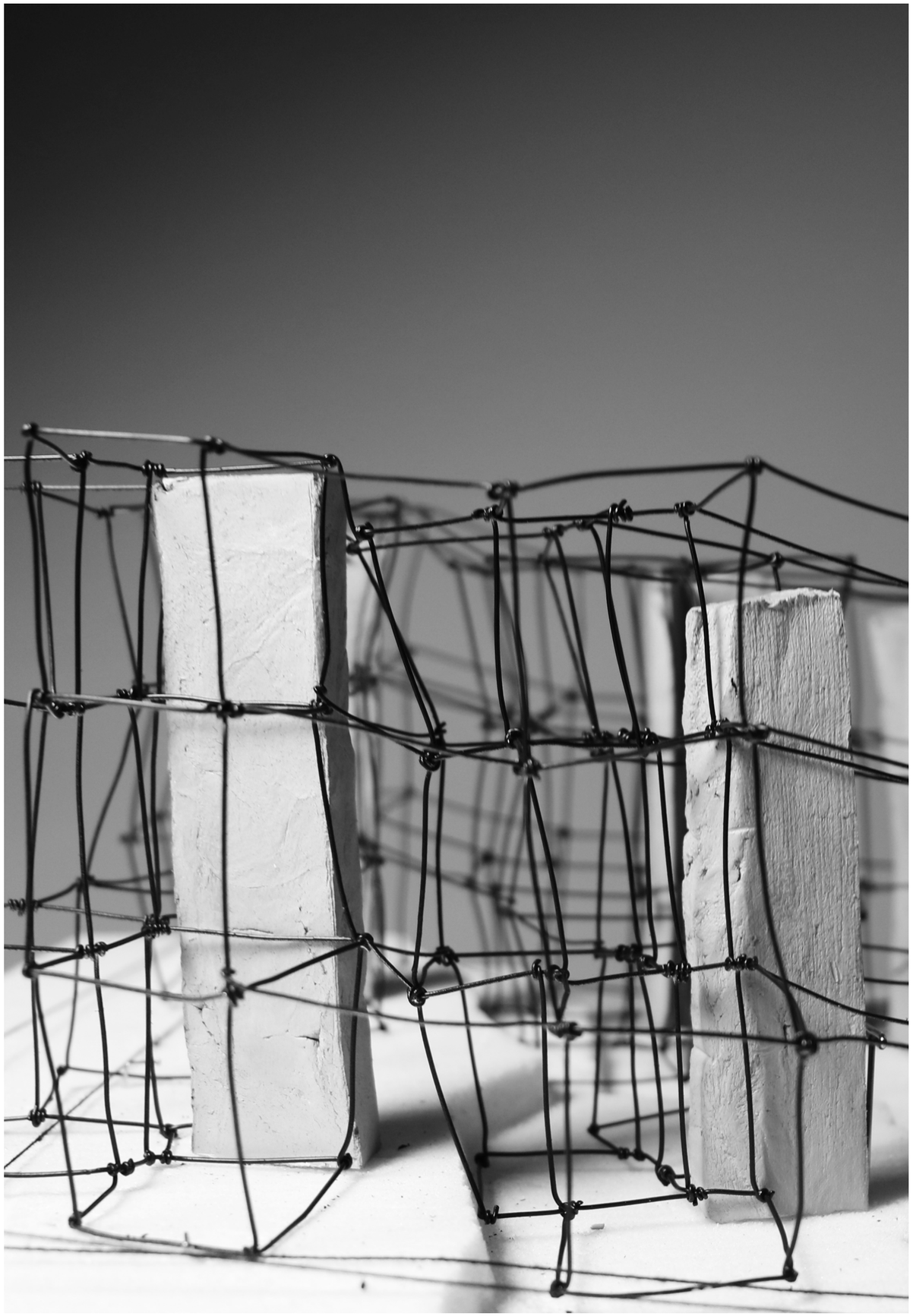
◀ Final site concept: I retained the idea for aggregation of the pod forms. This became a repeating form using angles to create complexity and intimate moments.



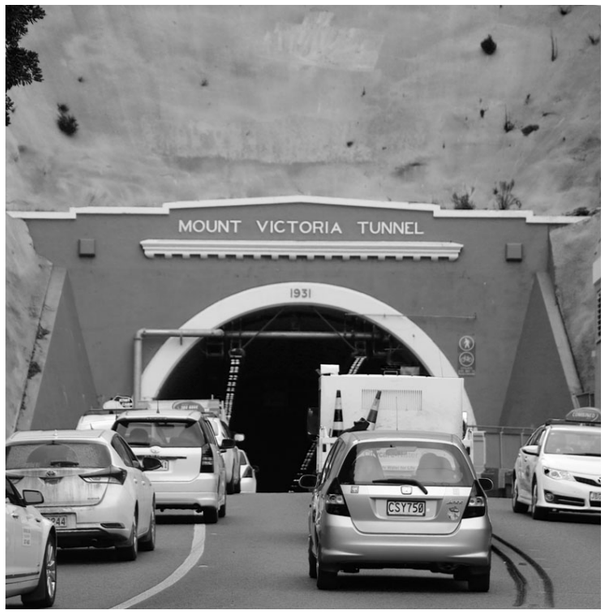
◀ Final concept development: Testing the repeating forms and angles became the floor plans of six houses angled in plan and section. Bringing in intimacy in material and craft and the structural system came in developed design.







2.3 Context: *Knowing the Site*

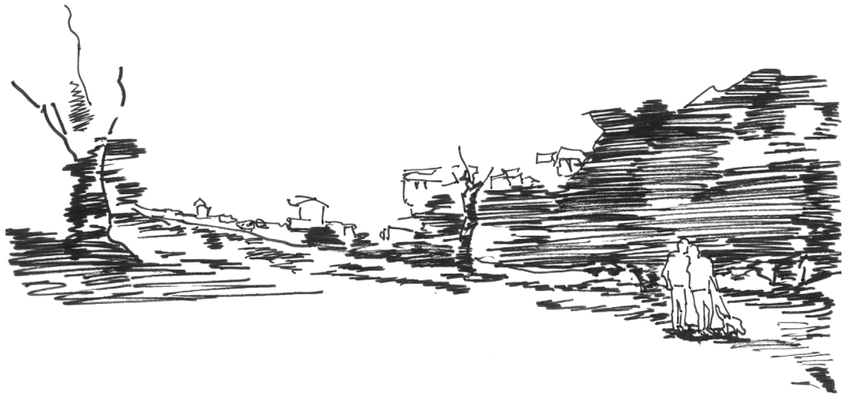


▲Fig 2.3. Mt Victoria car tunnel. The main route in and out of Hataitai.

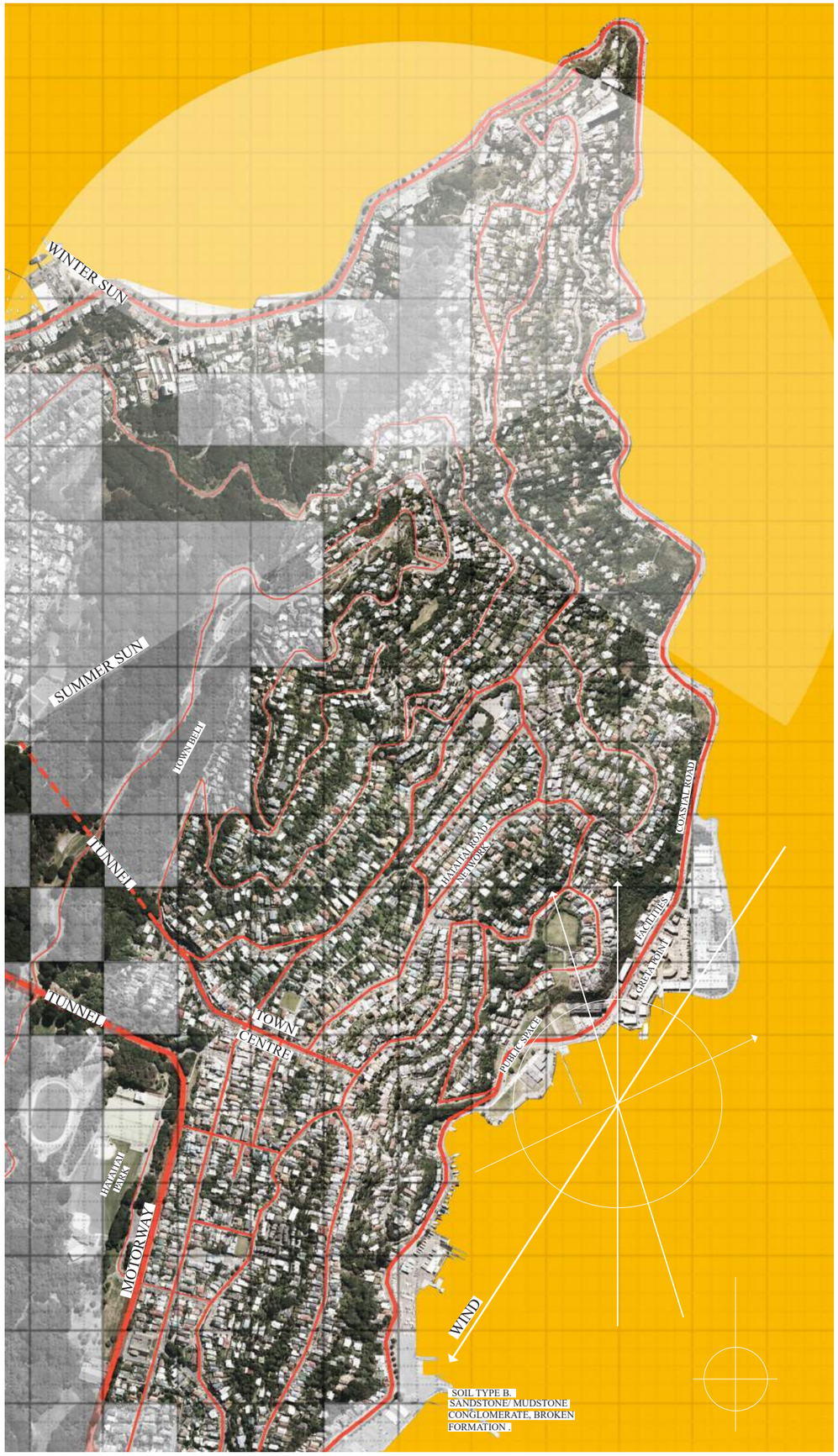
Hataitai is one of Wellington's eastern suburbs, directly connected to the central city by the Mount Victoria tunnel. Over the hill from the suburb of Mount Victoria's rigid grid, its roads contrastingly meander along the contours down to Evans Bay. These loops give huge, irregular blocks dotted with the classic New Zealand trope: the standalone dwelling.

Buses and vehicles from the airport and other eastern suburbs passing through the tunnels to the city make Hataitai a transport hub. This is due to amplify after the expansion of the car tunnel and motorway. This, in hand with Wellington's growth, mean Hataitai needs to densify to become an urban sub-centre of the city. For Wellington to achieve greater density, and thus lower carbon usage, it will be inner city suburbs like Hataitai leading the way. The research stream this project falls within is investigating this opportunity, to lower carbon use, benefit public health, and create stronger communities throughout the city. The central site and medium density housing project contribute to densifying the suburb from the centre out.

▲Fig 2.4. Early site sketch of a shop in Hataitai town centre.



▲ Fig 2.5. Early site sketch looking down to the suburb from Hataitai Park (the original site).



▶ Fig 2.6. Hataitai site conditions

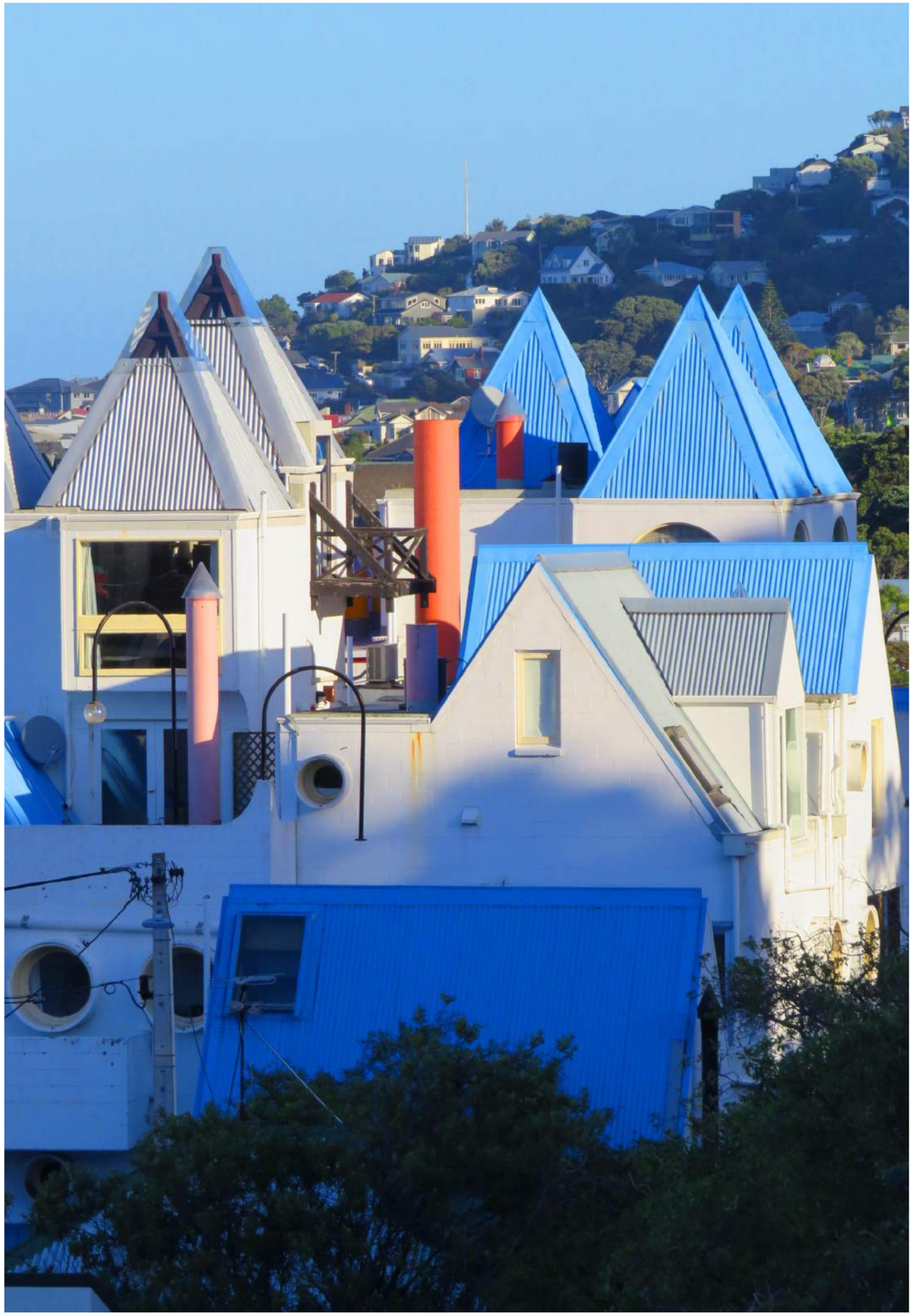
Hataitai is an example of New Zealand's attitude to suburbia and rejection of an urban realm in cities' peripheries.

As the drawn study of Raupo Street in Hataitai below exemplifies, in New Zealand's development of cities, the dominant housing type quickly became the single family, standalone dwelling. Geoffrey London writes that influence came through California's 1870s dwellings and they became cemented as the New Zealand domestic arrangement through mass state house building. European publishers exemplified standalone houses as the 'New Zealand' architecture they printed, in part securing New Zealand's perception of itself from the other side of the world. (London, 2003)

Though there are some examples of higher density in Hataitai, the concentration on the single dwelling as its own entity has largely led to a rejection of designing them collectively to create an urban realm. When writing about city evolution in *Architecture and Utopia*, Manfredo Tafuri refers to the, "uniformity ensured by pre-constituted formal systems" (Tafuri, 1976). The arrangement of front yard, side yard, back yard, with a house in the middle presenting a garage has given us our "pre-constituted formal system." 'Porch' or 'stoop' social culture replaced with private back yard culture, means the streets show little sign of life, despite the life a few metres further back behind closed doors. Increasing density of housing and embracing the street can create a more engaging, pedestrian focussed quality of living and break the suburban landscape the current system enforces only just outside the city centre.

◀ Fig 2.7. Hataitai building density and use.

▲ Fig 2.8. Raupo Street elevation in Hataitai



◀ Fig 2.12. Park Mews

These are all symptoms of, despite being one of the most urbanised countries in the world, a preoccupation with our natural landscape, and whether consciously or unconsciously an unwillingness to overshadow it with the built environment. London writes,

"Most New Zealand architects demonstrate their attitude to suburbia by turning away from it. The conventional alternative to the suburb is to project the context of the house as being landscape." (London, 2003)

When an interviewer accused Walker of using his projects to experiment at the expense of their suburban context, he replied:

"What is suburban context?"

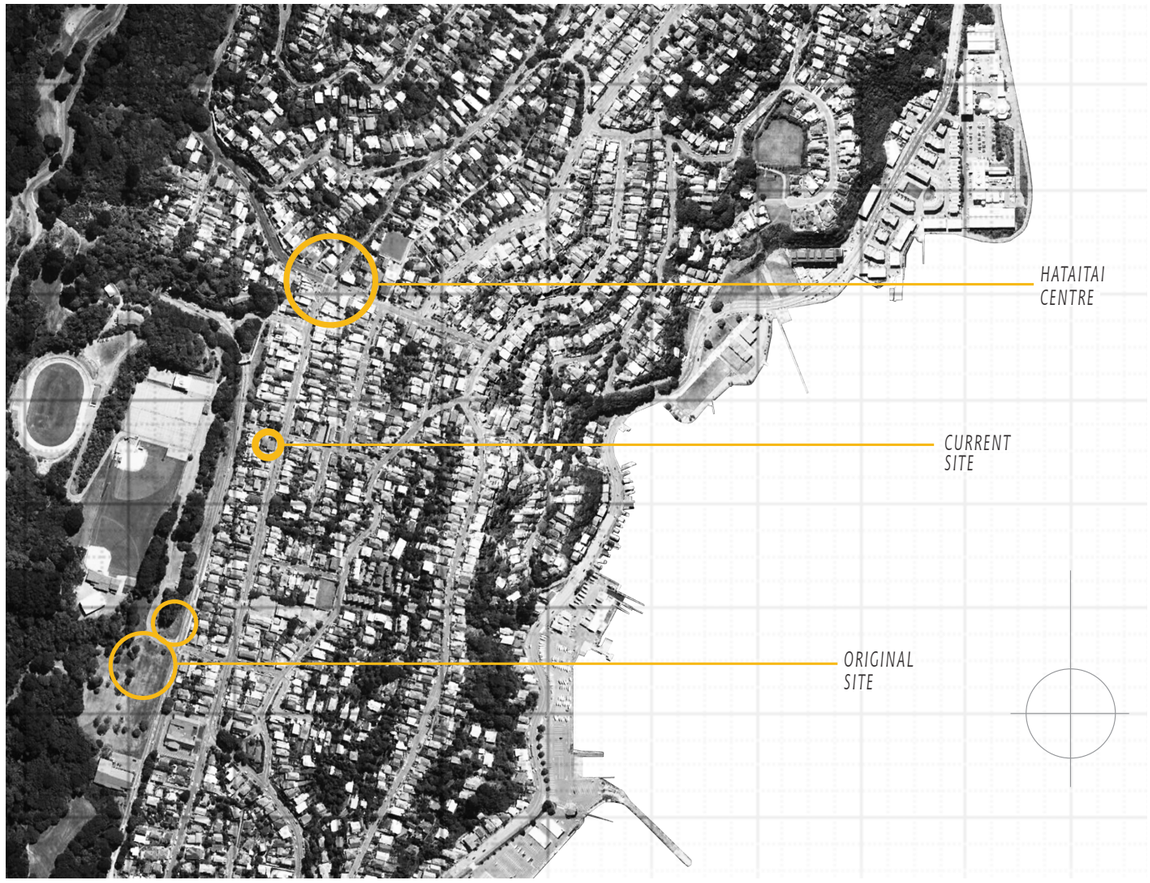
"Context does not necessarily imply the aping of something already there. It can work by contrast. Or you can look to the landscape..."

(Melling, 1985)

The landscape eclipses the urban realm as the appealing context, despite the nature of designing/ adding a house inherently contributing to the urbanity of the area.

Using the design to investigate densification and addressing the street front in New Zealand suburbia, as part of Hataitai's development into an urban sub-centre is how my research aligns with the Hataitai stream. However, densification for the sake of densification does not produce houses for familiarity and comfort of dwelling. The importance of using the bionic hand at the centre of this research is to design density with richness and intimacy to enjoyably inhabit.

2.4 Process: *Knowing the Site*



▲Fig 2.13. Changes in site.

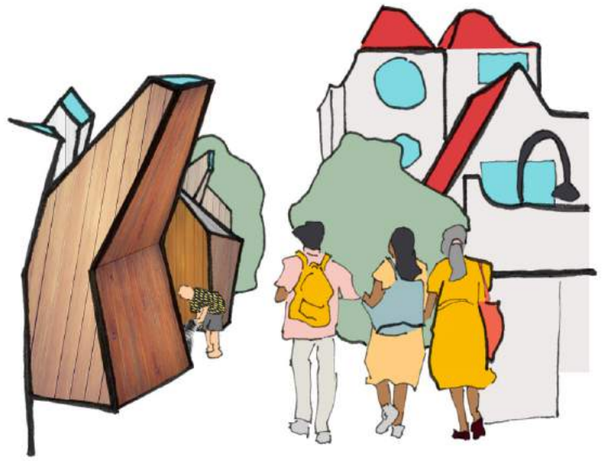
The site's proximity to the suburb's centre was key for the design to contribute to Hataitai's densification from the centre outwards. Initial site selections of general green spaces changed after critical analysis of the urban nature of the work I was producing. The densified housing programme made proximity to the centre relevant, and the tendency in designing towards complexity made comparison to Park Mews inevitable. Thus, the final site is within the block of Park Mews, on the corners of Moxham Avenue and Tapiri Street.

While a full historic thread of designing complexity exists in the background (refer page 96), the recognised version in this country remains the post-modern style of Park Mews. My site within the same block gives opportunity for direct comparison across the decades, as shown in the sketch of an early concept below.

Adjacent sites allow an easy comparison between the two projects in engagement with the street and surounding context.

The same suburban block means both projects are working with the same site and contextual conditions, with similar higher density housing programmes. Therefore, Park Mews is a strong case study for pertinent comparison in approach to complexity and construction of that complexity across time.

▲Fig 2.14. A sketch comparing an early concept with Park Mews on the Tapiri Street elevation



▲ Fig 2.16. Cartoon of an early concept's relationship with park Mews

◀ Fig 2.15. The chosen site

2.5 Context: *The Bionic Hand*

The bionic hand is a name for the way many students and practitioners are already working. It takes two sides of a false dichotomy in architecture - the hand and the digital - and combines them toward a rich and efficient architecture. Both in the design process (formation) and built outcome (form).

Pallasmaa is a key author relating to the importance of handcraft in the formation of architecture. In *The Thinking Hand* he writes,

"As a consequence of the mental transfer from the actuality of the drawing or the model to the reality of the project, the images with which the designer advances are not mere visual renderings; they constitute fully haptic and multi-sensory reality of imagination."

This is the way I used drawing to generate intimacy in the project. He goes on to write,

"This is an intimacy that is surely difficult, if not impossible, to simulate through computer-aided means of modelling and simulation." (Pallasmaa, 2017)

In this project, I have not attempted to use digital tools for this purpose. I aimed for synergy in the range of tools. I used each for their own strengths to enhance the capability of other tools. I used drawing to generate and push ideas, creating an imaginary world.

▲Fig 2.17. Loblolly House

The firm Kieran Timberlake used predominantly digital tools in designing and constructing the Loblolly House. They have stated a parametric model design process forced collaborative design between parties and eliminated repetition of work increasing efficiency in formation of the building. Geometric and dimensional certainty through digital fabrication of parts sped up the construction workflow. (Kieran, 2008)

Mies Van der Rohe wrote,

"Whoever regrets that the house of the future can no longer be constructed by building craftsmen should bear in mind that the motor-car is no longer built by the wheelwright."

(Conrads, 1970)

Advancing digital techniques in the building of my design aim to make the construction more efficient. Hand constructed, labour intensive materials were concentrated to moments most valuable in the project, closest to the body. Digital design tools accelerated repetitive, laborious testing in the design process.

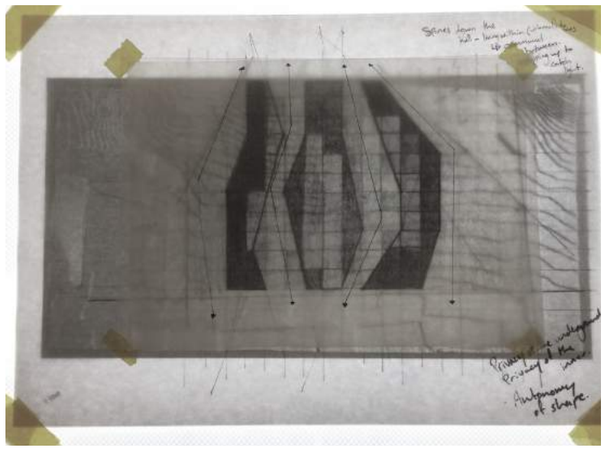
Process: *The Bionic Hand: Thinking Hand*

2.6

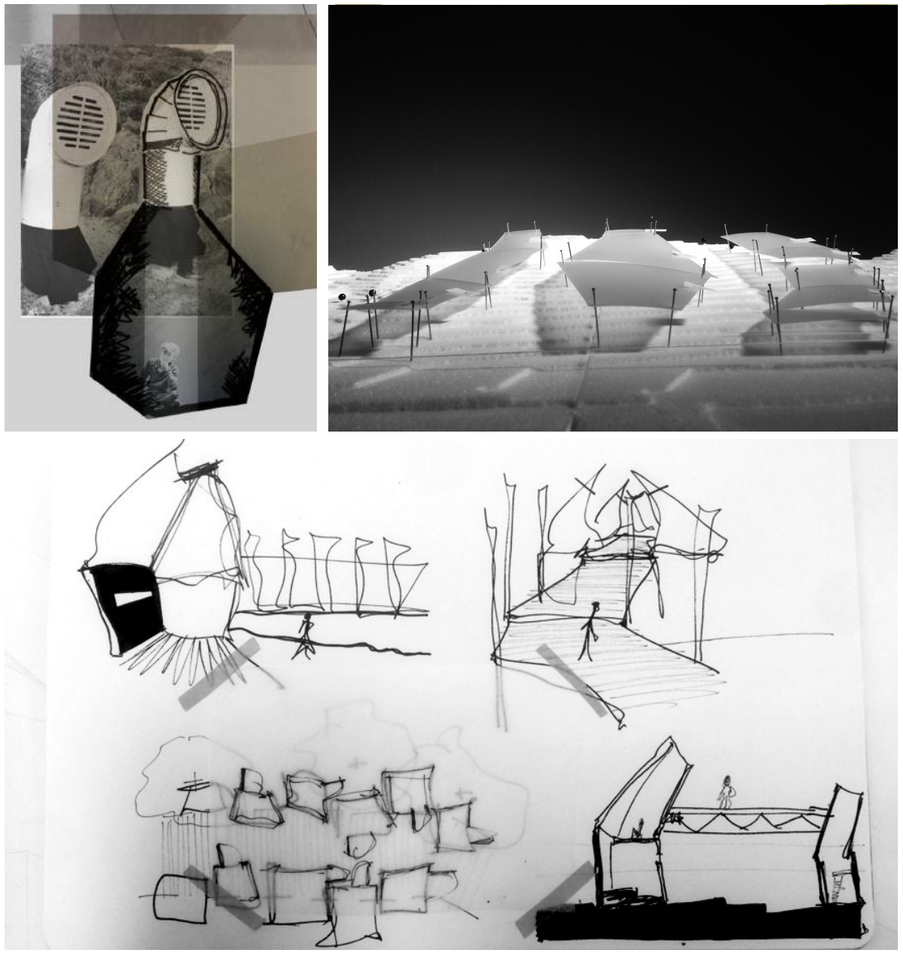
In my work, I initially used the thinking hand for freedom of ideas without it needing to make sense to others. This occurred through collaged drawings of one thought leading to another. I mixed perspective, with plan, with section, with detail, with texture etc. Each drawing expanding as the lines provoked further thought. Some of these drawings and models are shown in the following pages.

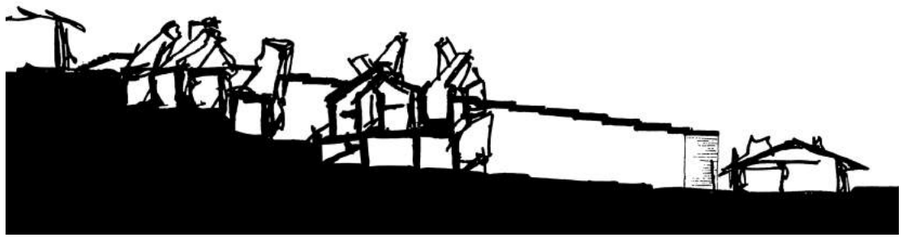
In 1948 Alvar Aalto wrote,

"I simply draw by instinct. Not architectural synthesis, but what are sometimes quite childlike compositions, and it this way on an abstract basis, the main idea gradually takes shape, a kind of universal substance that helps me to bring the numerous contradictory components into harmony." (Aalto & Schildt, 1998)



◀▶ Figs 2.18-2.22. Examples of early thinking hand concept work across the initial sites and the final site, and compositions of thinking hand work for comprehension by others.

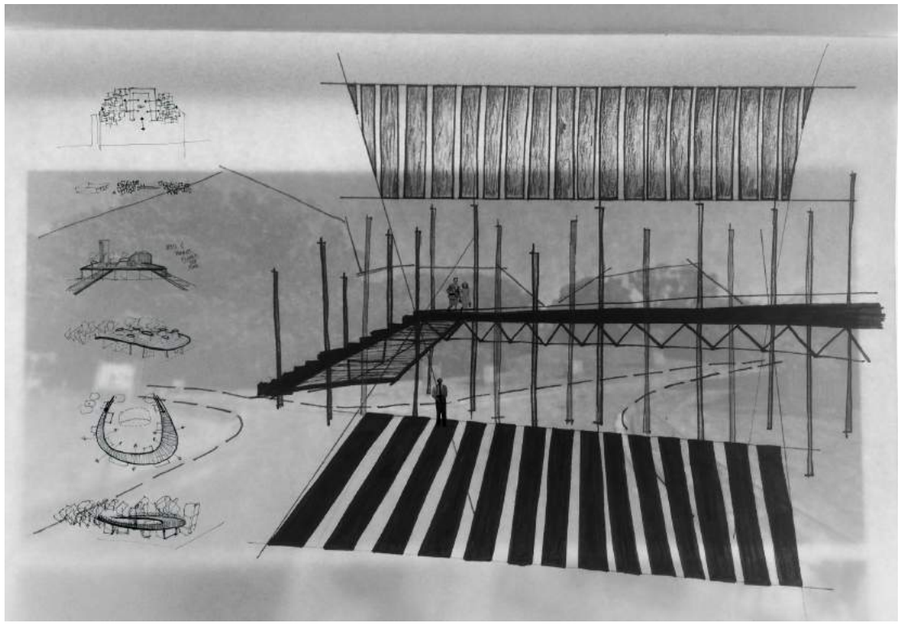


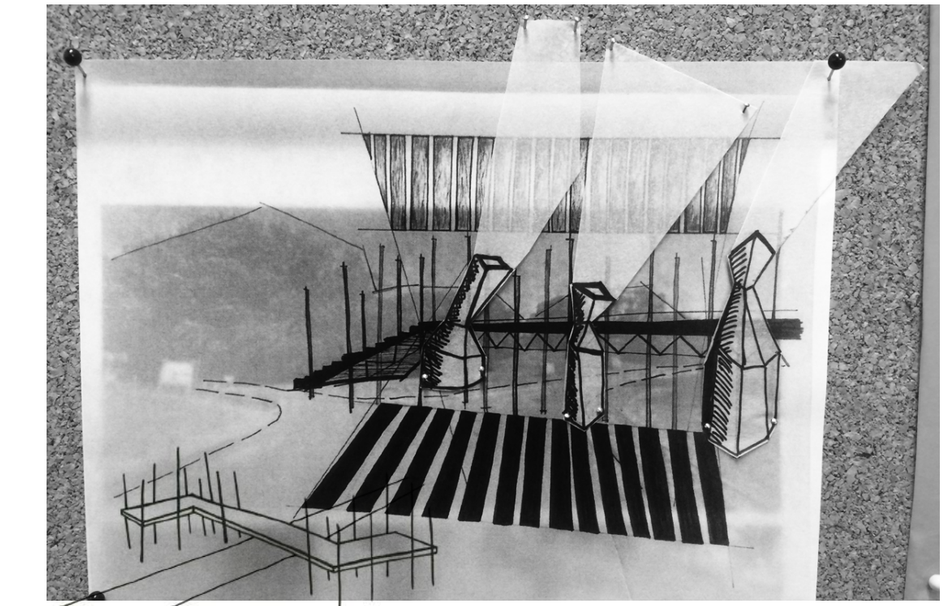


▲ Thinking hand drawings and models for a concept of accommodation pods supporting a pedestrian bridge across the motorway.

▲Fig 2.23. Cartooning the view of the pedestrian bridge from the road

▶Fig 2.24. Thinking hand drawings conceptualising the bridge in form, structure and material. Both physically and digitally collaged together.





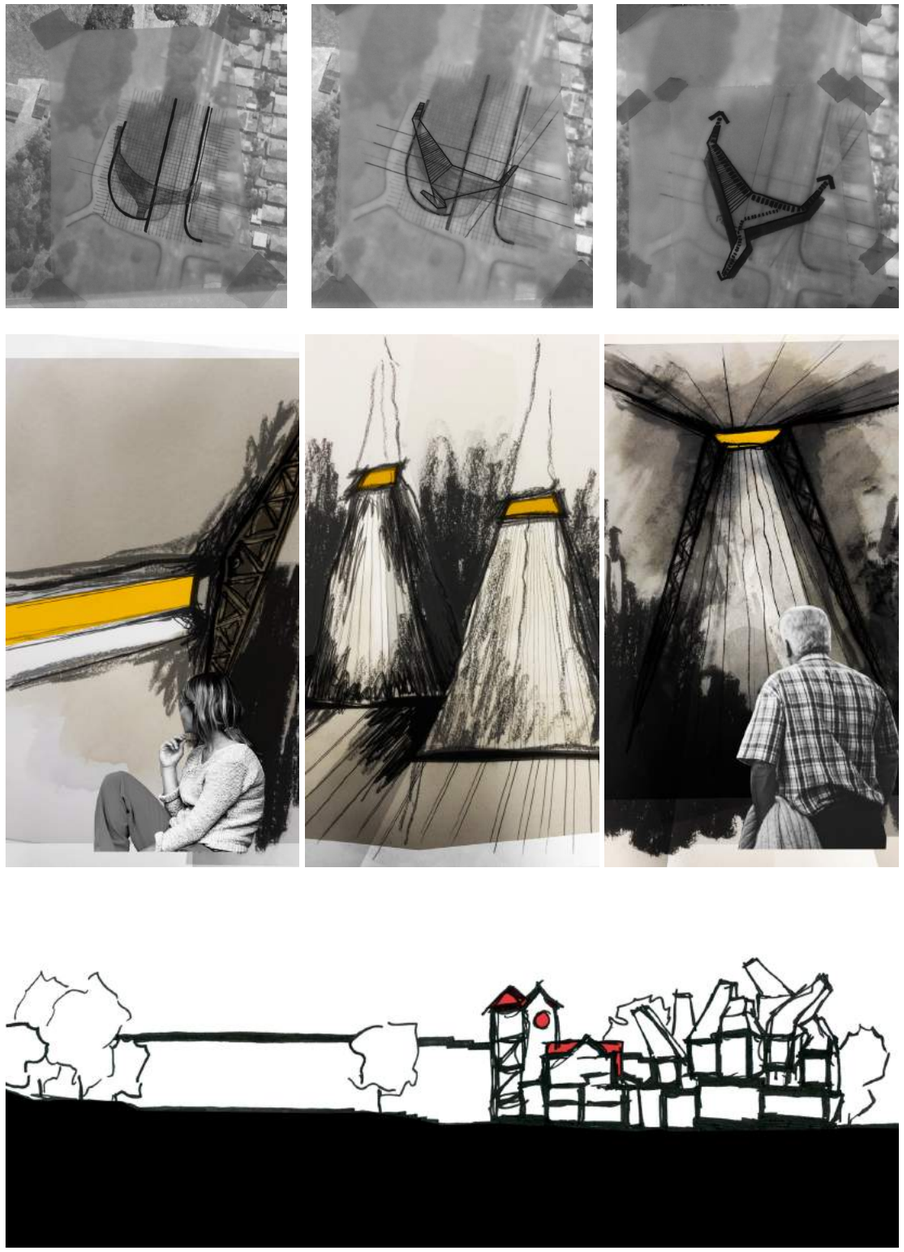
▶ Fig 2.26. Iterative sketching plans of the pedestrian bridge.

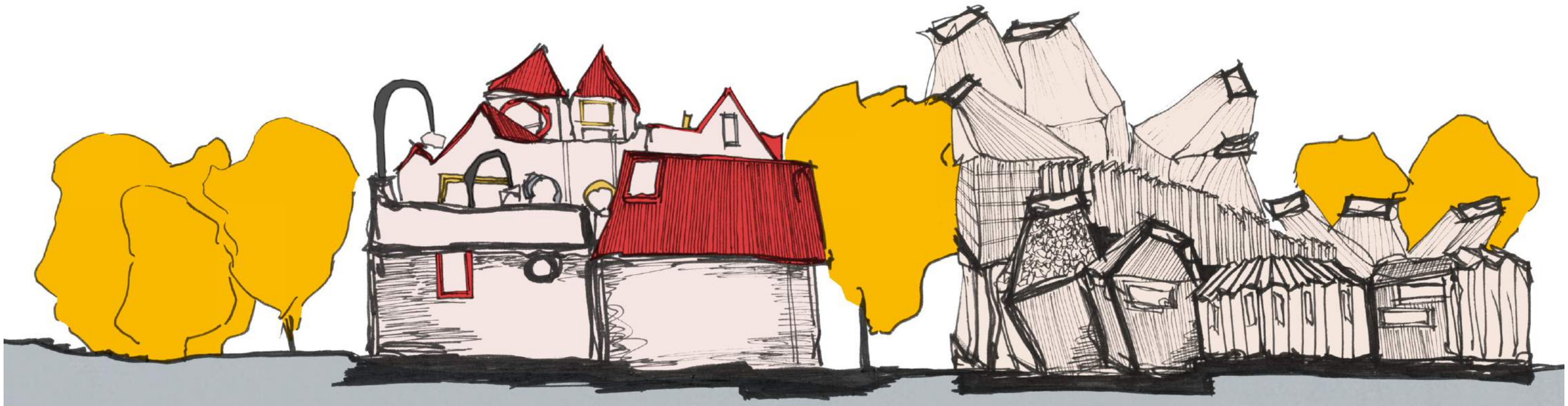
▶ Fig 2.27. Thinking hand sketching augmented by digital collaging of the inside of conceptual accommodation pods.

◀ Fig 2.25. Cartooning the view walking along the pedestrian bridge.

These drawings became concepts (refer page 48). Through developing these drawings and making them more coherent, I advanced the ideas. I could also explore how my invented building would relate to existing context, particularly Park Mews. This was a relationship tested early through sketched sections and elevations (fig 2.28).

▶ Fig 2.28. The concept of accommodation pods moved from the bridge site to the final site within the block of Park Mews. This was the concept taken forward to be refined into the final building.



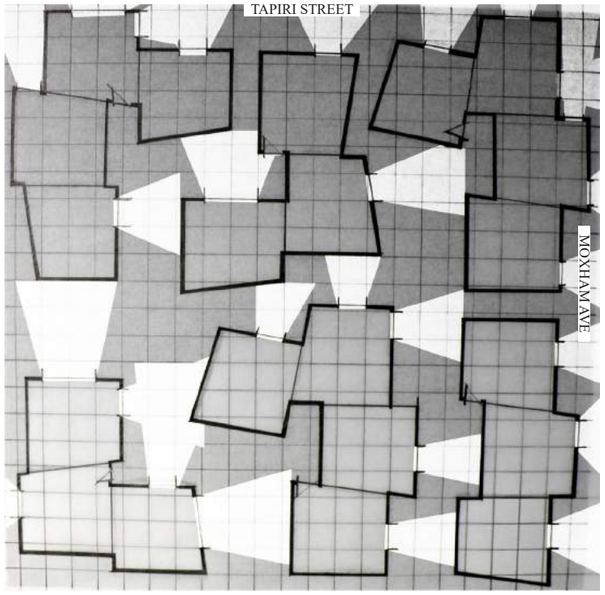


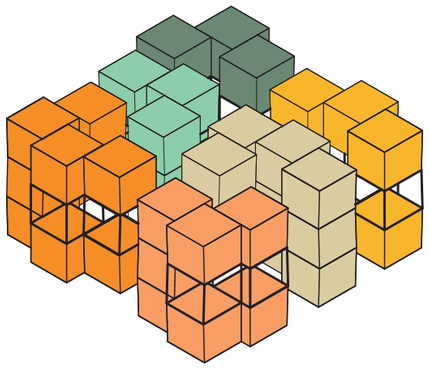
▲Fig 2.30. Elevation on Tapiri St to test it in contrast with Park Mews. The initial concept on the final site took the idea of individual accommodation pods from a concept on the previous site. These were aggregated together partly as a process of arranging pods, and partly as an aggregation of the cartoon moments I had imagined through the thinking hand around the site. These pods became the final design after angle and length manipulation in dynamo, and six groups of the pods being merged together to form six irregular house plans.

Process:
The Bionic Hand: Digital

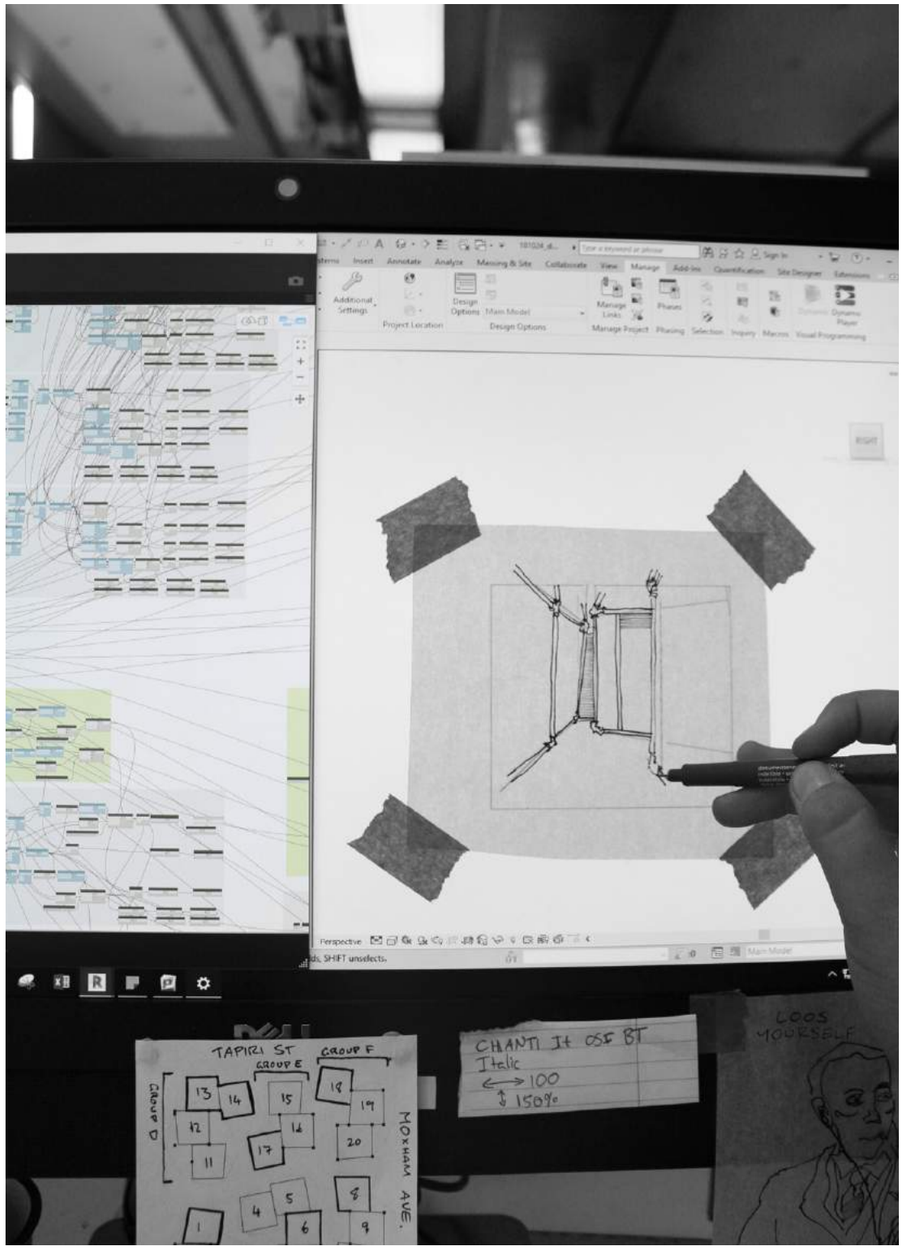
2.7

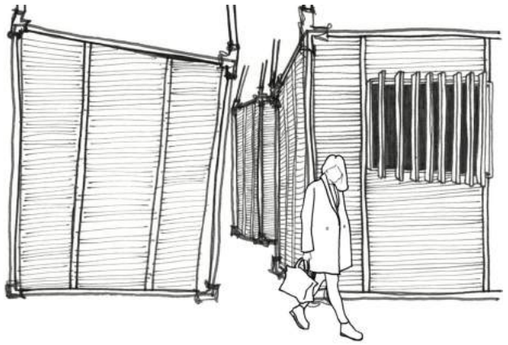
The thinking hand provided the flow of imagination to create initial ideas. I used the digital side of the bionic hand, a parametric model providing a tracing base, to make the hand drawing more efficient (fig 2.33). This pushed the thinking hand drawings past form. Later drawings focussed on development of material, structure and detail.

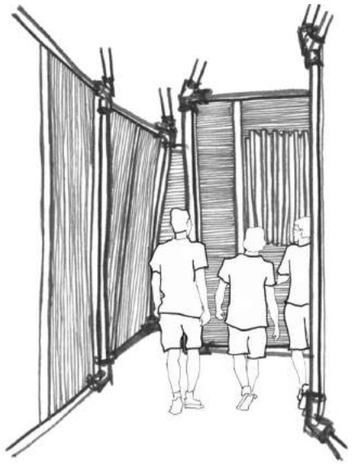


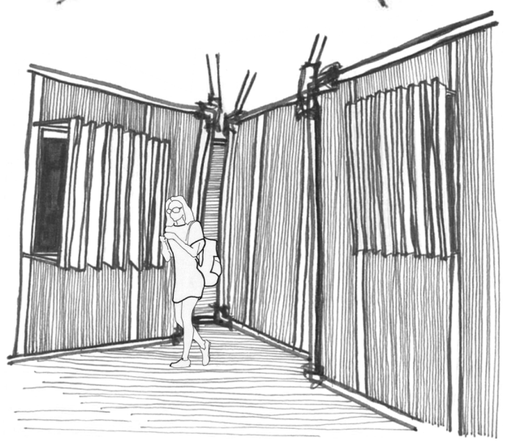


▲ Figs 2.31- 2.33.
▶ The hand generated plan above was used as the template for a parametric model where each angle and length in both plan and section was controllable. It was used as a base to draw over.

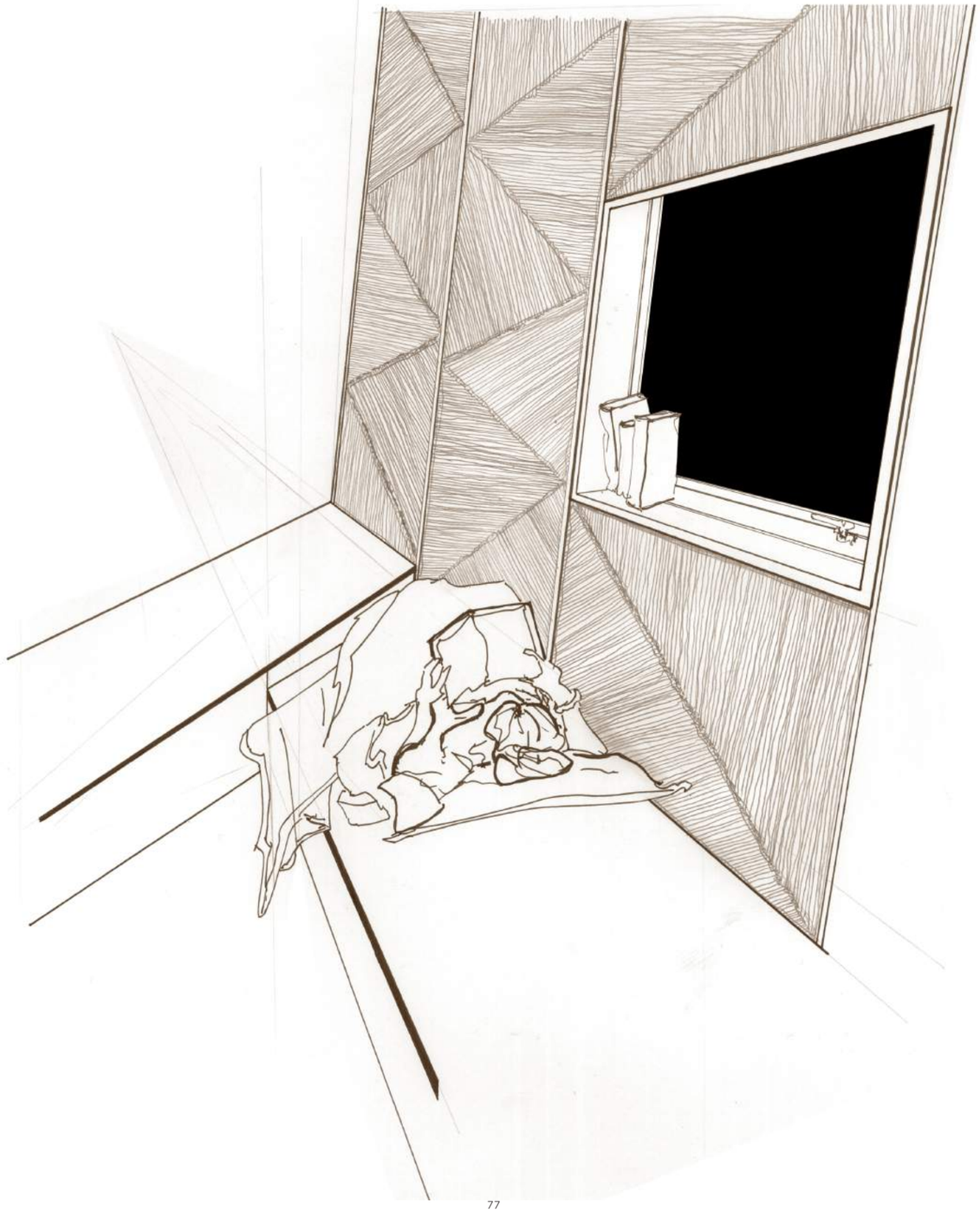


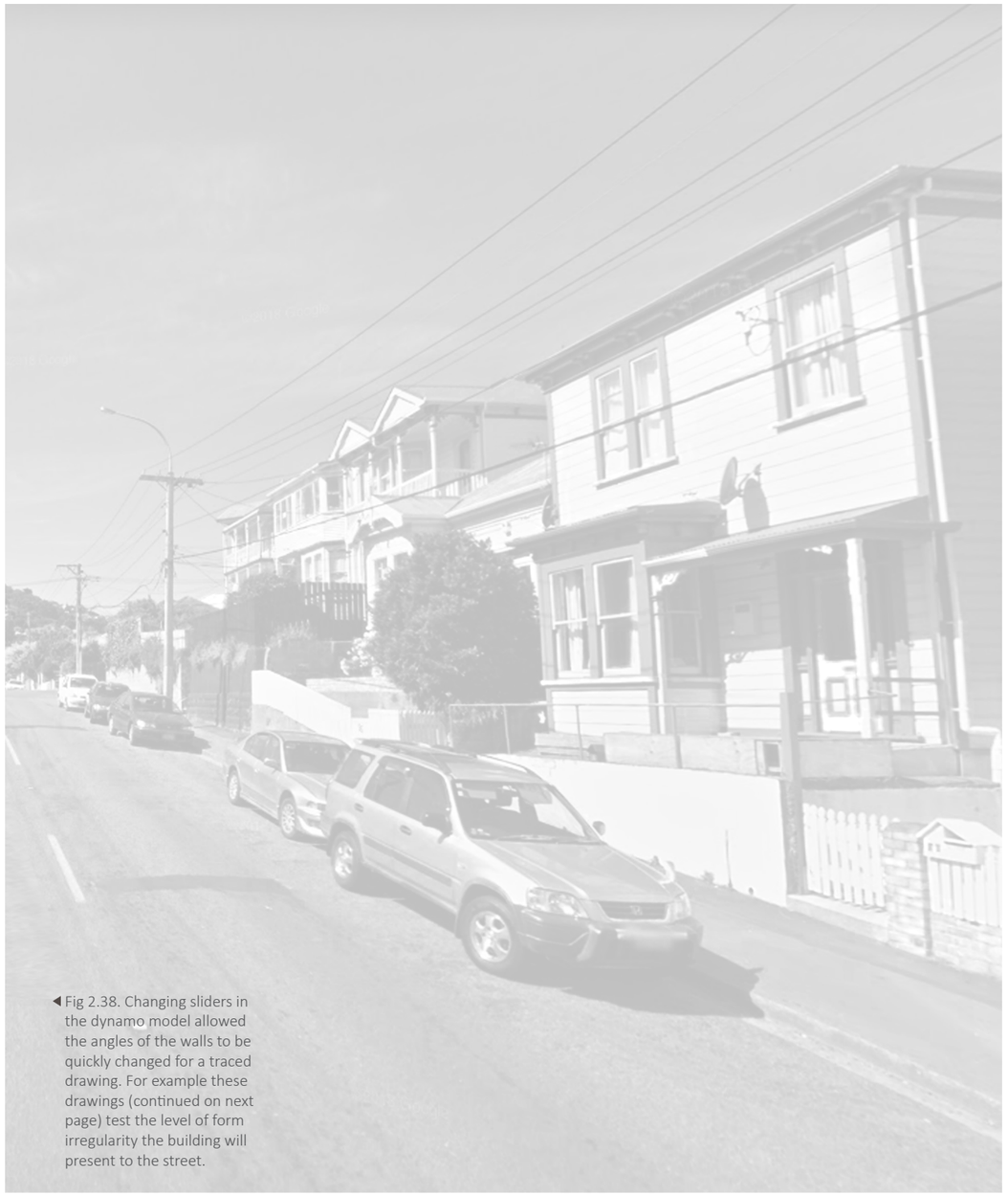




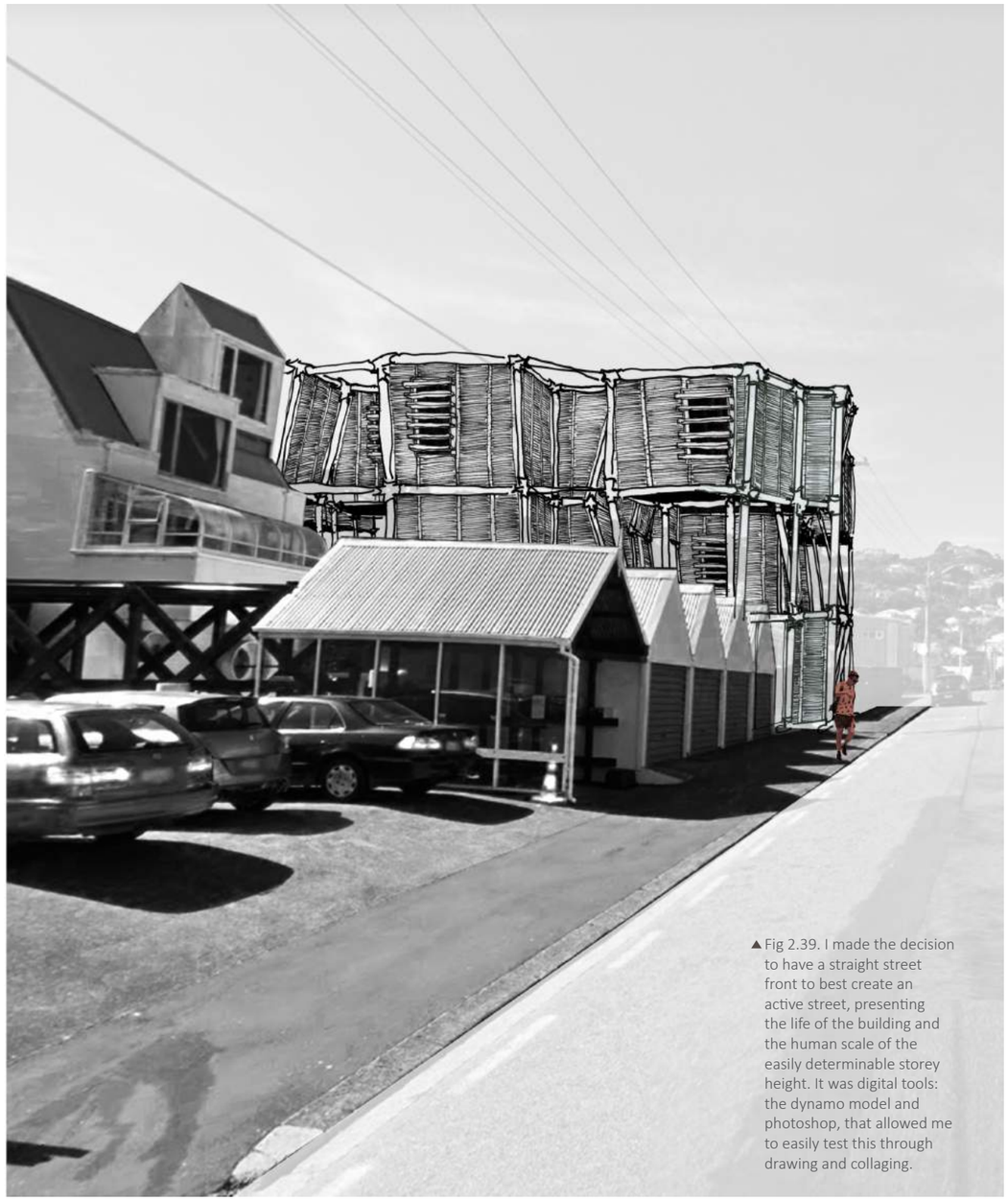


◀ Figs 2.34- 2.37. These ▶ drawings originated as tracings over snapshot views in the dynamo wire frame model.





◀ Fig 2.38. Changing sliders in the dynamo model allowed the angles of the walls to be quickly changed for a traced drawing. For example these drawings (continued on next page) test the level of form irregularity the building will present to the street.



▲ Fig 2.39. I made the decision to have a straight street front to best create an active street, presenting the life of the building and the human scale of the easily determinable storey height. It was digital tools: the dynamo model and photoshop, that allowed me to easily test this through drawing and collaging.

Process:
The Bionic Hand: Staircases

2.8

The process of designing the stairs neatly exemplifies a way I used the bionic hand in design.

The concept for the staircases came from evaluation of the precedent Walmer Yard. As will be discussed in depth later (page 108), Peter Salter's work embodies a contemporary version of complex design. It is complex not just spatially, but also in material and craft. Crucially, the building has diversity in material throughout the various spaces. This is something, upon reflection, I found to be lacking in my building. The interior spaces have warm material and craft for dwelling within, and the exterior circulation has contrast between wood cladding and steel structure. However, these remain consistent throughout the building. There was regularity in material. The staircases provided an opportunity to diversify this material palette, and create a threshold between the outdoors and the intimate dwelling spaces within.

As the exoskeleton sits lightly on the site, the concept for the staircases was to be weights within the building. They would seem to ground it to the site. The contrast of the stair material reflects the contrast in programme between passive dwelling spaces I had been focussing on, and active circulation spaces. As artist Rachel Whiteread said,

> *"Stairs are the throat of the building, the place through which everyone and thing must pass to go from top to bottom. Stairs are not places in which you can be passive and stationary but are sites of movement dynamism, diagonal space that cut through a building, linking floors and people"*
>
> *(Mullins, 2004)*

▲ Fig 2.40. Augmenting of hand and digital tools to create images testing ideas for staircases in the building.

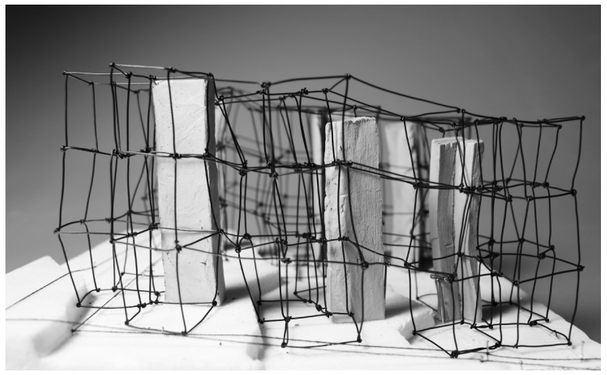
Whiteread's work casting staircases was the inspiration for the 'weighted' staircases.

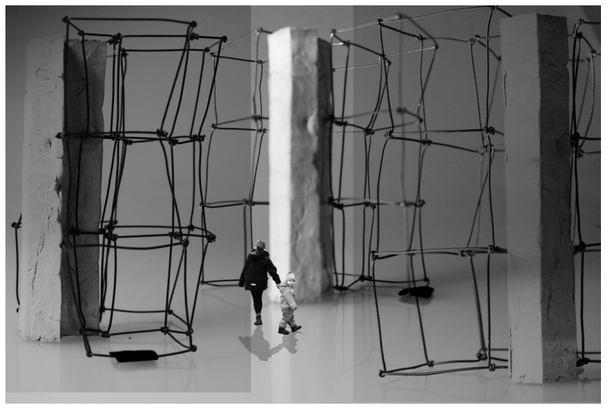
I used the bionic hand to test and design these ideas. Firstly, this was through digitally collaging photos of Whiteread's work and my own drawing (fig 2.40). Tracing over the dynamo model, and the photographs of the sculptures allowed flow of imagination for how the framing and house forms could wrap around the staircases. Digital editing of those together allowed me efficiency in bringing in other tests, such as bringing in surrounding context without redrawing.

The next step in the thinking hand designing was modelling the concrete forms in the light frame. This showed the weight of the forms and the impact they would have on the site. This could be emphasised with the digital side of the bionic hand, by editing the photos and adding people (fig 2.41).

I also explored the impact on the site and people moving through the site through the drawing style I had already been using (fig 2.42). I based the drawing partly on a photograph of the hand model and partly on the dynamo model.

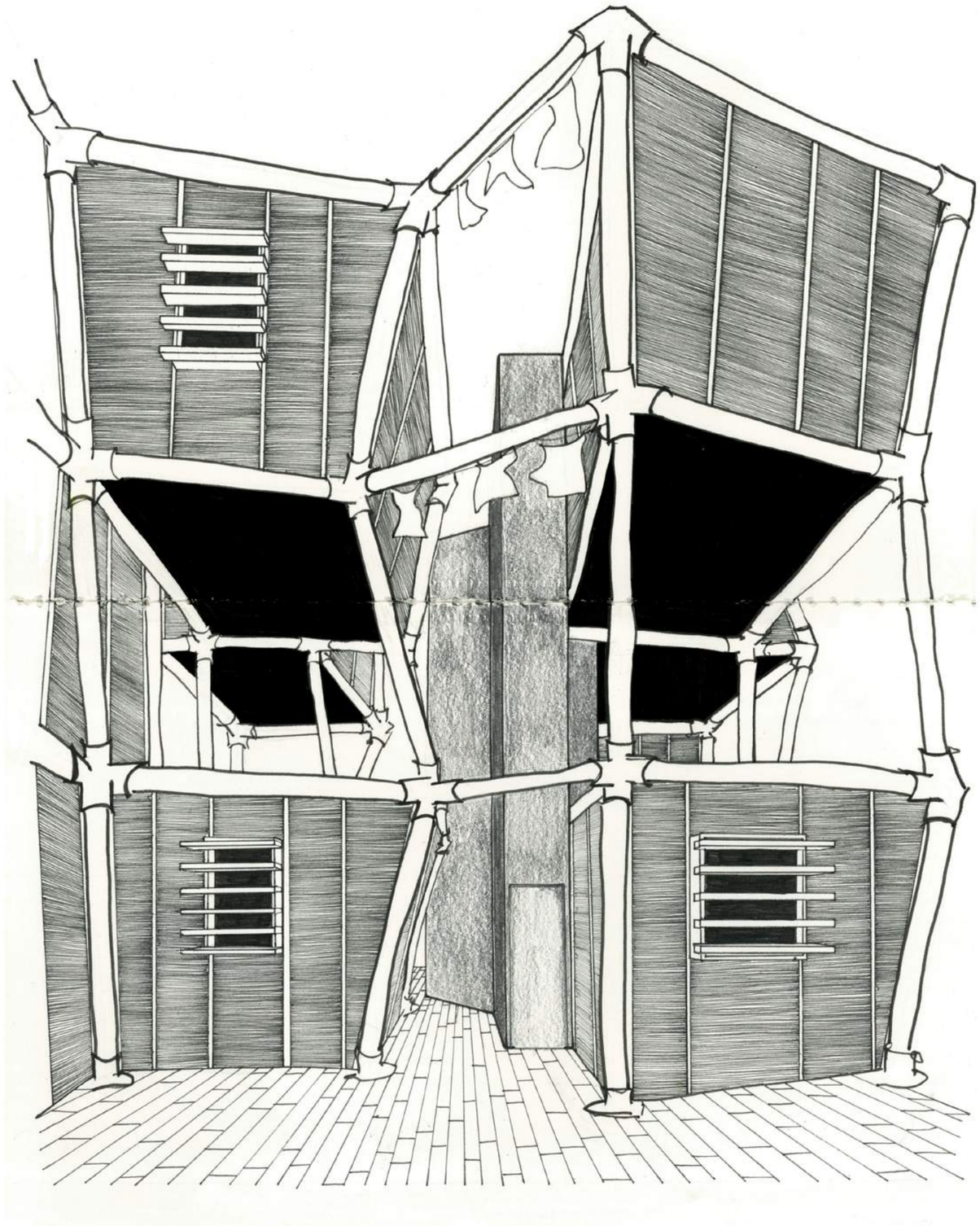
All processes benefitted from the strengths of both sides of the bionic hand. The thinking hand to create and express ideas, and digital tools to make this way of designing more efficient.





▲ Fig 2.41. The photos of the
◀ models were digitally edited and collaged to test the impact of the staircases.

▶ Fig 2.42. Drawing to test the staircase from human view amongst the exoskeleton and house forms.



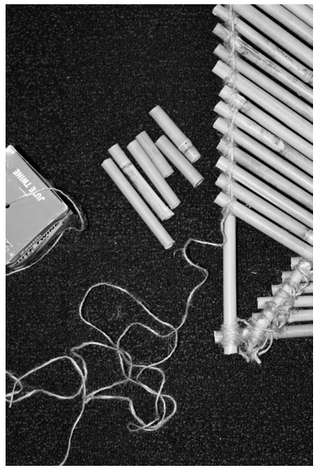
Process: *Thinking Hand: Prototyping*

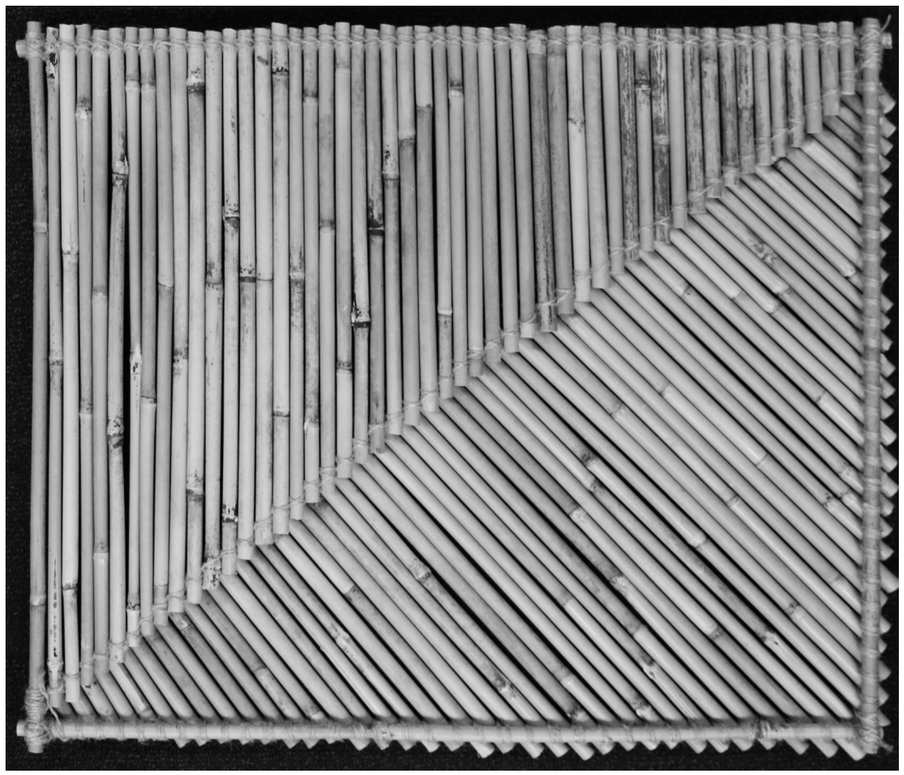
2.9

Within the **form** of the realised building, the thinking hand would come through interior material. By drawing and prototype modelling, I developed a handcrafted bamboo interior lining system. I made a 1:1 sample of what I had been drawing (fig 2.43), and then an iteration of that based on its weaknesses (figs 2.44 - 2.46). Switching media from drawing to prototyping allowed me to see the sparsity of the first lining. Crucially it showed how this would affect the potency and richness of it as an interior material. Through the making process, I was able to understand the 'irregularity' the handcrafting was producing. Building of material with the thinking hand allowed an unsanitized, bespoke, richness to the material. This is in the same way the thinking hand can give a bespoke richness, and humanity, in drawn designing.

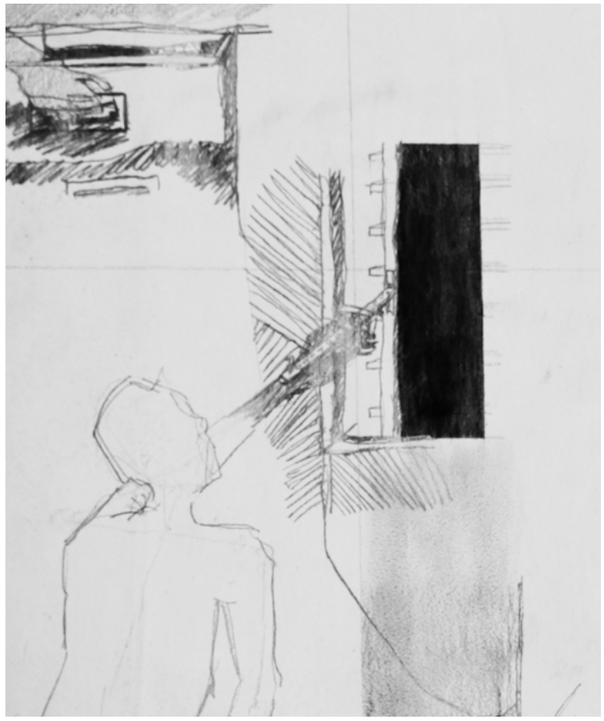
◀ Fig 2.43. The first prototype was made on site at a stream exhibition in Hataitai. When built and in place, the sparsity of the bamboo and thus its unsuitability as an interior lining became apparent.

▶ Figs 2.44- 2.46. The second prototype addressed this sparseness to create a richer lining for dwellers to interact with.



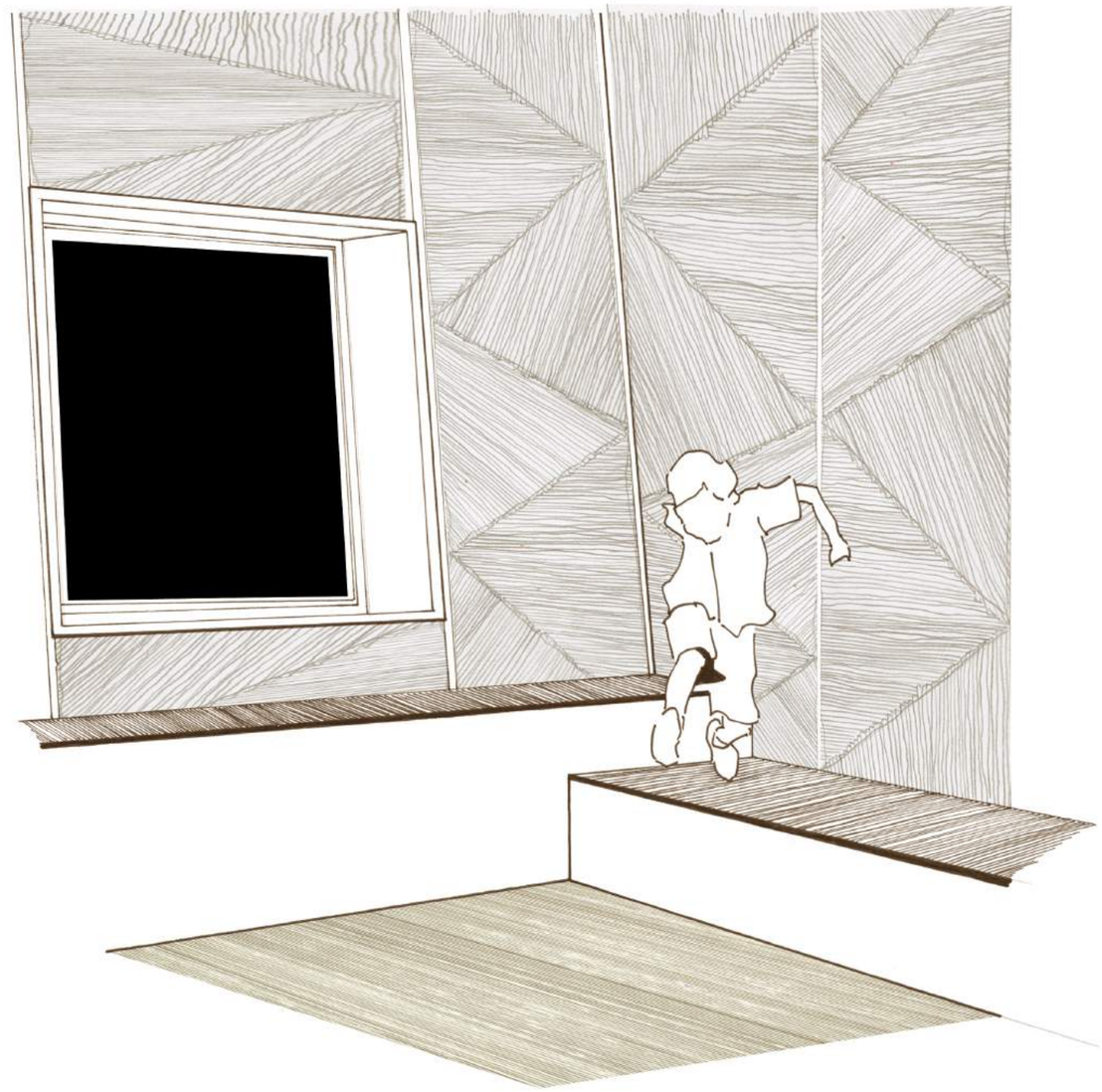


Existentialists mused on the importance of the architecture that is closest to the body. This thinking is still relevant today. Pallasmaa in his book *Eyes of the Skin: Architecture and the Senses* writes, “The door handle is the handshake of the building” (Pallasmaa, 2012). I applied this thinking in establishing the balance of the bionic hand in the built form of the building, between rich, bespoke handcraft interiors and the digitally built exoskeleton form. The bamboo is labour intensive, so has been limited to areas where it can create most intimacy. Lining of other spaces will be regular lining appropriate to the programme of the space. Focussed richness will be in the living spaces with the inbuilt furniture where, as Bachelard would say, users can inhabit with intensity, and familiarity with their surroundings, such as the space in fig 2.48. This decision works alongside the digitally fabricated node connections of the structural frame, to mitigate exhaustive levels of bespoke labour. The construction balances between efficient digital construction and labour intensive handcraft, while maintaining complex, intimate space.



◀ Fig 2.47. Part of a drawn study of the hand’s journey around the building to understand areas most important to the body.

▶ Fig 2.48. A drawing of a dwelling space in the homes where the rich material would be valuable.



Process:
Digital: Prototyping

2.10

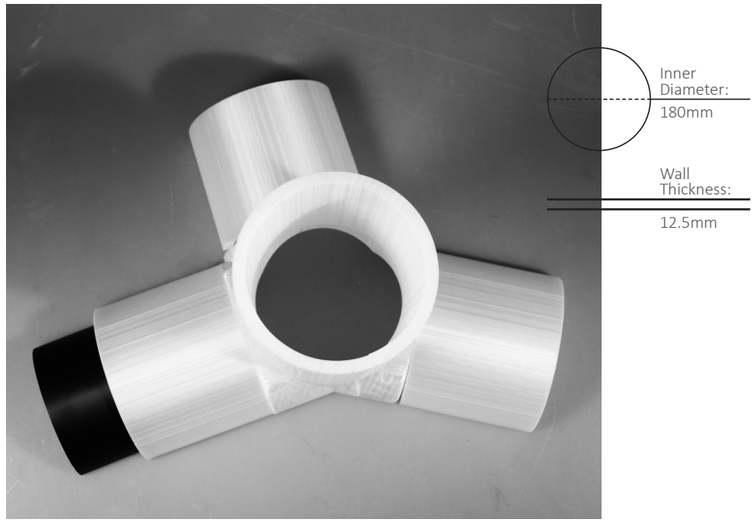
Changing from formation to form in the design process through prototyping was a key way to progress the digital side of the bionic hand as well. The nodal connections of the exoskeleton accommodate spatial complexity and are the digital in the building form. Testing around these was key to understanding how the bionic hand could fit coherently into intimate, rich architecture.

The intrinsically three-dimensional nature of the nodes posed difficulties in me being able to understand them through a two-dimensional image, individually and as part of the overall building composition.

Initial prototyping at 1:5 (fig 2.49) and the 1:1 (figs 2.50 -2.51) proved this difficulty. The prints of what I had originally computer modelled were laughably big and baring little similarity to what I had been drawing. Especially in their relationship to the body, despite their coherency with the architecture in the rhino model. The power of the digital tools allowed me to refine the design of the connections quickly and at real size.

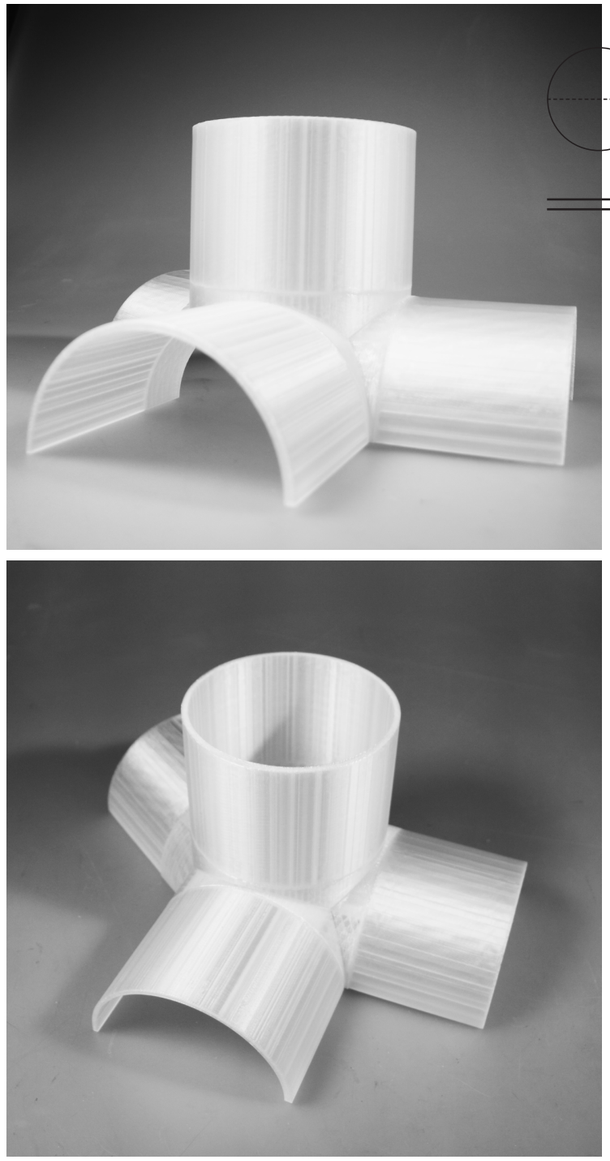
◀ Fig 2.49. The first 3d print prototype at 1:5 gave understanding of form but not scale. Using a 3d printer it was equally easy to test at 1:1 as at 1:5.

1:1 prototype one



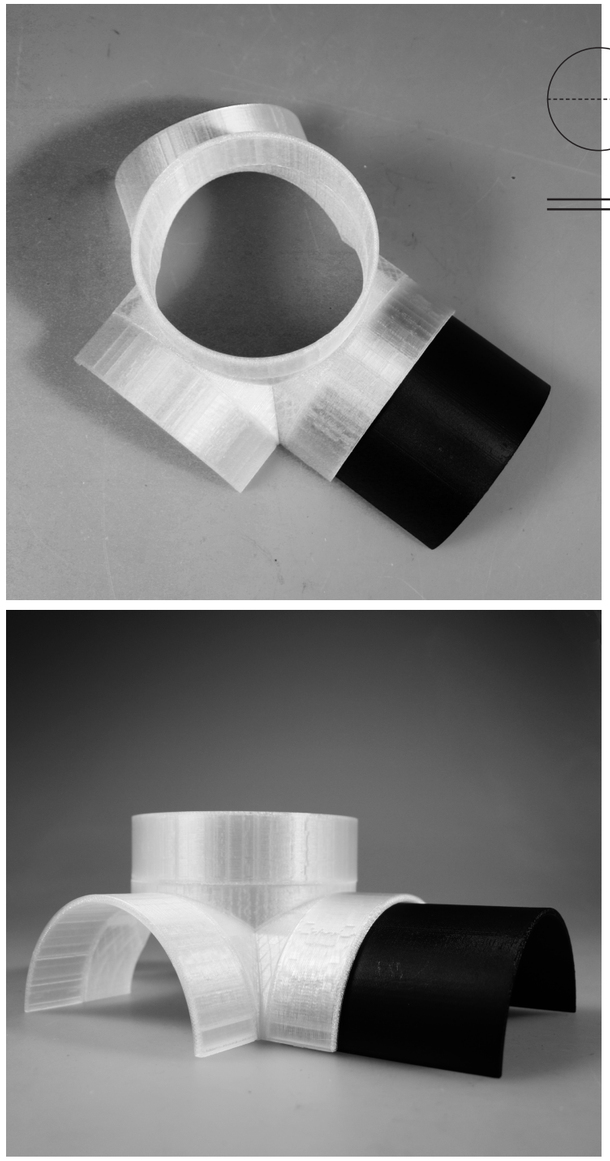
▶ Figs 2.50- 2.51. The first 3d print prototype at 1:1 was the same computer model as the original 1:5 model. The scale was closer to structural members of a much larger building and didn't resemble the subtlety of how I had drawn them.

1:1 prototype two



◀ Figs 2.52- 5.53. The second prototype brought back the delicacy of form from the drawings by decreasing the wall thickness. This also made it significantly lighter and more efficient in material. However the scale was still too large to have the subtlety of the nodes in the drawings.

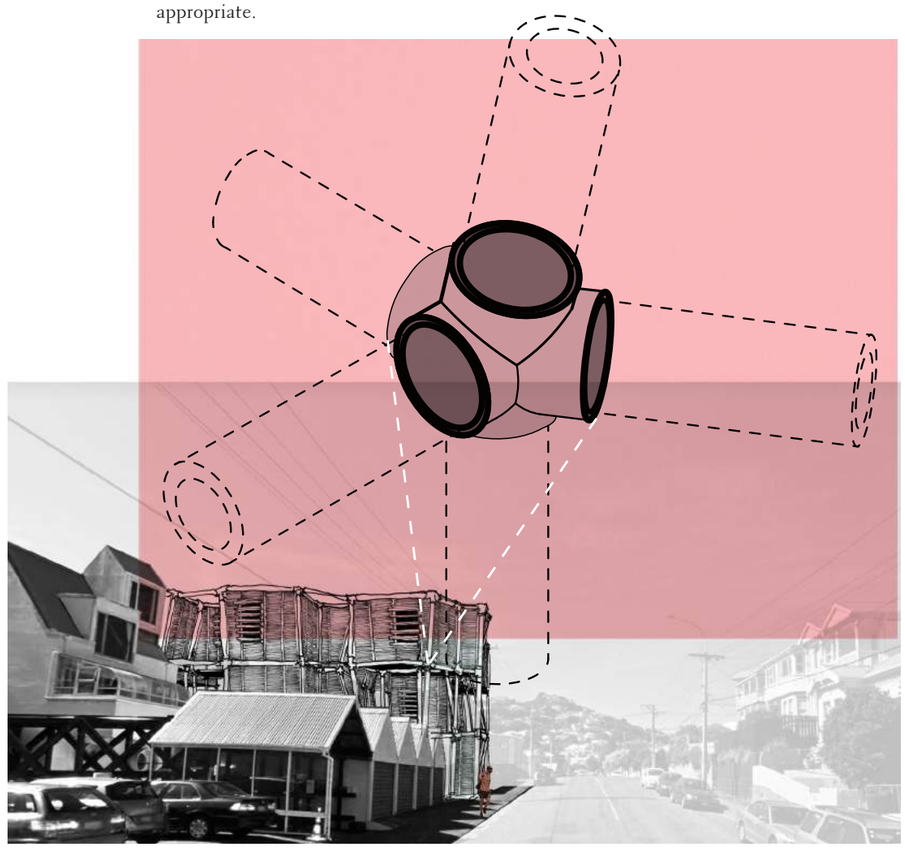
1:1 final prototype



▶ Figs 2.54- 2.55. The final prototype maintained the delicacy of the thin walls, scaling it down again and also changed the form by cutting down the arm length. This brought it back to the subtle form close fitting to the steel structural poles that I had imagined through the original drawings.

▲Fig 5.56. An early development drawing integrating the idea for bespoke digitally fabricated connections into a preexisting design of aggregated forms.

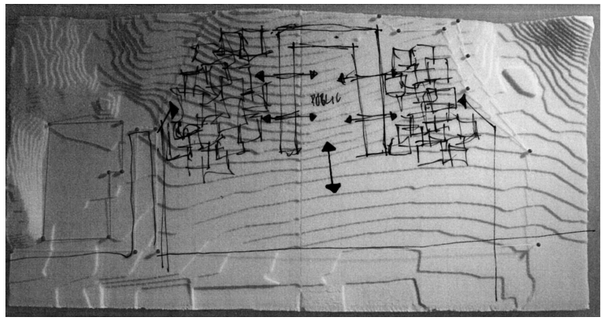
The 3D computer modelling and then offsite printing would give the "geometric and dimensional certainty" that Kieran Timberlake referred to in digitally fabricating the Loblolly House (Kieran, 2008). It will bring simplicity to construction of a complex form. In the same way the rich bespoke craft is relevant to dwelling spaces on the interior, the digital prefabricated-put-together-puzzle is appropriate to make up the building structure. While the bespoke nature of the nodes become ornaments in themselves, it is the form they accommodate giving spatial intimacy, not the material and crafting of the nodes giving intimacy. Thus, efficient digital fabrication of generic metal is appropriate.

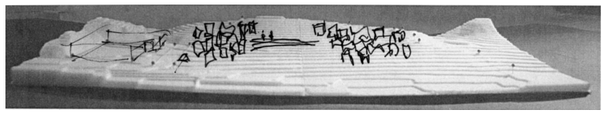


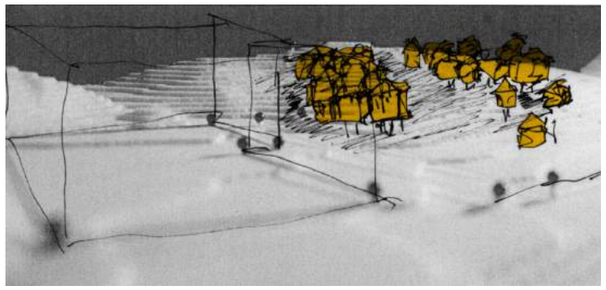
▲Fig 2.57. The role of the digitally fabricated nodes is to connect the steel exoskeleton structure of the building.

Context:
Disciplinary Positioning

2.11

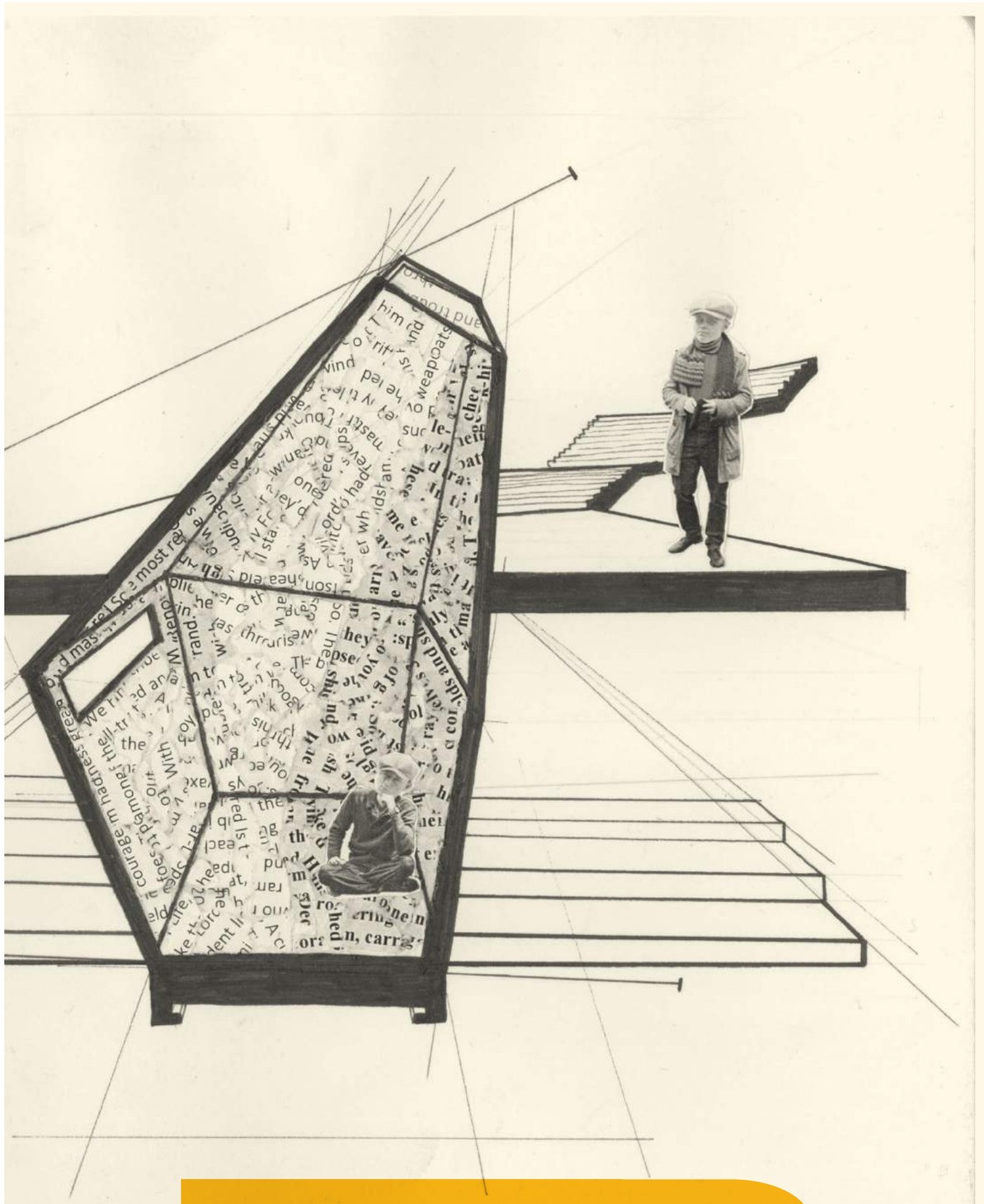






The original thinking hand drawings and models, exemplified on this and the following pages, conceived and expressed initial ideas for a building on an early site (refer page 48). While they provoked thinking toward development of the final design, their legacy in the work was as the catalyst in understanding the design work's position within the discipline. Irregular angles and spaces I generated in plan and section were creating surprising, intimate, sporadic nooks and moments. After critical reflection of this work, it became clear I was designing in rejection of standardised forms shapes and angles. Therefore, the position of this work is within a thread of "complex" "irregular" designing and craft in architectural history.

▲Figs 2.58- 2.69. Examples
▶of early concepts of a single storey building of single unit dwellings on a sloped site, generated by the thinking hand which show a tendency to irregularity and complexity. These drawings became the pod forms of the bridge concept and then the single pod dwellings of the initial concept on the final site.



▲◀ Fig 2.70. This collaged image of a housing pod section, and these pods together in a plan as the concept for living pods holding up a pedestrian bridge, was the main spark for understanding my tendency towards complexity in design. I was using the unusual angles in the plan to create difference between the uniform pods, and the angles in the section to give intimacy within the pods.

The recognisable version of 'complexity' in New Zealand architecture is the formal complexity as a version of post modernism, made famous by Roger Walker and Ian Athfield.

The word complexity in this context throws the mind to Robert Venturi and his book *Complexity and Contradiction in Architecture*. Here he expresses that complexity in architectural element and form is a reaction to the bareness of modernism.

"Less is more"

"Less is a bore"

"By embracing contradiction as well as complexity, I aim for vitality as well as validity."

... "Architects can no longer afford to be intimidated by the puritanical moral language of orthodox modern architecture." (Venturi, 1977)

▲Fig 2.71. Moore Rogger Hofflander
Condomonium Los Angeles completed in 1976

▲Fig 2.72. Condominium One designed by
Moore and others as MLTW. Completed 1965.

Working at the same time, Charles Moore's version of complexity reclaimed old forms (diverging from the favoured 'box' of the modernists) and aggregated these together. While Venturi, talks in terms of form and element, Moore prioritises human understanding of the forms as space. He emphasised the importance of designing for people, their feelings, and prioritising human perception of spaces over Euclidian geometry. (Moore, 1978)

see print copy for image

▲Fig 2.73. Athfield house and offices, Kandallah.

see print copy for image

▲Fig 2.74. Buck House Te Mata Estate, Hawke's Bay. Ian Athfield, 1980.

see print copy for image

▲Fig 2.75. Johnson House Roger Walker, Kandallah.

This attitude to postmodernism, mainly through Walker and Athfield, defined New Zealand's understanding of complex architecture. David Kernohan sites the audacious work of Walker and Athfield as one of the major factors in the development of an endemic New Zealand/ Wellington domestic style (Kernohan, 1989). Like Moore, Athfield and Walker used aggregated forms to create site responsive and spatially surprising forms and journeys within the domestic projects. The genesis of these ideas was also a reaction to modernism. Walker spoke of his respect for the detailing in Sir Miles Warren's modernism, but noted,

"There seemed no room for children in his buildings."
(Melling, 1985)

Dr Russell Walden wrote of Walker's Johnson House in a 1981 *Architectural Review* article, that, "the rambling house with its 48 corners clearly shows that even in this situation Walker is still strongly against the box" (Walden, 1981). The site within the block of Park Mews (a strong example of this postmodern style on a larger scale), in Hataitai was deliberately chosen for comparison between the projects.

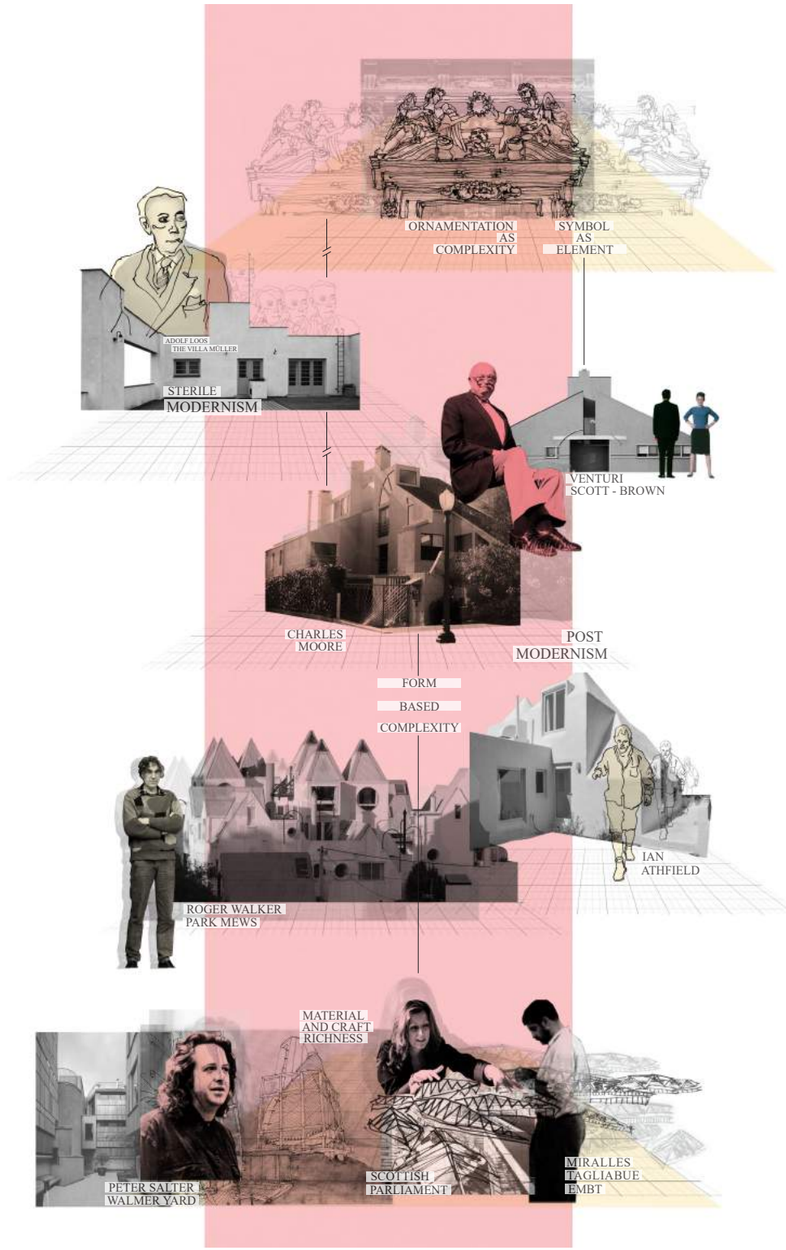
Outside of New Zealand, a contemporary version of complexity has developed to include craft and material intricacy and richness, as well as the spatial complexity. The development, exemplified by projects such as the Scottish Parliament by Miralles Tagliabue EMBT, draws on the spatial complexity discussed as well as the material intimacy being explored during post modernism and earlier by practitioners such as Alvar Aalto and other existentialists (Littlejohn, 1984).

This focus on material and craft gives the spatial nooks and moments more richness and relevance to the user, bringing the spaces the intimacy written about earlier. This is the version and thread of creating complexity in which I position my design.

A key example of this contemporary version of complexity is Peter Salter's London four-unit housing project: Walmer Yard, shown below.

see print copy for image

▲ Fig 2.76. Walmer Yard's street front conceals the complex spaces and highly crafted texture combinations within the building.



▶ Fig 2.77. A selected time line of complexity since pre-modernism ornamentation, resulting in projects rich in detail and craft such as Walmer Yard.

Context:
Richness as Ornamentation

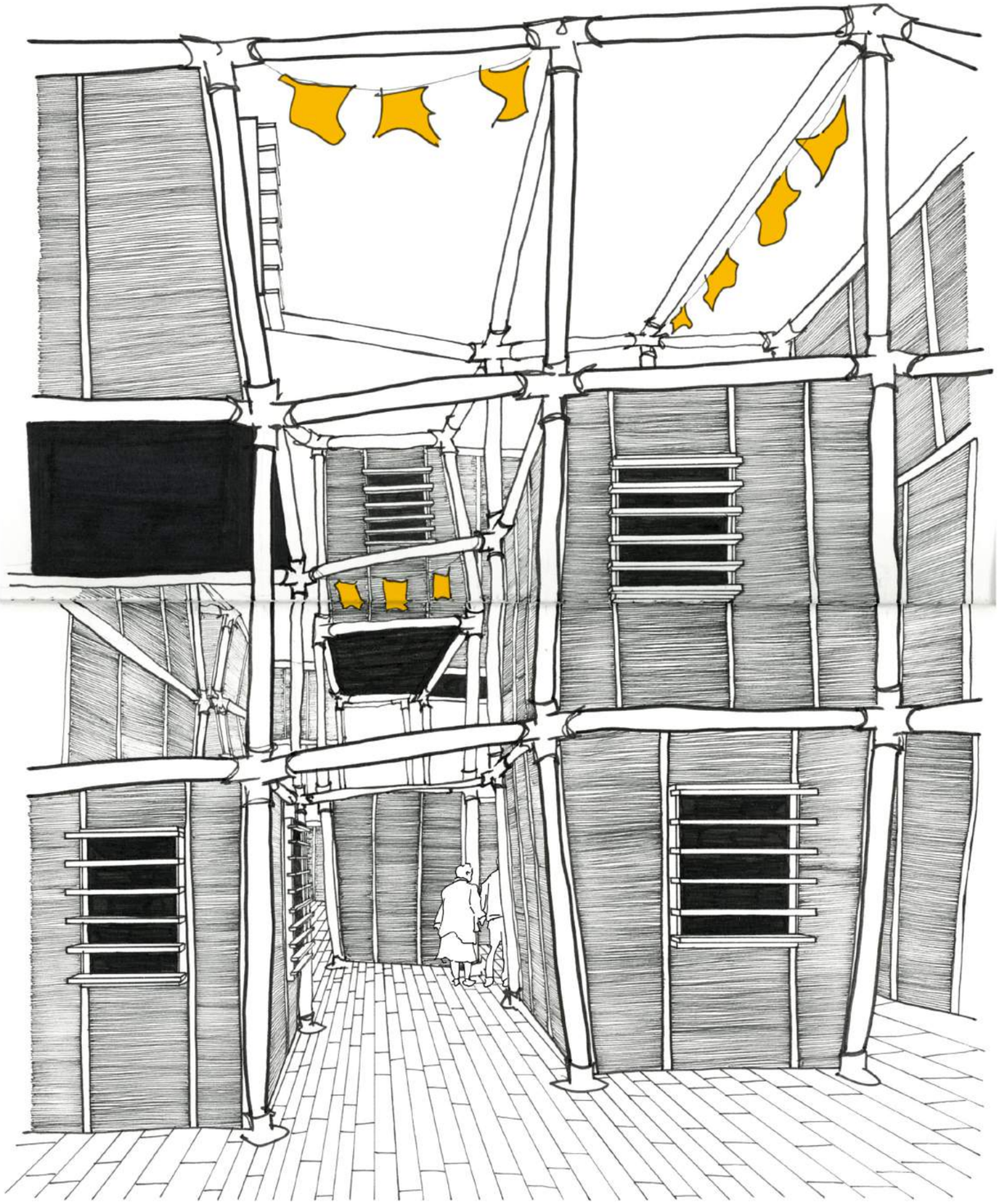
2.12

In the past ornamentation could be seen as having gone out with the modernists; Adolf Loos called it a crime after all. The what some would call, cynical inclusion of it in post modernism may have been its final nail in the coffin. However, the value of visual richness remains relevant to the human experience of space.

A contemporary version of 'complexity' plays a part in a new ornamentation. A version not reliant on application to the surface as an afterthought, but informing the form, material and craft to provide visual richness of their own. This is both in the building form as spectacle, and in the detail. Composition of the material and craft creates ornament. In its form, it is the impact on the body providing intensity. The sloping walls of my design do not add economic value, quite the opposite. However, evaluating the building holistically, these irregularities give the building its resonance for users. The intimacy of space they create is shown in fig 2.79.

In addition to the scepticism surrounding ornamentation since modernism, perception of digitally fabricated projects is that they also reject this pursuit of vibrancy. Prefabrication can conjure ideas of the generic and dull. This is the power of augmenting **both** sides of the bionic hand. The hand, aided by the efficiency of digital tools, can still pursue ornament. The digital can make ornament of itself. The node connections are ornaments within the external building form. The over all unusual building form creates ornament of the structure in itself, as well as the visual richness of material and craft details.

◀ Fig 2.78. An early cartoon for another concept showing engagement with textural richness.



▶ Fig 2.79. The sloping walls, nodes and beams as rich ornament within the site. Development sketch.

2.13 Case Study: *Walmer Yard*

Walmer Yard occupies a similar size site to my project (fig 2.80). The design is four opulent, highly crafted town houses. The project is spatially complex, creating bespoke spaces and nooks in each house (fig 2.81). Intricately detailed and crafted together is a broad palette of materials. The combination of these factors produces intimate and enriching spaces for the residents to dwell in and, as Bachelard would say, "inhabit with intensity" (Bachelard, 1957).

see print copy for image

▶ Fig 2.82. A photograph between the houses on the Walmer Yard site, showing the diversity of form, space and material.

◀ Fig 2.80. Walmer Yard overlaid on to my Hataitai site as a comparison of site size and density between the four Walmer Yard houses, the 32 units within Park Mews, and surrounding stand alone dwellings.

◀ Fig 2.81. Walmer Yard floor plans showing the spatial diversity and complexity within the building.

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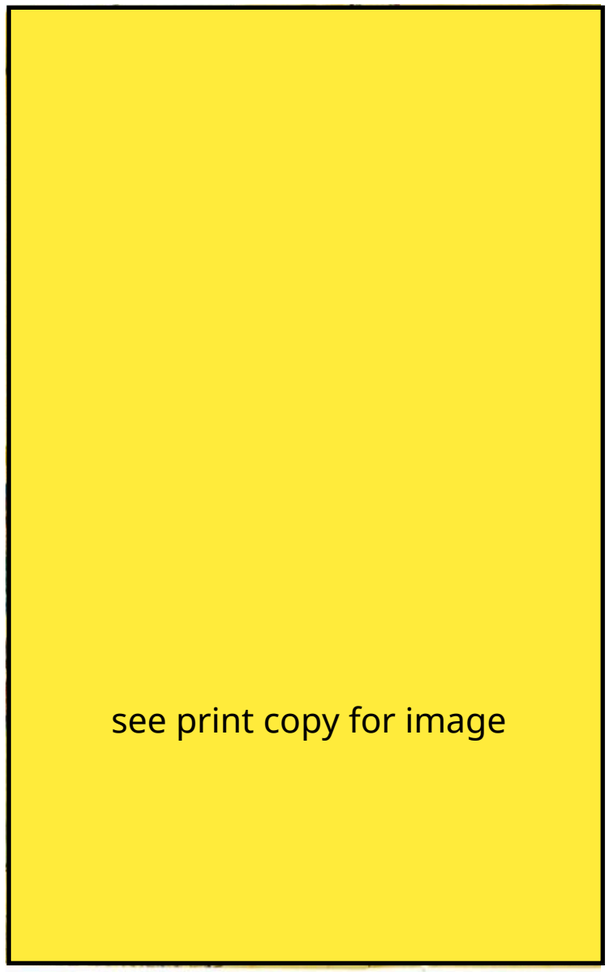
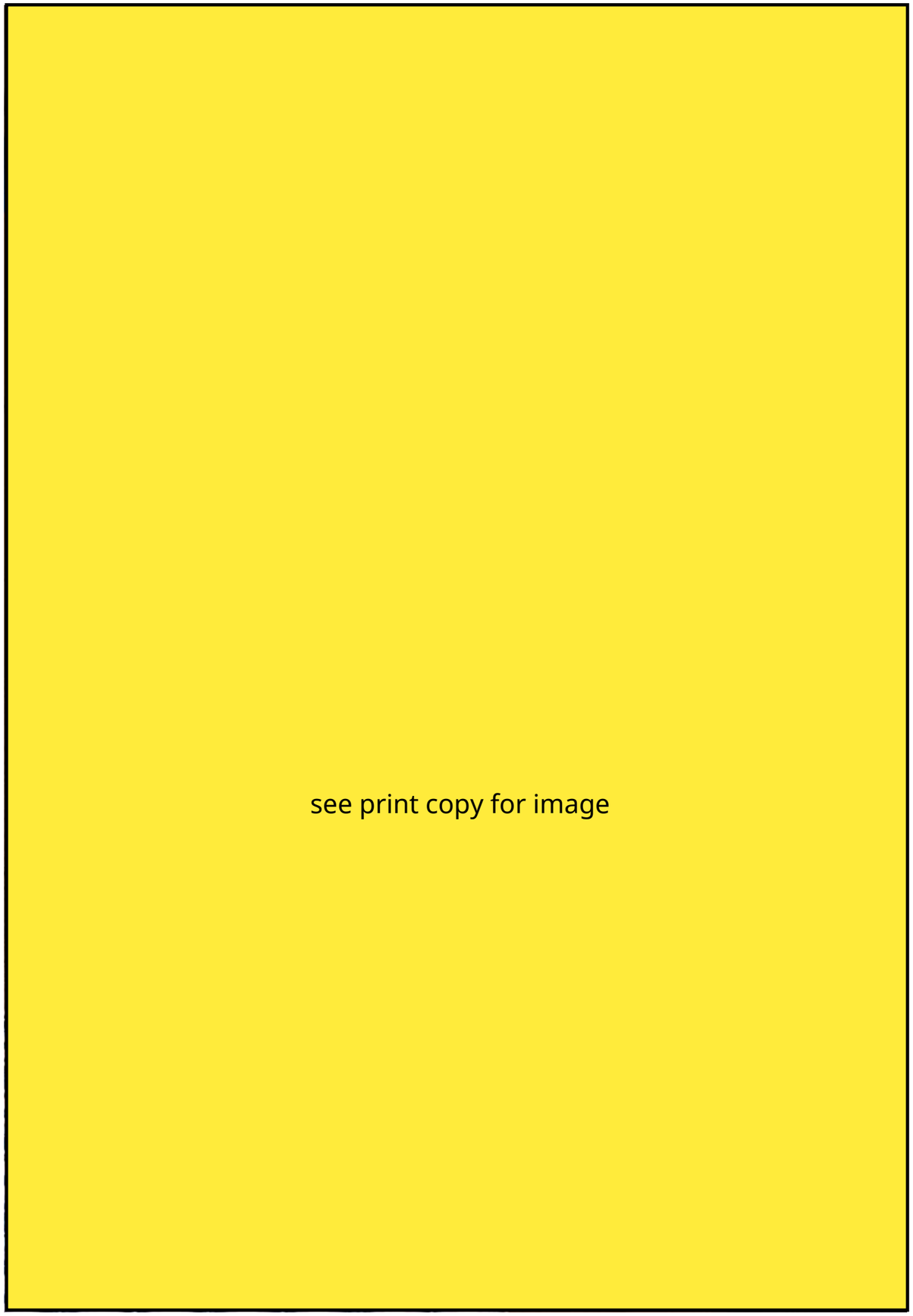


◀ Fig 2.83. Salter's rich perspective drawings conceptualised the richness of craft in constructing the materials to create tactile surface and intimate space. These drawings became drawn details which were constructed to become the rich spaces.

The origin of these spaces comes back to the thinking hand. Salter produced expressive perspective drawings, like above, to understand the human experience of the space and its craft and material. The highly detailed nature of the perspectives then led to hand drawn detailing of the varied tectonics through more axonometric and detail drawing. The bespoke nature of the drawing meant these details were bespoke and heavy on hand labour in construction. The product after ten years of labour was varied, rich, bespoke spaces both within and between the four homes, hidden behind an austere facade.

▶ Fig 2.84. Diversity of material within a Walmer Yard space.



◀ Figs 2.85- 2.88. As the ▶ complexity of the material palette is the aspect of Walmer Yard which makes it a significant precedent for this research, I collaged the material of spaces around the building. This emphasised the range and unusual and complex combinations used within each space.

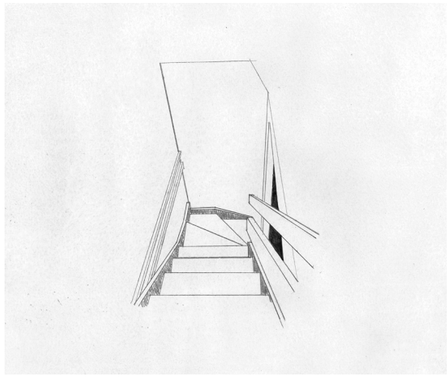
2.14

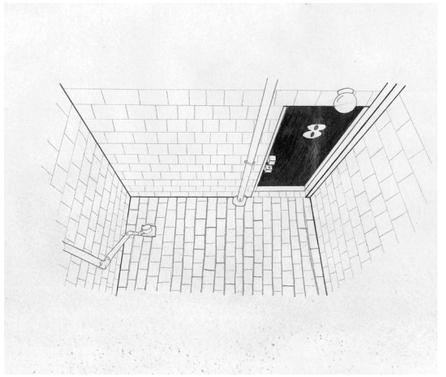
Case Study: *Park Mews*

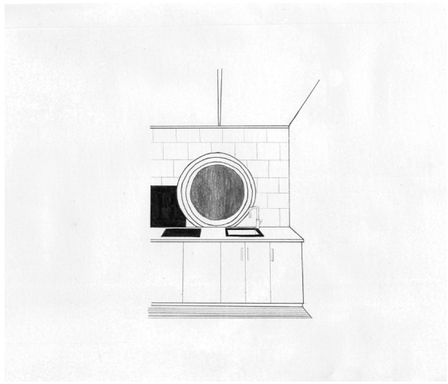
As the Hataitai example of how New Zealand understands of complex architecture, I carried out a drawn case study of moments around Park Mews (figs 2.90 -2.100).

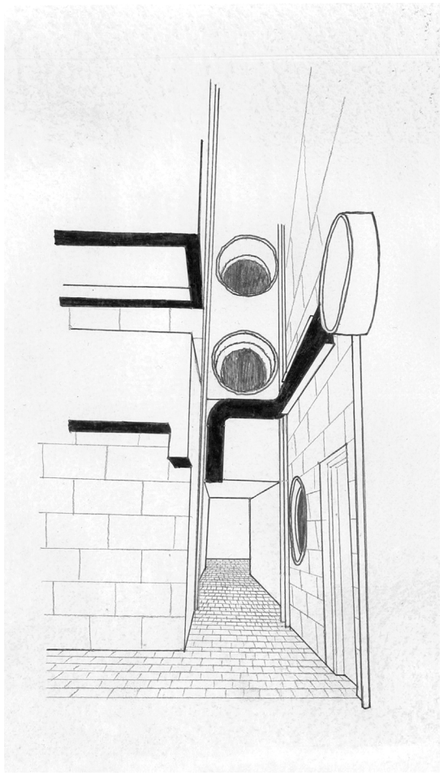
This study and visit confirmed the change in priorities when creating complex architecture across time. While Park Mews is spatially intricate full of surprise and variation, it is largely mono-textural. White painted concrete block dominates both interior and in between spaces. This sits in contrast to Peter Salter's work, which is willingly diverse in material and craft.

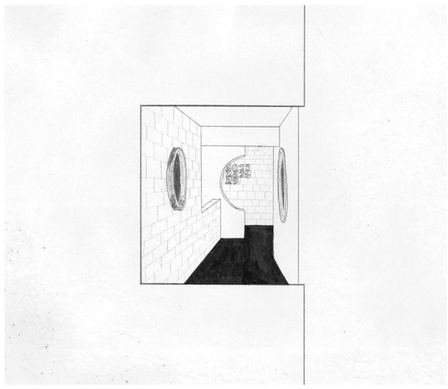
◀ Fig 2.89. The view to Hataitai out of a famous Park Mews port hole.



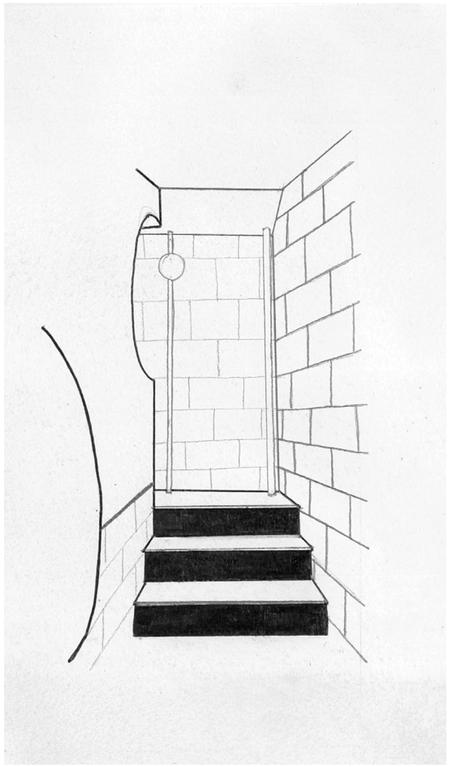


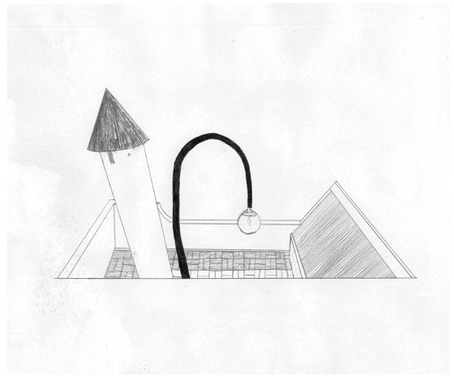


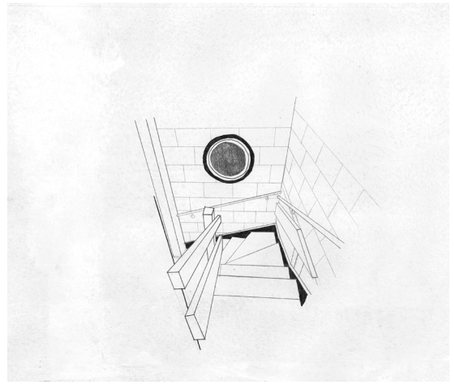


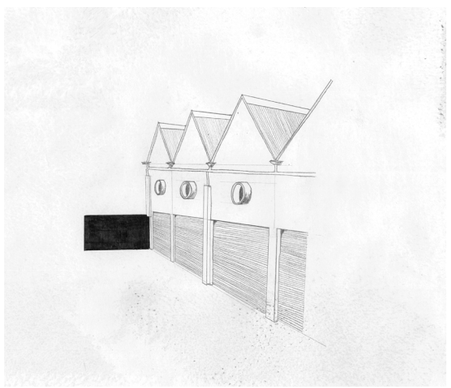


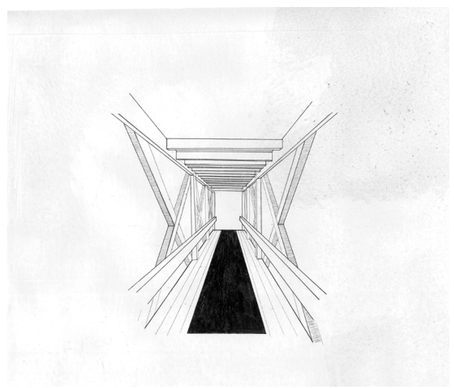
▶ Figs 2.90- 2.100.
▼ (Continued next two pages)
As the spatial complexity is the aspect of Park Mews which makes it a significant precedent for this research, I did a series of snapshot drawings of intimate spaces within the building. The range of these showed the formal complexity achieved by just 90 degree moves in form.

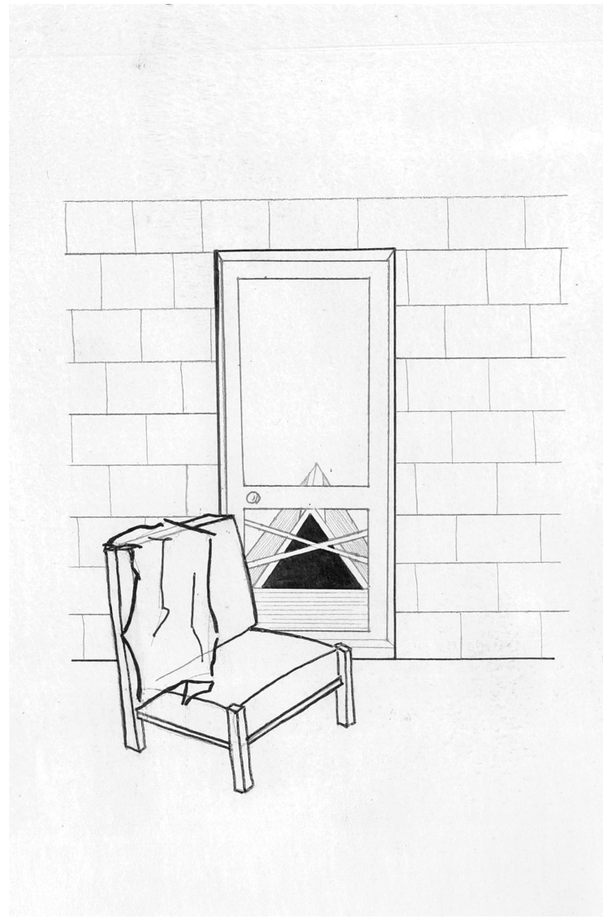












In relation to my designing, the efficiency of the single material interested me, and the system of building to generate complexity that it provided. Roger Walker on the tour talked about blocks being as cheap to lay at 90 degrees as they were in a straight line, thus creating complex arrangements was easier. However, the monotony of the block and its cold nature did not spark material intimacy in the spaces designed to dwell. These luxuries came through the soft furnishings and wall coverings, not the architecture.

Process:
The User in the Design

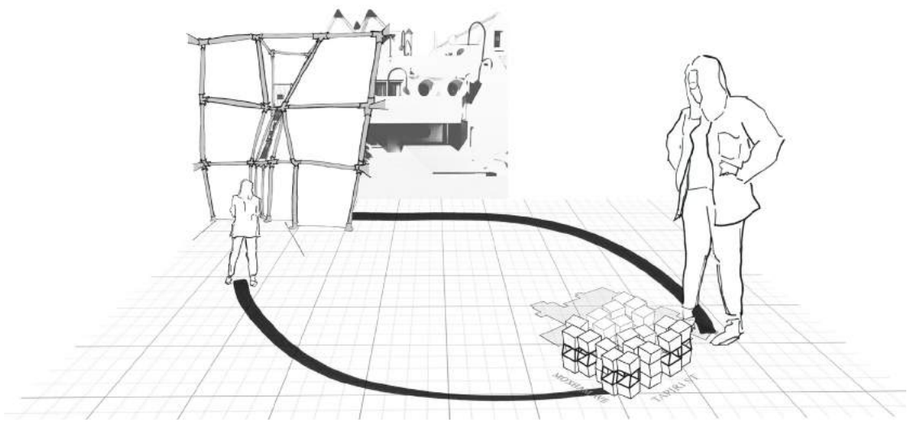
2.15

Similarly, to Moore, Athfield, Walker and Salter's focus on human understanding, personal feeling in space and moments was a driving factor in establishing the intimacy within and between the buildings. Prioritising these experiences was done by orbiting between drawing those moments as snapshot cartoons (fig 2.103). Then stepping out and holistically looking at the scheme, by aggregating these moments together. This orbiting design method is diagrammed in fig 2.101.

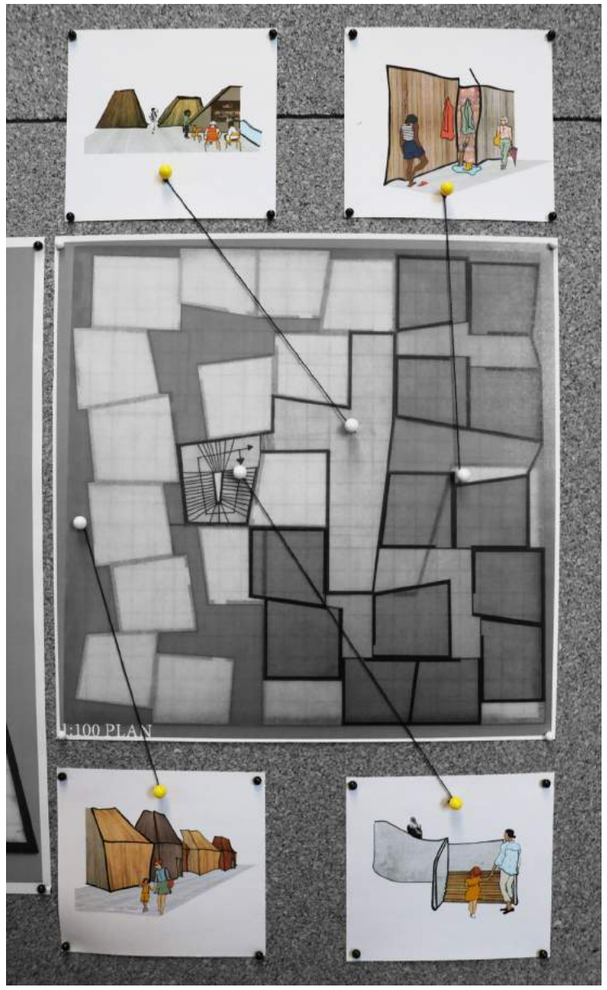
The thinking hand is inherently a tool of, and part of, the body. I used the brain and body's subconscious understanding of space and translated this into worlds on the page.

This went through a few iterations (refer page 48). The first key breakthrough was the development of a pod form; this related to the development of closeness, privacy and intimacy. This initiated as part of a scheme from an earlier site, but carried over to the Park Mews site as a starting point for bringing these snapshot cartoons together.

On the final site, it became a series of a repeating shape with the irregular angles in plan and section to create these nooks for dwelling in and intense spaces between the buildings (fig 2.102). With walls sloping away or over you, and voids for balconies and light.

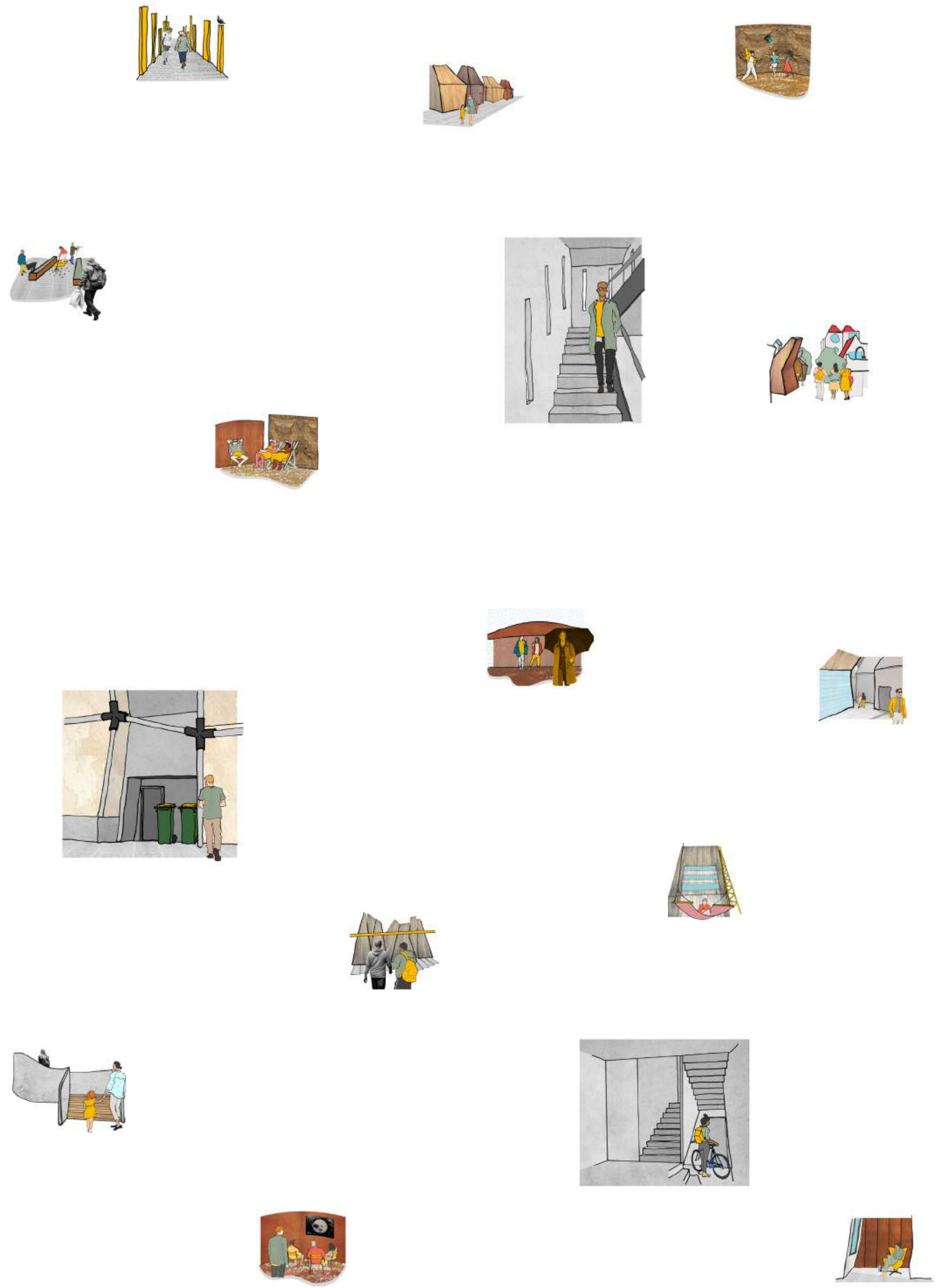


▲ Fig 2.101. Designing through a human perspective within the site and seeing the scheme as a whole allowed me to understand the human experience.

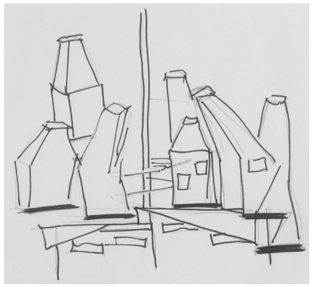


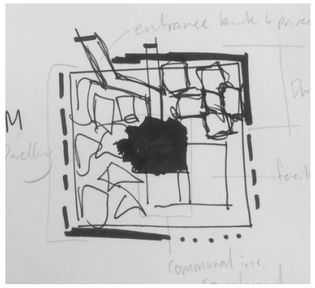
▲ Fig 2.102. Each cartoon is a perspective snapshot of a moment within the plan. Or a way of testing an idea for development of the scheme.

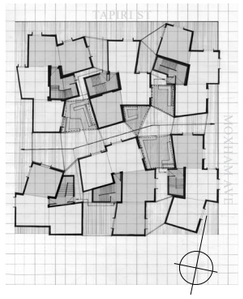
▼ Fig 2.103. (Next page) The cartoons were a way of working that spanned the year. The array of cartoons shown here reflect that. Many do not relate to the final scheme, but reflect moments other concepts or development ideas along the way.

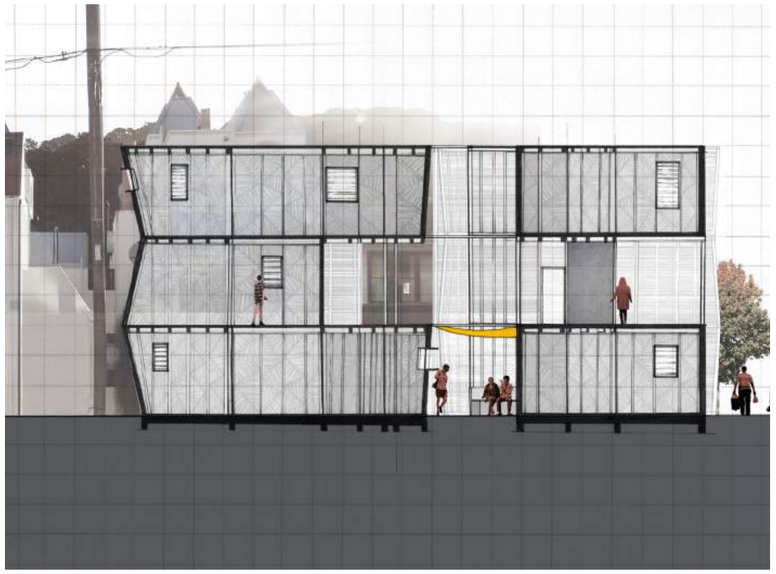


◀ Fig 2.104. The snap shot views around the site drawn in response to overall scheme design and also to inspire development of the overall scheme as possible moments in the building.

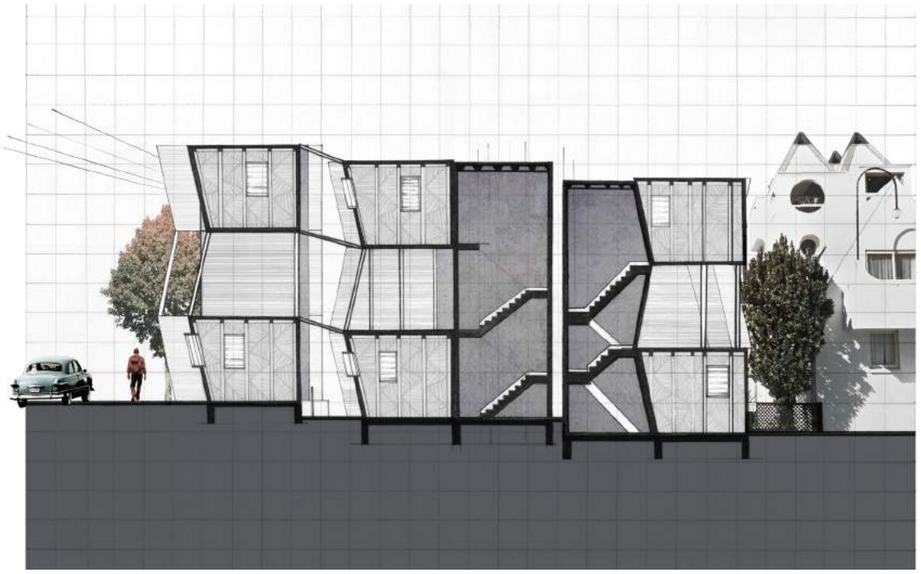


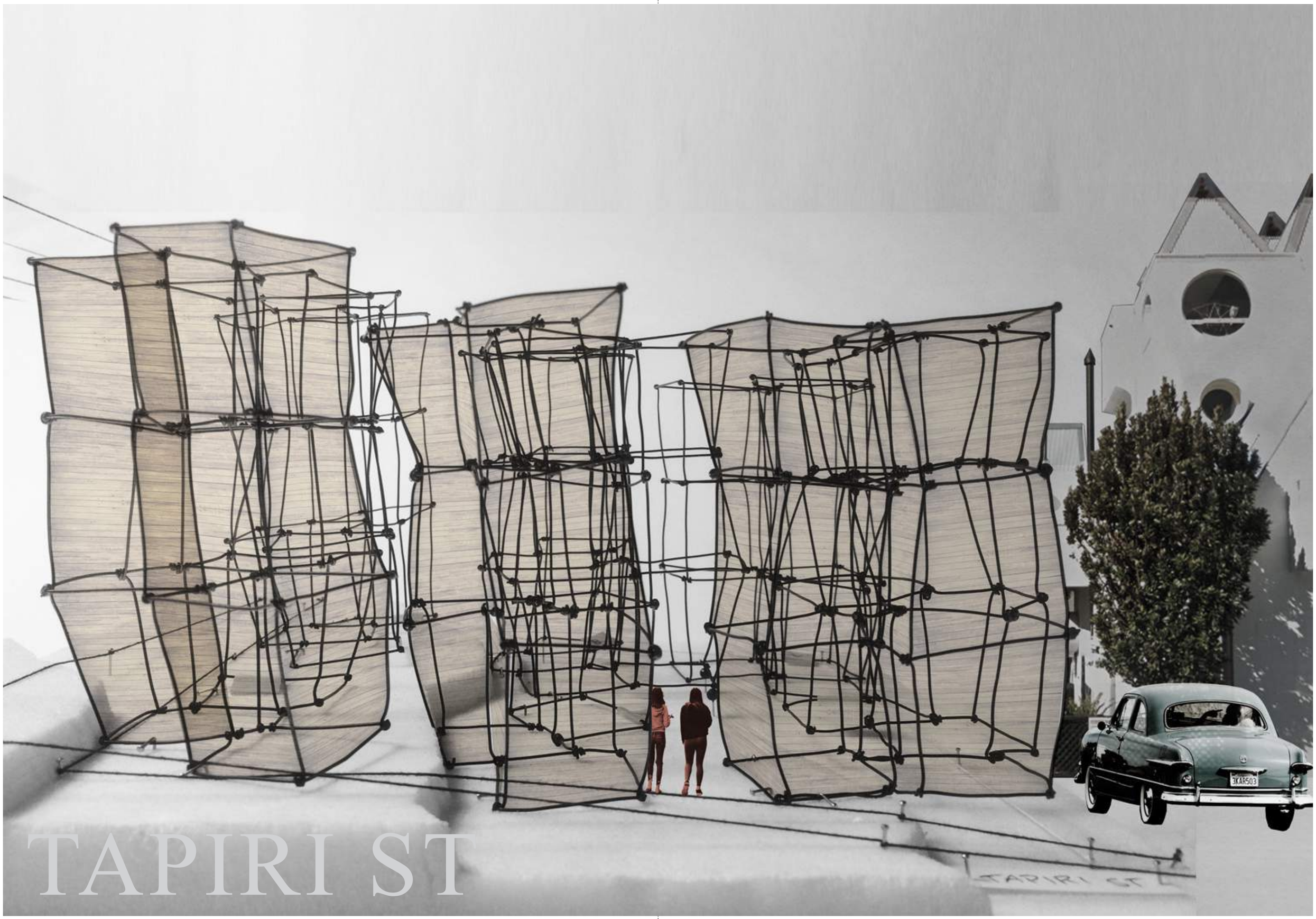






▲ Figs 2.105- 2.122. These ◀ images (continued next ▶ page), in conjunction with other design methods previously discussed, are thinking hand drawings and models generated as concept and development drawings as an aggregation of cartoon snapshot spaces, or drawn to develop these spaces in existing concepts. This was part of orbiting between designing from the 'human' view and looking at the scheme as a whole.

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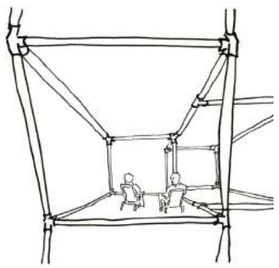
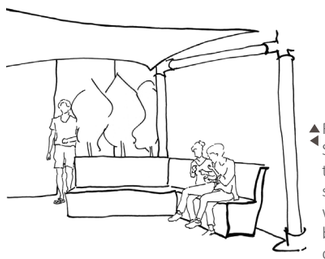


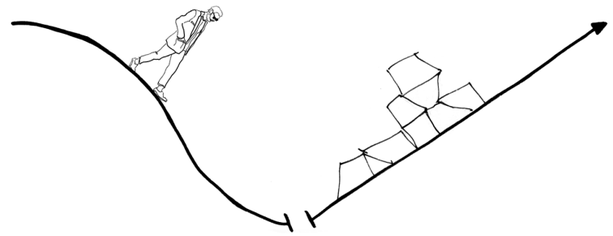


▲Figs 2.123- 2.129.
◀Snapshots of spaces around the site. And the developing scheme of which spaces within were both inspired by and inspiring these drawings.

Process:
Breakthrough in Drawing

2.16

The process of perspective cartooning was the context of a breakthrough in the design research process. Throughout the designing, I drew more than 30 of the snapshots. Although a core part of the process, their relevance waned over the year, but a change in perception gave revival.



▲Fig 2.130. The usefulness of the cartoons returned after a change in perception

Peter Cook's conceptual cartoons for personal interactions he wanted to accommodate in the Gold Coast Bond University design firstly inspired the technique (Cook, 2016). Initially, along this vein, I called the drawings 'vibe cartoons,' as I was using them to express human understanding of the spaces, the intimacy, the hygge… the vibe.

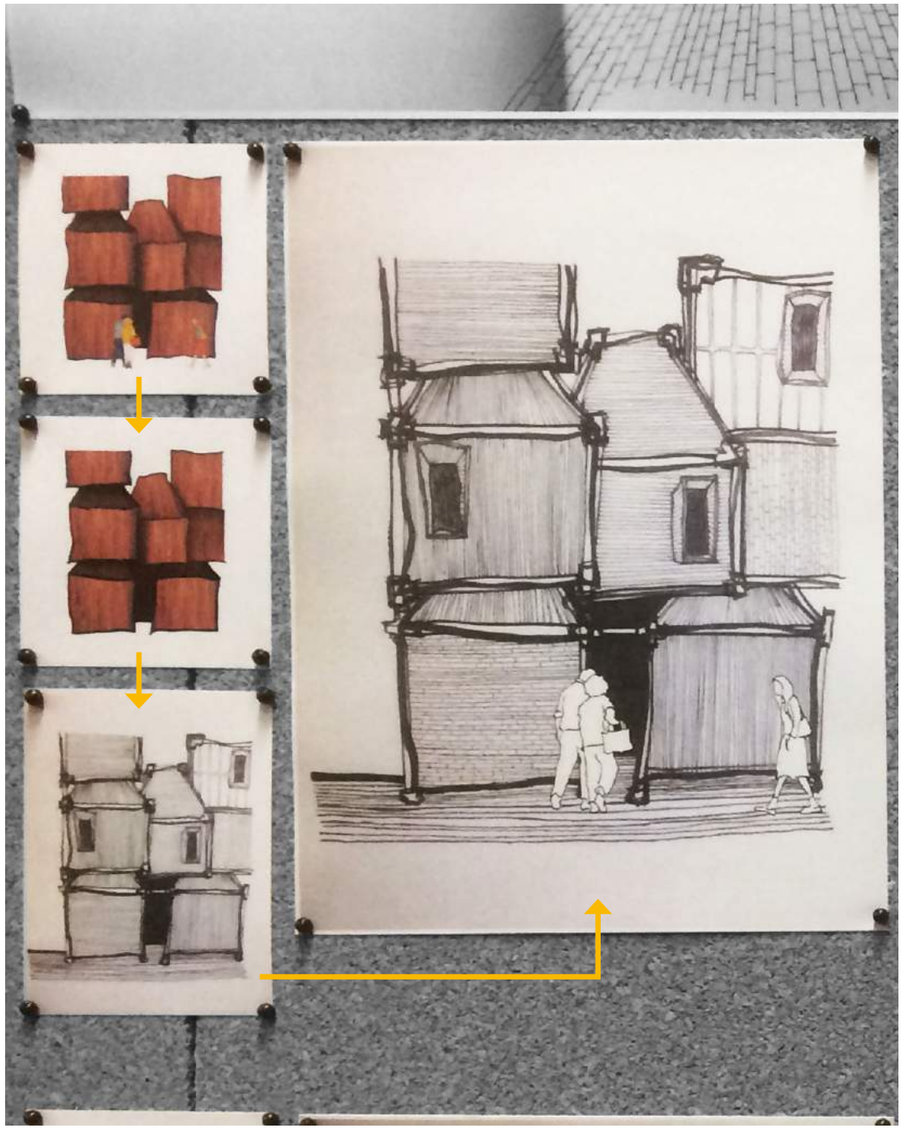
While this had value in conceptual stages, prioritising people over the architectural detail was allowing me to linger on the symptom of intimate, complex design not the cause.

I was stagnant in facilitating in the vibes I wanted to create as the designer. I was using people to express hygge and intimacy in drawings not architecture.

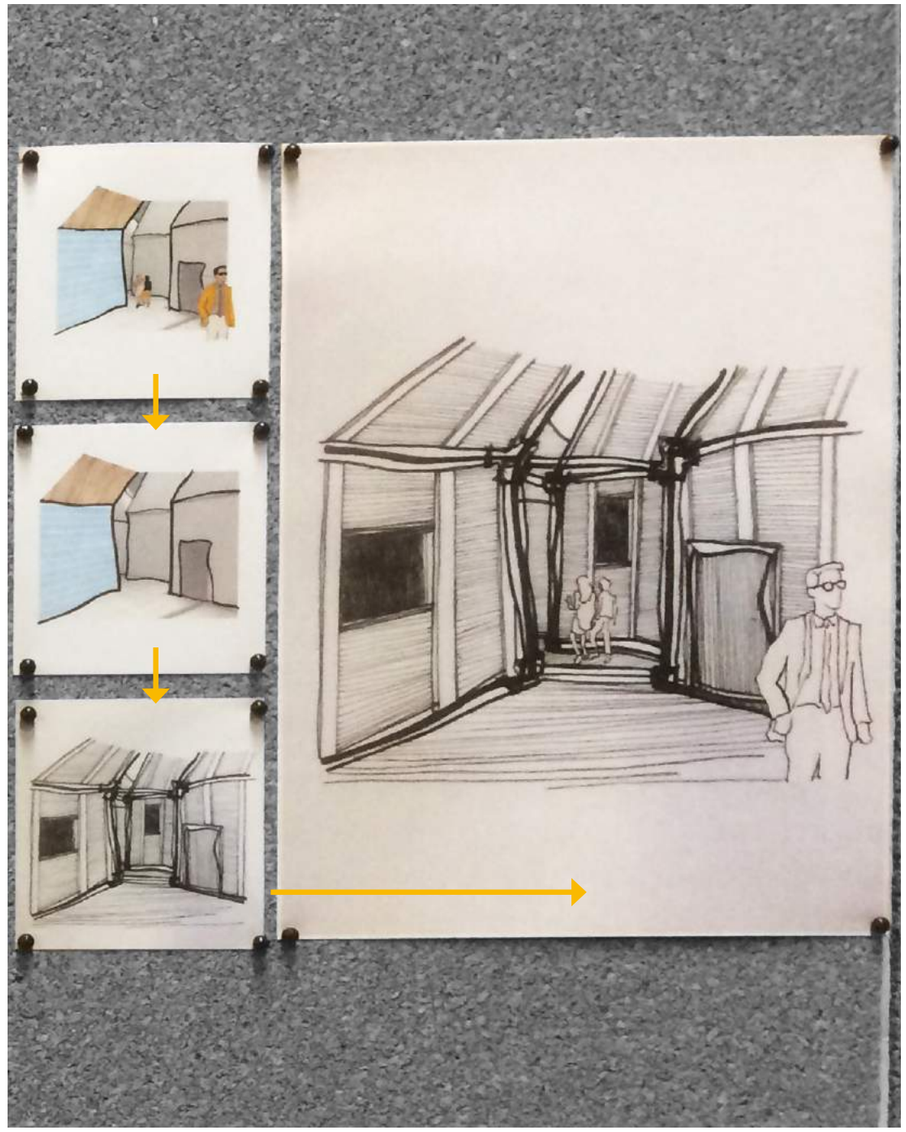
The breakthrough came when I deliberately reversed the focus. I redrew existing drawings without the figures, and instead drew over them with ideas of detail, material and craft in each moment. The change in technique related to change in my perception of the design from a social problem to a material problem. A realisation that as a designer the material, craft and detail is what I have control over to generate interaction between users and the building. The change in the use of the thinking hand made it more efficient in processing the architecture.

▲Fig 2.131. A cartoon of the building form, focussing on the human in the foreground.

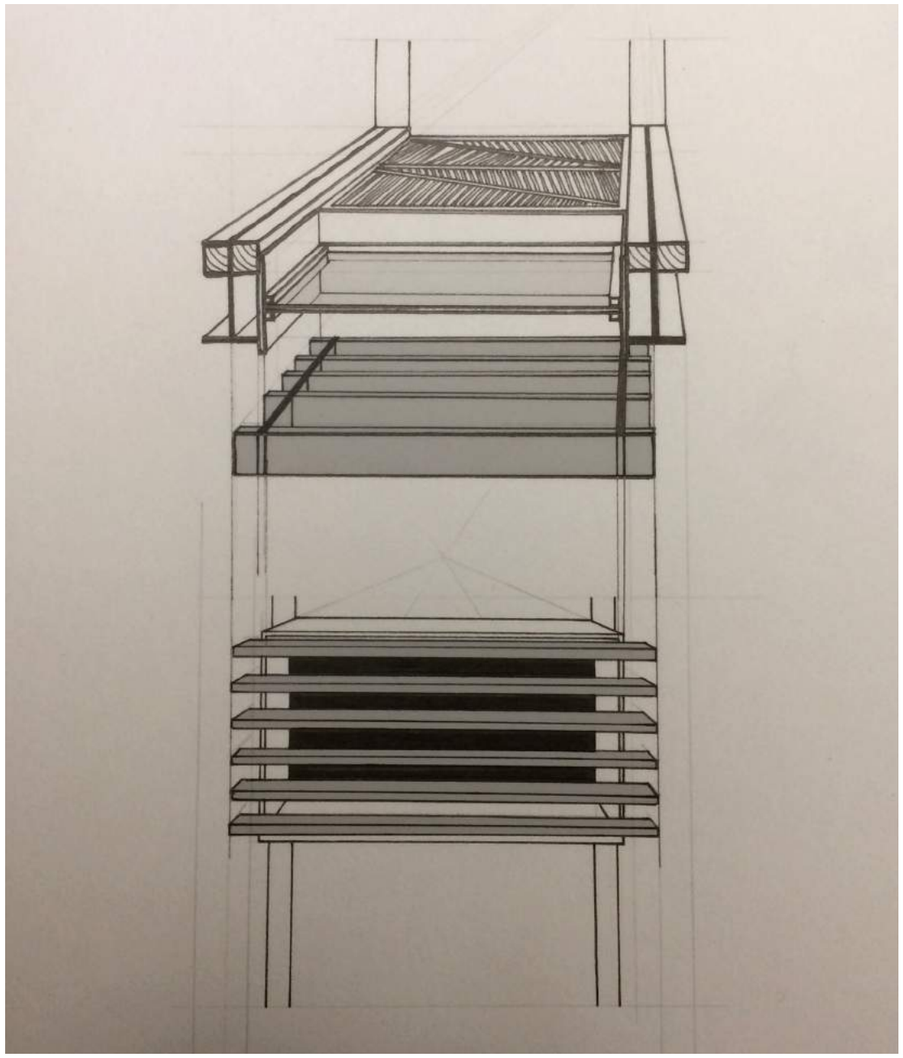
▶Fig 2.132. The redrawn cartoon with concepts of material and window elements, without the distraction of a person. The design is made to seem inhabitable through the architecture not the person.

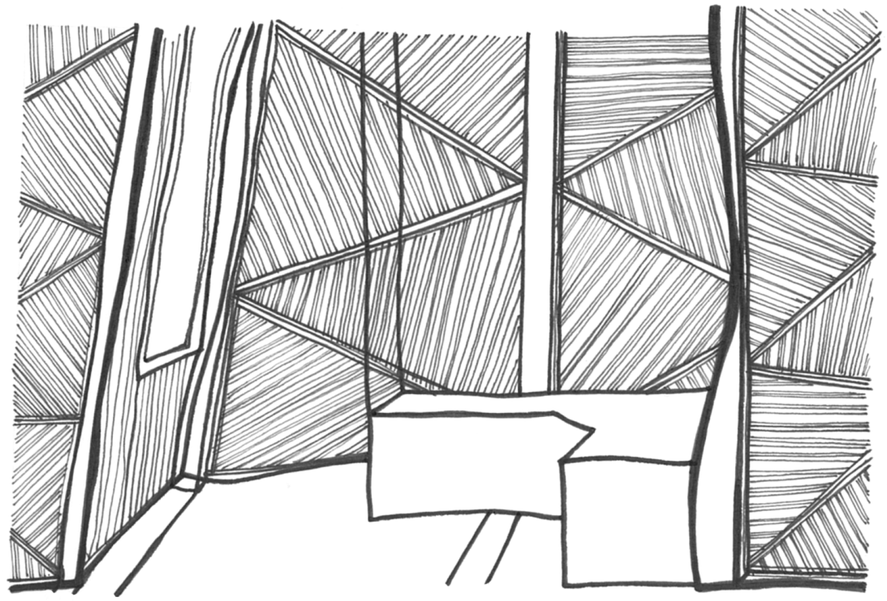


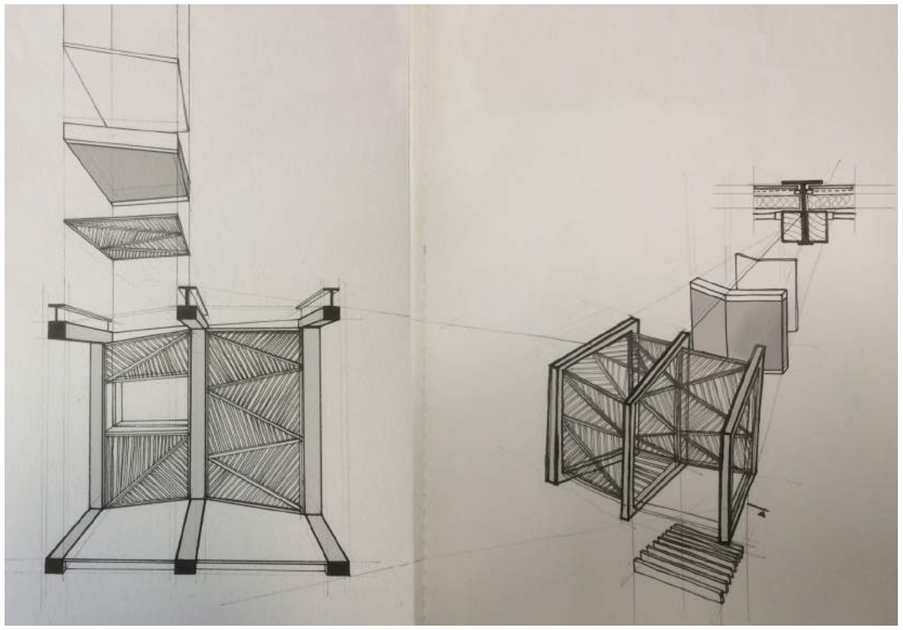
▲ Fig 2.133. Photoshop was used to remove the people from old cartoons. These were then redrawn with ideas for material and tectonic of the building.



▲ Fig 2.134. Once the drawings have been developed to push the architecture forwards the people could easily be digitally slotted back in. The contrast between the final and original drawings shows the value the change in perception gave to my design process.







▲Figs 2.135- 2.137. Development of material, craft and tectonic through the snapshot
▶drawing led to development of these elements through detail drawing. I designed a rib system to enclose cladding, insulation and interior linings- the bamboo panels. These were refined through digital modelling to a lightness that puts all structural weight on the exoskeleton Through drawing and later digital modelling I developed the detailing of the box windows within the rib system.

2.17

Context:
Labour in Construction

Peter Salter wrote of his work on Walmer Yard, that,

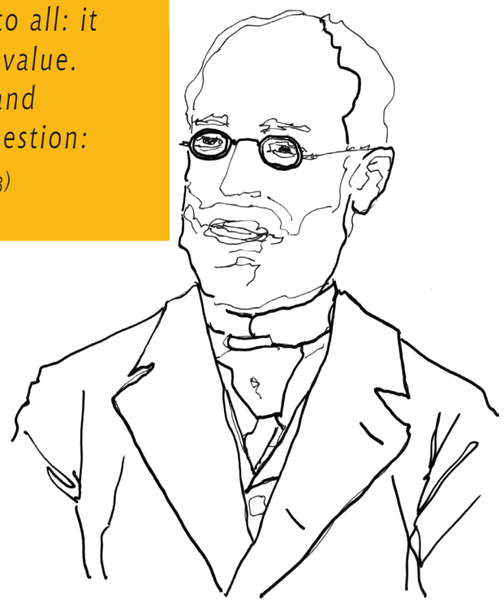
"Bespoke architecture is synonymous with invention of detail," and that when this invention is constrained, "What is left of the bespoke is probably only form." (Sheil, 2012)

In Walmer Yard, in full invention mode, he developed an intensely bespoke version of architecture generated and built through careful handcraft. This produced rich intricate spaces and moments for the inhabitants (page 108). However, it also took more than ten laborious years to design and build. This is a means only possible at the top tier of housing. A tier in which Walmer Yard's wealthy London suburb of Kensington, and ornate design, exists.

This method for generating richness within a home is unsustainable for middle-of-the-curve housing. However, changing methods of construction in the digital realm can bring hope to the idea of a more holistic focus in ordinary house building, to bring intimacy and richness into the experience of an 'ordinary' home.

When evaluating the state of the city and its preoccupation with the economy, philosopher Georg Simmel wrote,

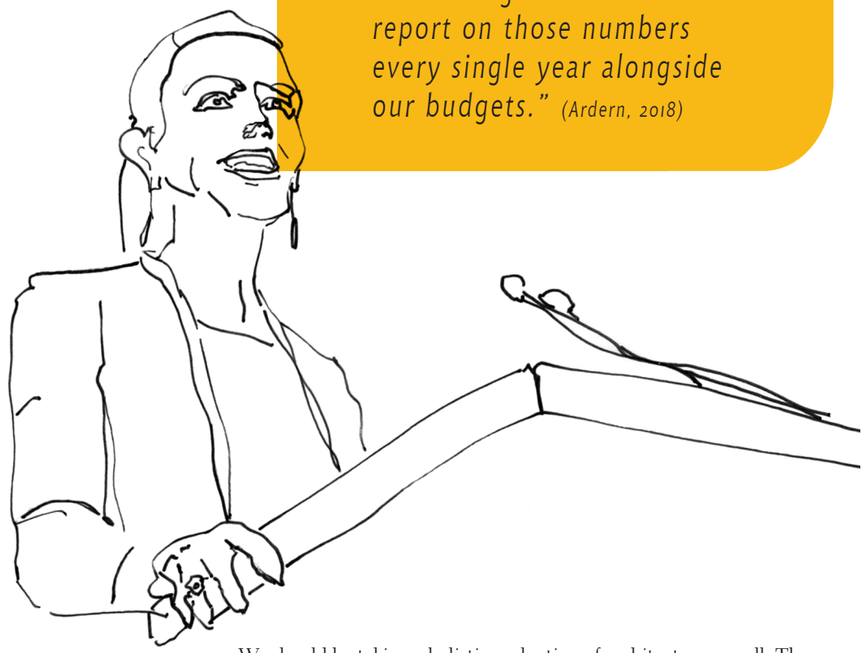
"Money is concerned only with what is common to all: it asks for the exchange value. It reduces all quality and individuality to the question: How much?" (Simmel, 1903)



The focus on the economy instead of human centred outcomes in design has led to extremes of banal, regular architecture. Alternatively, unsustainable levels of labour, danger, or time for construction workers.

Jacinda Ardern stood up at the United Nations and stated that our country was no longer going to evaluate ourselves through simply the economy, but instead holistically.

"We can measure material deprivation, and we can measure poverty, and so we will. And not only that, we are making it law that we report on those numbers every single year alongside our budgets." (Ardern, 2018)



We should be taking a holistic evaluation of architecture as well. The user experience and construction worker experience should be as important as economic savings in development of housing.

◂ Fig 2.138. Labour in construction collage.

Architects have always had an awareness of their influence over the labour occurring on construction sites. Peggy Deamer writes that architecture students protesting in 1968 chanted, “three deaths a day on the construction site” (Deamer, 2015). Worker health and safety on projects in the United Arab Emirates attached to big names in architecture, such as Frank Gehry have recently highlighted this.

Although the scale of building and level of control a designer has on the construction site of these examples overseas is different to residential construction in New Zealand, the complexity of my design means on site construction simply from a set of drawings would be confusing, time consuming, and dangerous. The geometric certainty of angles and sizes that digital fabrication gives can alleviate this.

Using digital fabrication alongside handcraft allows each to bring their own strength to making the construction and final building better for users and contractors. Advancement of digital tools give the opportunity to mitigate dangers of construction through more controlled fabrication methods. However, this does not need to be utilised universally across the construction. The richness of handcraft can remain to generate **material** complexity and intimacy in spaces requiring engagement and tactility for the user. The efficiency of digital fabrication to make bespoke connections and angles generates the **spatial** intimacy, as an element that does not require tactile engagement with dwellers, but crucially makes on site construction easier for workers.

In my design, this was the role of the metal 3D printed nodes, fabricated to the same strength as aluminium. They form the connection points to make the steel exoskeleton angled and irregular. This eases construction of the rest of the building envelope attached to it. From the fundamental steel exoskeleton, it becomes a logical build despite the complex form. Consequently, the envelope, particularly the handcrafted bamboo linings in living spaces, can fill its role generating the intimacy of the building. Intimacy also comes through the angles in plan and section facilitated by the nodes, which create nooks and moments within and between the homes.

Although the nooks are time consuming to print and sort, they convert the labour that would be hazardous, spent up high measuring complicated angles and doing dangerous welding. It becomes computer modelling, printer overseeing and off site refining of the joints. Thus, creating a complex form through simpler, safer labour.

Process:
Labour in Design

2.18

Deamer also writes about the high levels of labour involved in a design process. Anecdotal evidence in both study and practice confirms this. Deamer derides the attitude of 'architecture as a calling not a career,'

"How could architecture have become so completely deaf to the labor discourse that it could so unselfconsciously subscribe to the honor of labor exploitation?" (Deamer, 2015)

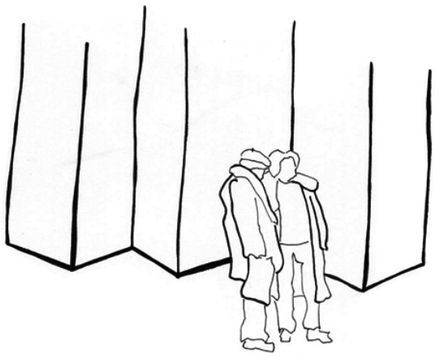
This especially resonated with my own design process, due to the time-consuming nature of hand drawing.

Within my process for this design, iterative development drawings became an opportunity to augment the labour of drawing with digital tools.

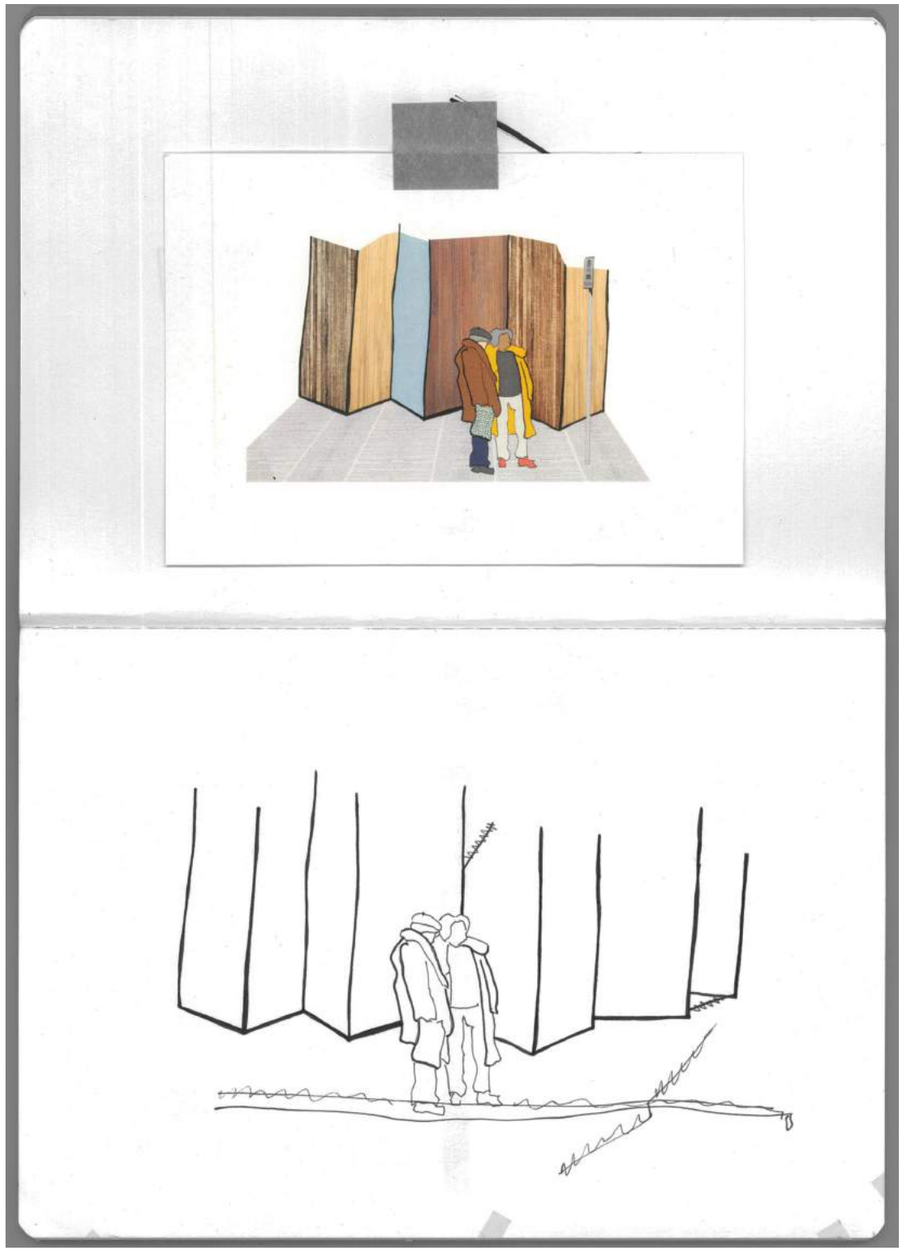
As previously written (page 74), I saved time in development drawings by using screenshots of a wire frame, parametric model as a base to trace over with more detailed hand drawings.

Photoshop as a digital tool also augmented the hand drawing to decrease labour and increase their merit in the design process. I used digital application of colour and texture for testing material on all of the cartoon drawings. This was less time consuming than drawing, and allowed accurate understanding of some materials when this was a relevant to what I was trying to test. Digital editing of mistakes, gave me confidence in drawing, which resulted in faster drawing. Many drawings I would have restarted, if I did not edit out slips of the pen or changing design decisions (figs 2.140 - 2.141).

These processes augmented the design hand in labour, but still allowed the creative power of the thinking hand to generate ideas.



◀ Fig 2.139. The clean line version of the drawing, edited in photoshop, with no material testing.



▶ Fig 2.140. A thinking hand drawing in its edited final state: testing material, with clean lines.

▶ Fig 2.141. A thinking hand drawing in its original state. It was quickly drawn with no worry of mistakes due to confidence instilled by my ability to use digital tools to make it relevant to testing.

▲Fig 3.1. Early site sketch of a foot path in Hataitai town centre.

03. Findings

Research Findings:
Introduction

3.1

Designing this building, with the understanding of the site and the method of using both sides of the bionic hand: the thinking hand, and the digital machine, has led to five key research findings. These are:

1. The value of a process augmenting both sides of the bionic hand in the **form** of architecture.

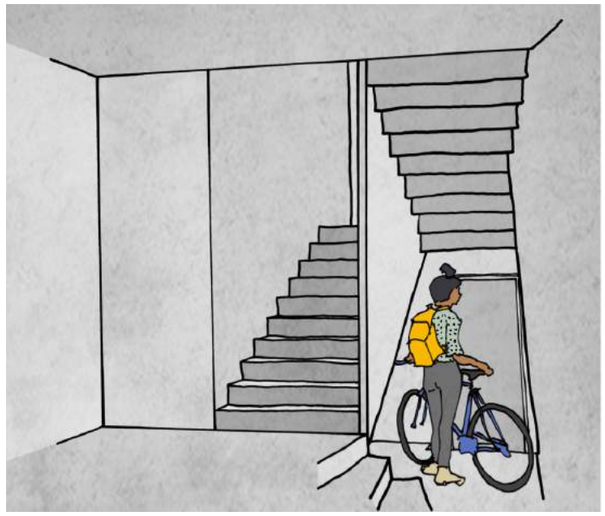
2. The value of a process augmenting both sides of the bionic hand in **formation** of architecture.

3. The integration of complex design into Hataitai and New Zealand's version of suburbia.

4. The bionic hand as a way of working, in the history of complexity in the architectural discipline.

5. Understanding my own perception of the project and the impact of this on the design process.

▲Fig 3.2. Balcony space.



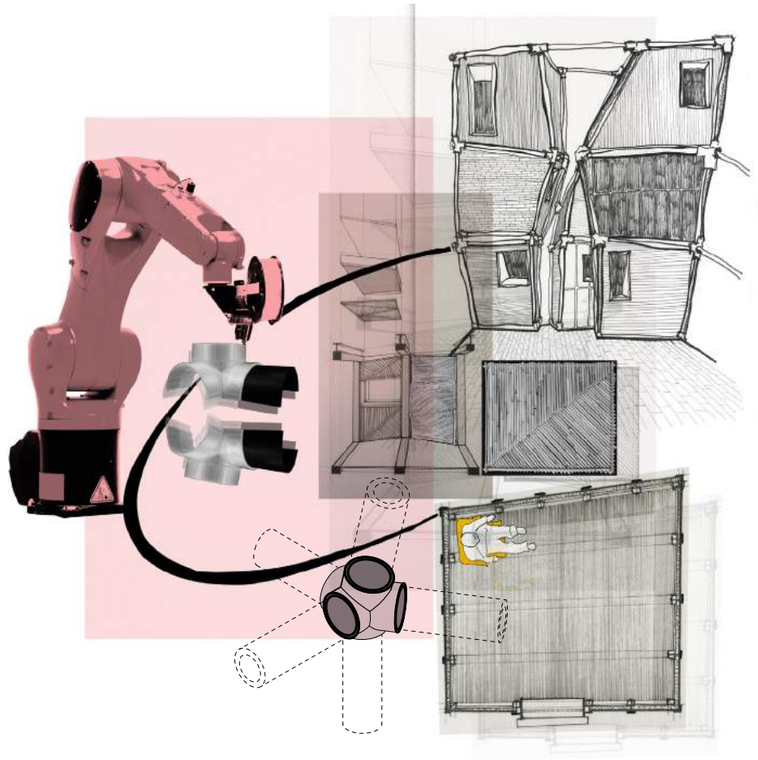
▲Fig 3.3. Storage space in the staircase entrance

Research Finding 1:
The Bionic Hand in the Form of Architecture

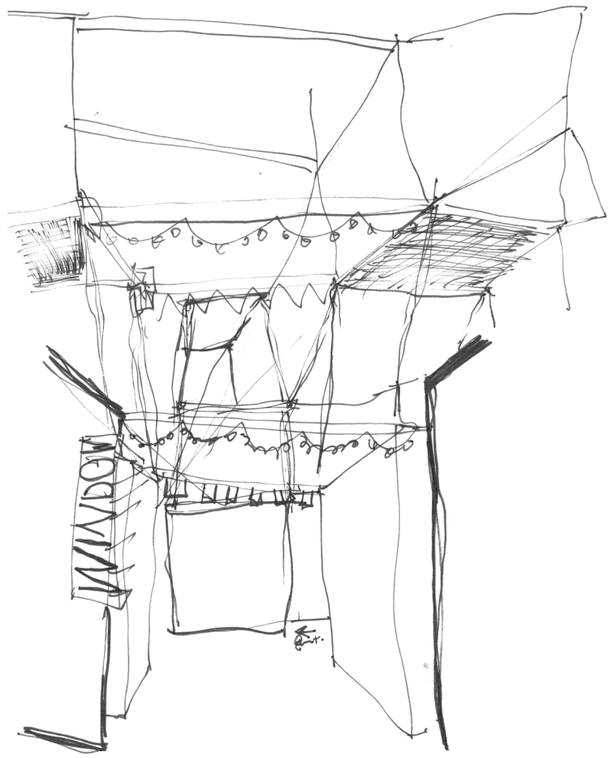
3.2

The synergy in augmenting the two sides of the bionic hand means a built form with complex richness and efficiency of construction. The strength of the bionic hand is that it provides a balance of these. Holistic evaluation of this architecture means judgement over this efficiency in money, but also the experience of those building it, and the richness for those inhabiting the final product. Common perception of digitally pre-fabricated building is chasing efficiency to the point of design banality. While richly crafted projects such as Salter's Walmer Yard or Miralles Tagliabue EMBT's Scottish Parliament are criticised for their ludicrous inefficiency in money and time. In designing through augmenting hand and digital building tools, I aimed for a balance of the two.

In my design, this came through the overall building language, hand crafted bamboo linings and the digitally fabricated node connections.



◀ Fig 3.4. Collage of the elements of both sides of the bionic hand.



▲ Fig 3.5. A thinking hand drawing experimenting with the sloping wall and structural language.

Through the process of orbiting between hand and digital, the language of the building in the sloping walls, irregular structural frame and complex planning is that of the thinking hand. I maintained this language from early conceptual drawings and their 'wonkiness.' The inherent understanding of space by brain and body means the thinking hand is the direct tool to create and express this. Our brains and bodies do not work by Euclidian geometry. Why should our homes be slaves to it? Maintaining this language through the digital / hand flip flop in the design process was deliberate to use the strengths of each side of the bionic hand. In this case, the ability for the thinking hand to produce engaging, intimate space. Within the homes, sloped walls give a surface to rest against, and irregular corners into which to crawl. Between the buildings, angled walls give closeness in circulation spaces. These were not decisions to be made in a computer programme, but through a body's understanding of what inhabiting these spaces would be like. The synergy of the bionic hand in my project was identifying the strengths of each side and applying them.

◀ Fig 3.6. An intimate, highly crafted interior dwelling space.

Creating spaces to inhabit with intensity using the thinking hand came through craft as well as spatial design. The same wonkiness that comes through in thinking hand drawing also comes through in hand-led craft. This is the place of the handcrafted bamboo panels in the building. This wonkiness gives tangible richness to interior spaces allowing users to inhabit with intensity. In living spaces closest to an inhabiting body in the homes, the rich craft gives a bespoke nature, tactility and visual richness. This brings the strength of the thinking hand to generate richness into the form of the building.

In the same way the bamboo panels bring the strengths of the hand side of the bionic hand into the form of the architecture, the 3d printed structural connections bring the strengths of the digital side. The digital tools in both the design and the construction gave efficiency to a complex project. This is the role of the nodes. They are as easy to fabricate bespoke, as they are to fabricate generically. Through computer design and metal 3d printing this accommodates the irregularity of the angles in the exoskeleton as easily as it would right angles. Thus, any angle generated by the thinking hand can become the reality. By accommodating the complex form, the nodes and the structure created by them make construction of the rest of the building, through systematic cladding and windows, and in-situ concrete floor slabs, logical for a complex building.

The node system is not perfect, due to the sorting and refining that would occur post printing. However, they do transfer the labour from precarious, awkward measuring and welding on site, to in workshop digital fabrication. It is a blue-sky proposal for the potential impact digital tools could have on making complex design easier for contractors. As Deamer asks,

> *"How can the architect think all at once material resources, manufacturing technologies, laboring bodies, the fetish of the commodity, and the production of real habitable space?"* (Deamer, 2015)

Habitable space is key to the needs of the user. However, when evaluating the impact of architecture holistically the construction process is a significant factor. Wellbeing of the workers is at the core of this. This use of the digital does not hugely reduce the work, but replaces dangerous, difficult handwork with smarter tools.

The bionic hand within the form of architecture in this process relied on identifying and using the strengths of each side. On one side, the inherent ability to generate intimacy through hand drawing and craft. On the other side, the potential for efficiency through digital fabrication.

Research Finding 2:
The Bionic Hand in the Formation of Architecture

3.3

The key finding in the design process is the synergy of the two sides of the bionic hand. The intimacy, visual richness and craft I could not have envisioned as they are without the thinking hand. Yet the project would have been laborious and unfeasible without digital tools. This conclusion came from specific breakthroughs of collaboration between the two sides of the bionic hand. These included augmenting drawings and modelling photography with photoshop, using a parametric model as a base for physical drawing, and prototyping elements of the final building.

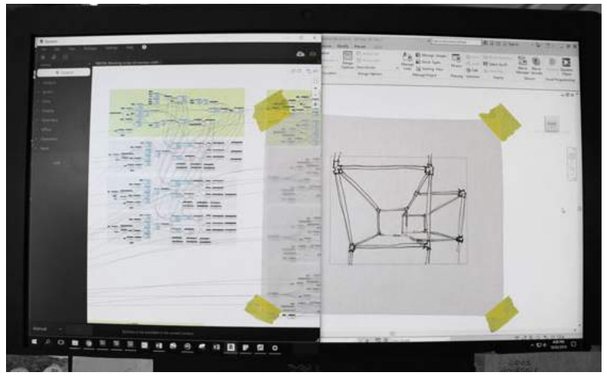
Idea generation in the designing occurred through the thinking hand; using the brain and body's inherent understanding of inhabiting space. As Pallasmaa writes,

"The pencil in the architect's hand is a bridge between the imagining mind and the image that appears on the sheet of paper." (Pallasmaa, 2017)

However, it was the inclusion of the digital side of the bionic hand, which allowed these ideas to be coherent and flow effectively. Photoshopping drawing and photos of handmade models allowed faster testing of material and intimacy and more confidence to draw quickly.

Being able to edit the drawings and photos to correct mistakes, overlay materials, or insert people relieved pressure in creating perfect images physically. This allowed me to work with a freer hand, and let ideas flow more naturally, knowing I could make them more coherent to others later. I was creating, like Aalto wrote, "Childlike compositions," (Aalto & Schildt, 1998). However, when needed I could edit them toward a broader audience. Or, edit them for a different design test. For example, taking drawings originally testing spatial intimacy, and testing material over the top. This was allowing the strength of the thinking hand to produce ideas organically, while using digital tools for their strength of creating efficiency. As I was able to draw faster with more confidence and avoid restarting drawings which went wrong.

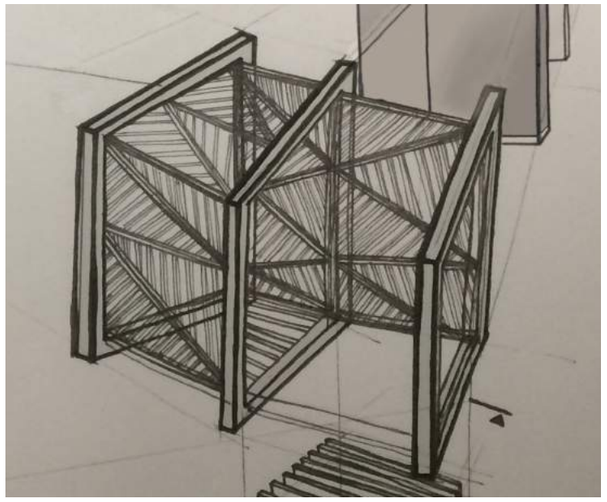
The main collaboration between the two sides of the bionic hand to generate intimate architecture efficiently was producing a parametric wire frame model to be the base for the thinking hand drawings. Various number sliders in the dynamo model script meant I could control the angles, lengths and heights of walls around the design. This allowed me to test ideas I had begun to generate through hand drawing and modelling quickly. This did not lose the direct connection of brain to pen as the testing was still through hand drawing. I took labour out of the process by not needing to set up the drawings.



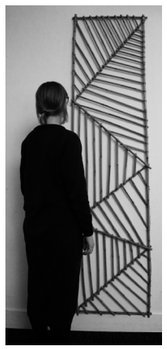
▲ Fig 3.7. The set up of tracing thinking hand drawings over a changing dynamo model.

I used prototyping in the design process on both sides of the bionic hand. I used handcrafting to test and iterate bamboo panels, and digital tools were used to test and iterate the 3d printed nodes.

Hand crafted fabrication existed just on the hand side of the bionic hand. It proved to be a process of evaluation and betterment of the drawing process that came before it. When drawing the bamboo panels as generators of richness and intimacy, the repetition of lines in small drawings had implied this without question. However, building this to full scale proved the sparsity the gaps would give as a lining. So further iteration at 1:1 allowed me to rectify this.

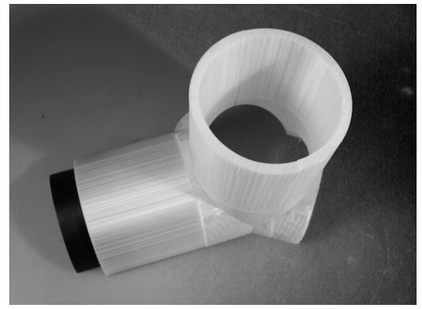


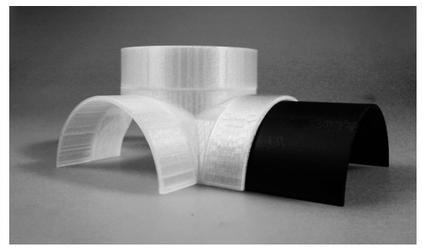
◀ Fig 3.8. The formation, designing thinking hand's version of the rich bamboo panels.



◀ Figs 3.9- 3.10. The two iterations of the form, constructing thinking hand's version of the rich bamboo panels.

▶▶ Figs 3.11- 3.12. Two of the iterations of the form, constructing digital tool version of the 3d printed nodes.





▶ Fig 3.13. The formation, designing thinking hand's version of the rich digitally fabricated 3d nodes.

Digital prototyping allowed the process of the bionic hand to come full circle in the development of the nodes. From being originally imagined by the thinking hand, to digital interpretation. The 3d printing allowed them to be understood and evaluated again by the hand.

It was easy to translate the full building form from drawing to computer model, to use as a frame for tracing over. However, translating details to realise their scale and form digitally was more challenging. Especially the nodes as they are so inherently three-dimensional. Understanding them as a two-dimensional image on a screen or even as a drawing was not enough. 3d printing as a tool meant it was as easy to generate the forms at 1:1 as at any other scale. So I could evaluate against the initial drawings to find scale and form of the same subtlety and relationship to the rest of the building and users. The bionic hand worked together according to its strengths. The hand's natural understanding of inhabitation, scale and form, and computer modelling and fabrication as tools to enable this thoroughly and effectively.

It was synergy in the combination of the hand and digital sides of the bionic hand that produced and progressed the form and formation of my final design. The use of these sides generated the imaginary worlds and determined a way for them to bring them into being efficiently, without losing the value of the original lines on the paper.

Research Finding 3:
The Design as Part of Suburbia

3.4

As landscape mainly made up of low density, single, low-rise dwellings, Hataitai exemplifies suburbia in New Zealand.

As previously discussed, these issues go deeper. Suburbia is willing itself away from being an urban landscape at all. This is in its rejection of the street front and creating an active edge. The creation of active residential streets is key to positive densification, in bringing Hataitai towards a people focussed sub-centre for Wellington.

This problem is not just prevalent in the low density, bungalow dwellings with street facing front yards. Park Mews and this version of postmodern complexity as a group can be criticised for its addressing of the street front. While existing as an interesting object within and from afar, on its main elevation, (Moxham Avenue) Park Mews presents garages and then steps back to a car park. The site within the Park Mews block allowed me direct comparison between the two buildings for critique and improvement.

My response has been direct and linear street fronting on both Moxham Avenue and Tapiri Street. The scope of the design is to be within a densified Hataitai. While the scale of the building is large against the low-density surround, it is a starting point towards denser living around the town centre. The elevation of the houses runs directly along the footpath edge. This contrasts with Park Mews, which has no living areas on the boundary, favouring service areas on the peripheries instead. In my design, both interior house and balcony spaces on the edges will contribute towards life and activity on the streets. The grid created by the external structural system, the windows and storey heights present a human scale building. Which, as Jan Gehl promotes, is the key to an active street (Gehl, 2010).

▲ Fig 3.14. The building is a step towards greater density around Hataitai's centre.

The building language in the sloping walls, irregular planning, and variation in lengths of structural members speaks of its conception by the thinking hand. The inherent 'wobble' in conceptual sketches informed these formal decisions. The language creates the intimacy between the buildings, invading space by overhanging. Meanwhile the formalised, Euclidian face only hints at this. It differentiates between intimacy for the inhabitant, and its role in unifying a densified active street.

This is in contrast to Park Mews. In my design a focus on deliberate interruptions in conventional spatial layout, and intricacy of craft and material makes for a 'simple complexity.' Concentration is on the personal experience in these moments for the intimacy and hygge. Not complexity for the benefit of the external form, like Park Mews. As a spectacle, it is less complex. However, it is complex in ways more personal to the user. This, as stated previously, allows the form to be part of creating a better street.

Despite Park Mews, and other postmodern examples in New Zealand, irregular forms still can and must have a place in creating an engaged and deliberate street front to densify suburbia.

▲ Fig 3.15. The site plan shows the contrast between my building's proximity to the street with Park mews and the single dwellings.

Research Finding 4:
The Design in the Discipline

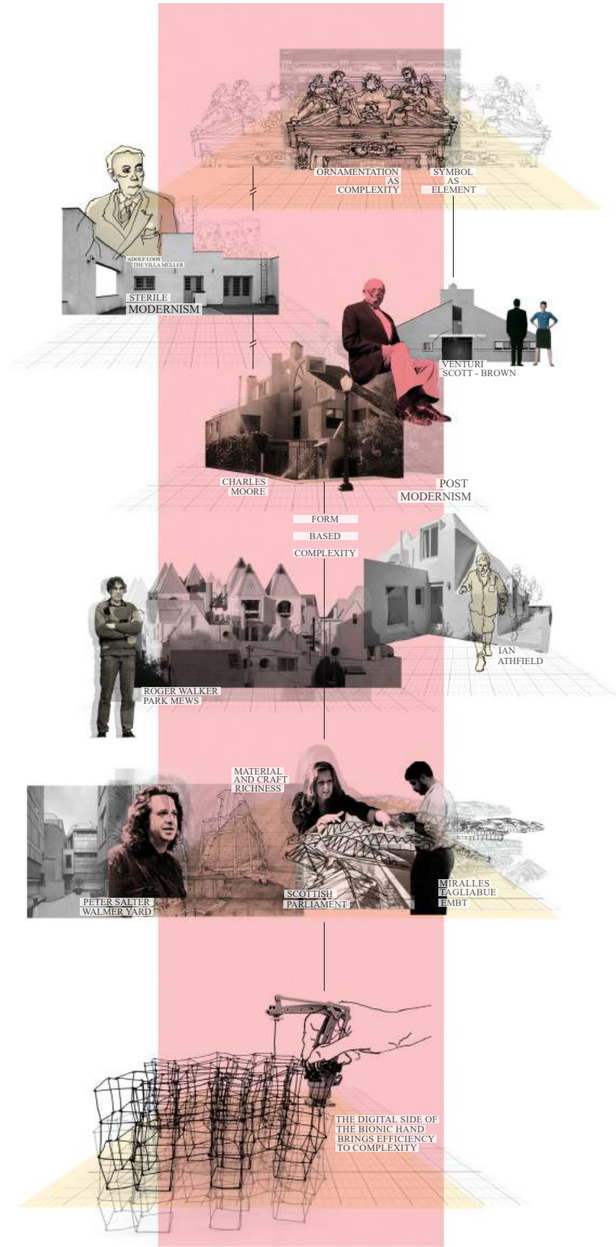
3.5

Direct comparison to Park Mews, as previously written about, also allows for the critical reflection of the work's position within the discipline. Park Mews provides an example of New Zealand's current understanding and relationship with the ideas of 'complexity' and 'irregularity' in architecture.

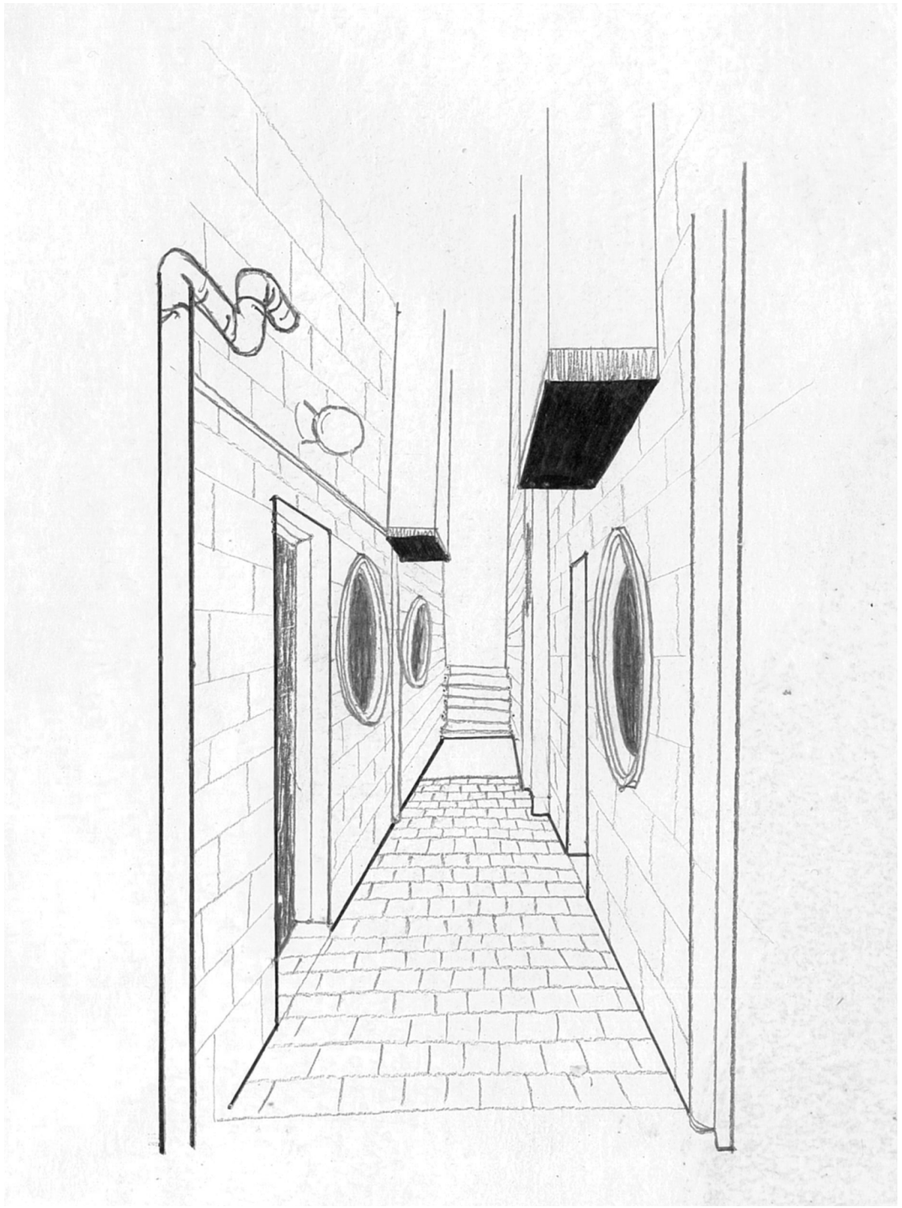
▲ Fig 3.16. Example of complexity generated through the thinking hand.

After critical reflection on early drawings, I identified a natural tendency in my drawing towards the contemporary version of complexity. That is, material and craft rich complexity focussed on the experience of the dweller in the building. Using complex design to create intimate, tactile spaces for dwelling and moving through. This is the version of complexity exemplified by practitioners such as Salter in Walmer Yard, and Miralles Tagliabue EMBT in the Scottish Parliament. It is at the contemporary end of the historic thread of complexity exemplified in New Zealand by post modernists in formal complexity in buildings such as Park Mews and the Athfield house and offices. Through the process of the bionic hand in both the form and formation of the architecture, I position my work at the future end of this thread in architectural history. I used two sides of the bionic hand, firstly to generate the complex and intimate spaces, while also attempting to reduce labour in both the design and construction. This is a documentation of a blue-sky design and construction process that could mitigate the restrictions high levels of labour puts on hand generated bespoke and irregular design, through digital processes in design and construction.

The digital side of the bionic hand is how I aimed to progress this contemporary version of complexity. As previously written, although Walmer Yard is a rich experience for the user, it was a laborious and time-consuming experience for both Salter as the designer and the contractors over ten years. Generating intimate, interesting spaces is attractive to me as a designer, but many contractors would have a hard time sharing this enthusiasm. Using digital fabrication in balance with high labour craft can mitigate either end of the spectrum. The building need neither be unfeasibly expensive and labourious in construction, or sterile and banal in design.



▶ Fig 3.17. The selected time line of complexity extended to include consideration of efficiency brought by a bionic hand design and construction process in complex, intimate design.

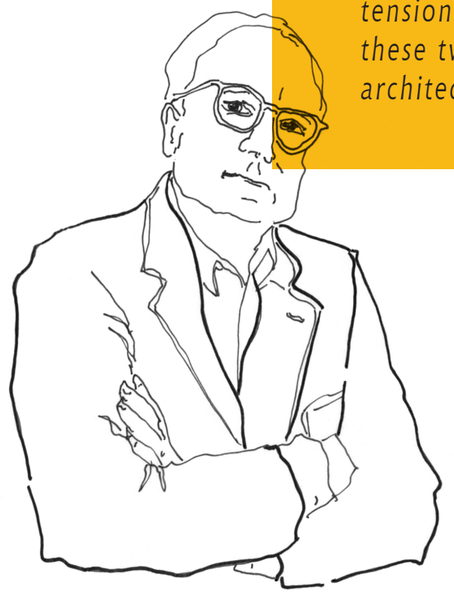


▲ Fig 3.18. Concrete block built Park Mews.

When leading a tour of Park Mews, Roger Walker was asked about his decision to use concrete block. His first answer was the expected: it was a cheap, durable material. Secondly, he showed his tendency toward complexity. He had realised that it was the same labour for contractors to lay these bricks at ninety-degree angles, as it was to lay them in a straight line.

Robert Venturi wrote…

> *"Louis Kahn has referred to "what a thing wants to be," but implicit in this statement is the opposite: what the architect wants the thing to be. In the tension and balance between these two lie many of the architect's decisions."* (Venturi, 1977)



The comparison between Park Mews and my nodal exoskeleton building shines a light on the state of this tension between the agency of the construction material form, such as the brick that Kahn famously referred to, and the free will of the architect.

It was the conventional rectangular form of the bricks, which determined Park Mews could vary at right angles. The advancement of digital tools, in this case the 3d printing of the connector nodes, means the broadening of the potential in material form. Instead of varying at ninety degrees, I had the freedom, and the agency as a designer to draw any angle that felt right as the pen hit the page.

Research Finding 5:
Perception of the Designing

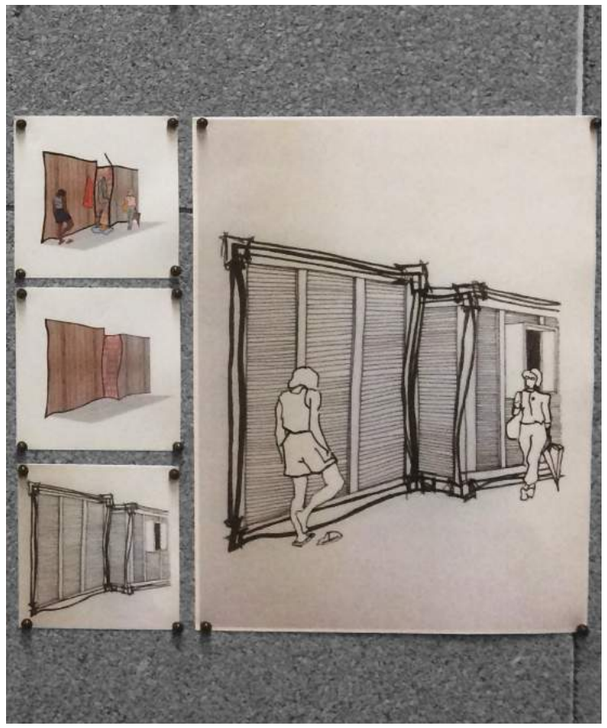
3.6

Within the process of the thinking hand, the breakthrough in the development of the detail and materials was a change in focus from people to architecture in the drawings. This was a part of the process of drawing cartoons of snapshots of human perception around the building. After critical reflection of the early cartoons, it became apparent the drawings were assuming feeling of the people in the space without drawing any architecture to evoke this.

Although efficiency is the domain of the digital side of the bionic hand, this perception was stagnating development of ideas through the thinking hand. It was a switch from drawing people, and human activities, to drawing the material, craft and structure – what a building really is.

This change came in hand with a change in my perception of the project. The original programme I had started designing for at the beginning of the year was accommodation integrating different sectors of the community. Therefore drawings I did, Peter Cook style, to establish vibes of the programme focussed on interaction between people (Cook, 2016).

◀ Fig 3.19. An early cartoon for an interactive viewing space. The people and their body language are the focus of the drawing over the forms surrounding them which have little consequence.



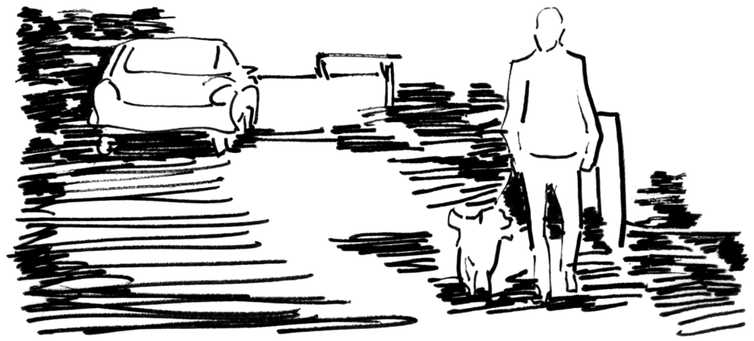
▲ Fig 3.20. The process of taking drawing that had not pushed the design forward: digitally removing the people, drawing in ideas for structure and detail, and reinserting the people to see a much richer image.

As a series of drawings, this tendency remained past the change of programme. When the change did occur, it was a realisation of the role of architecture, and the role of the designer.

Designing for people does not just mean drawing people.

I was drawing the intended outcome instead of the cause. I was focussing on the vibe I wanted to create, instead of the space to facilitate that vibe. Increasing the detail in the cartoon drawings enhanced the richness of spaces, allowing users to inhabit with intensity, instead of a drawing depicting them with the **assumption** they would.

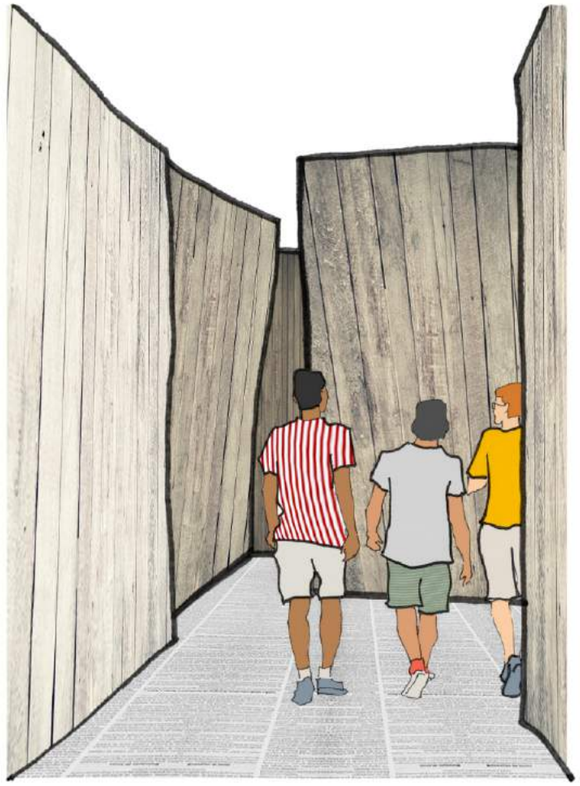
This breakthrough was the change needed for the value of the thinking hand side of the bionic hand coming directly from brain to pen in developing intimacy of space through material, detail and tectonic.



▲Fig 4.1. Early site sketch of a road in Hataitai Park.

Conclusions 04.

4.1 Conclusion Overview



I based my research around the idea of the bionic hand. That is, the way the efficiency of digital tools can work with the inherent connection between imagination and work through the hand. I investigated the role of this within the formation (design process) and form (built reality) of intimate architecture.

Upon reflection of my own tendencies in method, I became interested in the role of hand led design in a world of ever advancing digital technologies. Adjacent to this, analysis of my designing showed an affinity toward spatial and material complexity in creation of intimacy. From the combination of these interests, I asked the question:

How can emerging technologies and 'the thinking hand' augment each other in the design and construction of intimate architecture?

▲Fig 3.2. A design process cartoon.

4.2 Conclusions on the Work

The final building is six town houses within a single site, and the same structural exoskeleton frame. Each house spans three levels including a private balcony. The houses are each unique in irregular planning. Angles, corners and sloping walls create moments of intimacy between the user and the architecture, and interesting spaces to "inhabit with intensity" (Bachelard, 1957). This intimacy is between the buildings, in shared circulation space under overhanging sloped walls, and 'stoop' spaces to sit. Within the homes, intimacy is in the richly crafted living areas, bespoke furniture and stairway thresholds. Achieving these goals of intimacy and richness was through the bionic hand in the architecture's form and formation.

Part of the identified context of the design was Hataitai as a suburb – and Hataitai as an example of New Zealand suburbia. The goal of the research stream, that this project fits into, is the development of Hataitai as an urban sub-centre for a densifying Wellington. For Hataitai to achieve this it needs to densify from the centre outwards, creating active engaged streets as it does. This was an issue to address in my design. How can complex architecture still contribute to an engaged street front? Early designing in testing shape and angle of the plan resulted in similar issues to Park Mews. In the same way that I was creating nooks in the building interior, I was presenting negative space to the street. Upon reflection, I consciously straightened the street edges. This presents the vibrancy of living to the street, including the entrance to the semi-private social spaces within the shared circulation spaces. The Euclidian geometry of the street front hides the private moments and complexity reserved for the dweller within the structure.

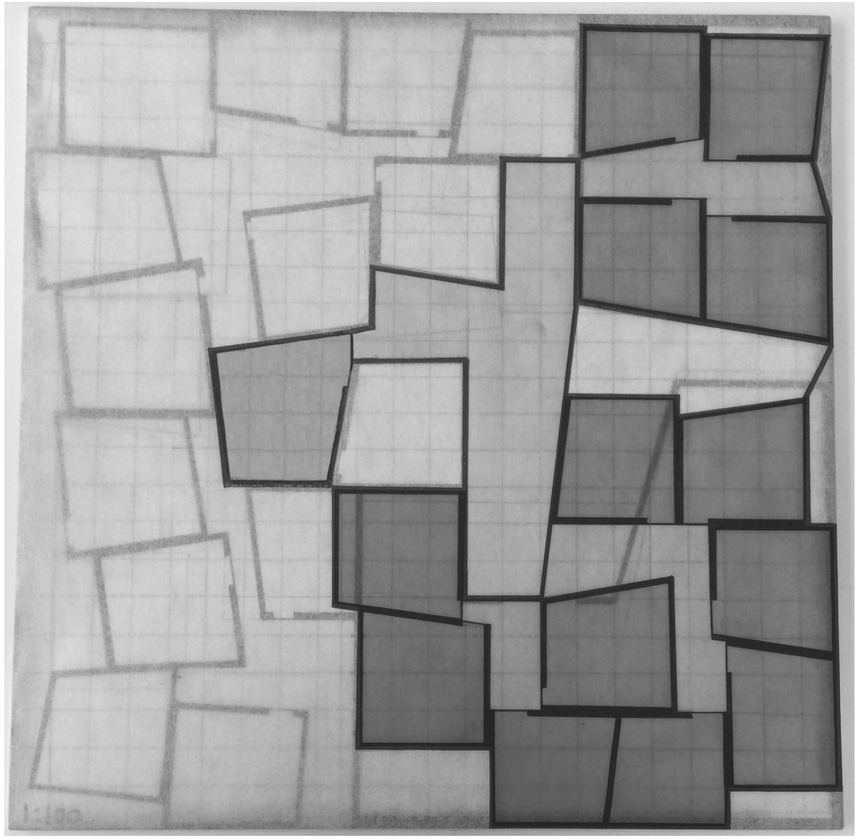
▲Fig 3.3. A design process cartoon.

Through the bionic hand I created the complexity and intimacy in the building. As design led research, the intention of this project was documenting and analysing my own design process. This analysis gave rise to understanding the bionic hand. Critical reflection across the full design method has shown the most effective and efficient ways of designing were through the augmentation of both sides of the process. The strength of the thinking hand is the natural expression of ideas from the brain. The strength of digital tools is the efficiency they can bring to designing.

While I naturally generated ideas through drawing, my designing became most efficient when I used the digital tool of dynamo to augment it. Making changes to the form on dynamo was easy through changing sliders on the script. However, it did not allow me to explore richness and intimacy of material, or visual richness of elements such as the structure and windows with the inherent creativity or tactile understanding the thinking hand provides. Thus, hand drawing over the dynamo frame utilised the strengths of both of these processes.

Digitally editing drawings and model photographs was another way of augmenting the hand and the digital. Knowledge that through photoshop I could fix mistakes, gave me confidence to draw quicker, making the work of the thinking hand more efficient.

Digital tools providing support allowed the thinking hand to be the true driver of the designing. Therefore, understanding and proper use of the thinking hand was paramount. A change in my personal perception of the drawing and building allowed progression of the thinking hand in designing. Early drawing focussed on human activity in the building. By removing the people and drawing tectonic, material, structure and craft instead, I got back to progressing the actual building design. This realisation made me appreciate my role as a designer of these physical phenomena – not a creator of behaviour.



▲Fig 3.4. A thinking hand drawn plan.

▲Fig 3.5. 'Wonky' building language was generated through thinking hand techniques such as this physical modelling

The strengths of each side of the bionic hand in the final form of the architecture accommodate the spatial complexity and richness.

Understanding the thinking hand in designing allowed me to understand the language and intimacy I had developed in the building form. Inherent wonkiness of hand drawing led to the wonky building language.

The complexity of this language created the opportunity for the efficiency of digital tools to simplify the construction. 3d printed nodes would accommodate the angles of the exoskeleton. While they were intended to save time in the construction, the process of prototyping them proved the printing and sorting process of the high number of nodes would not make them the 'just click print' process they may seem. However, this use of digital tools makes the construction an easier process for the contractor. This therefore begins to address the main hurdle of complex design – it is so difficult to build.

In the same way digital tools make construction of the building easier, hand crafted elements of construction make building actively more laborious. One role of the thinking hand in the building form is as tactile, rich material for dwelling spaces of the building. The inconsistency of hand making brings wonkiness and irregularity as interest. The inefficiency of this way of making is the reason projects such a Walmer Yard were so challenging to construct. Therefore, the panels, originally intended to line the full interior, were concentrated just to spaces for dwelling: living spaces. This gave hierarchy to the building for its intention in intimacy, and balanced the high levels of labour with the benefit of the panels.

The intention of the project is bringing intimacy and richness to realistically constructible housing. Use of the bionic hand in designing the building was an efficient design process towards this. Balance between the two sides of the bionic hand in the form of the building make the affordability and construction of this richness more feasible, and tolerable for contractors.

4.1 Opportunities for the Future

The bionic hand is a way of working and building that is only going to become more relevant as digital technologies advance. Therefore, this research is a starting point for my method of design in the future. Analysis and critique of my own process gave me understanding of strengths and weaknesses of design processes to use moving forward.

In the scope of this research, I explored the relevance of the bionic hand in intimate architecture. However, as a process the identified methods have a wider relevance than this. Processes such as digital editing of drawing, and tracing over easily adaptable digital models are relevant to most building design.

There are opportunities within this project relating to the bionic hand that with more time I would have liked to explore. It is the bionic hand in the final form of my building, which provides the most opportunity for development. In the final form, the digital side of the bionic hand exists only as the digitally fabricated nodes. The thinking hand manifests as the planning, building language, and bamboo panels. The remaining construction is broadly conventional. More of the building's detailing could harness the potential efficiencies digital fabrication allows. This would change the nature of the construction in the same way the nodes do. Transferring labour from intricate, on site, repetitive work to digitally fabricated work makes the construction easier for contractors and thus a better building when evaluated holistically, as contractors are stakeholders whose experience must be considered.

The research investigates opportunities within the discipline of designing complexity. High levels of labour in projects such as Walmer Yard, led me to explore ways to address this. The key finding of the role of digital fabrication as a way to build more efficiently is a starting block towards making complex design more feasible. Not only does it make the complexity more constructible, it can push the complexity further as well. In the same way Walker described the concrete blocks as giving him freedom to design 90-degree corners, the 3d printed nodes allow for any angle to be as feasible as 90-degrees is.

▲Fig 3.6. Intimate dwelling space in the final building the bionic hand was used to create.

In conclusion, in 1926 Walter Gropius wrote,

"It is only through constant contact with newly evolving techniques, with the discovery of new materials and with new ways of putting things together, that the creative individual can learn to bring the design of objects into a living relationship with tradition..." (Conrads, 1970)

As digital tools develop, they progress the potential in architecture, and the tradition of intimate space. However, as we move 'forwards' that does not undermine the relevance of existing techniques. The wide range of tools we have for architecture's form and formation will continue to expand. It is how we find the strengths of these tools and use them together that matters.

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