Contact and Continuity

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis.

This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Wayfinding. Embodied Learning. Craft Culture.

That material can harbour life inspires careful consideration of the craft of building.
Building is the agency of architecture; material—its medium.
The act of building engages the whole body; touch, brings together mind, and material.

Guided by traditions of craft, I learn to work with wood, in order to explore the synergy between thinking and making, body and material, through the act of building a table, with my partner, and a tree-house, for a family in Waterloo, Ontario.

Acknowledgements

I am grateful to the Belland and Carson family for opening their homes and hearts, you made it possible for me to learn, and grow, in ways I could not have anticipated. I will cherish your friendship always. Gregoire, thank you for believing in me from the very start, and for your help and advice.

To my advisor, and to my committee, I am indebted. Andrew, Robert, and John, you have paved the way for me, your patience, and guidance, has been a gift.

To students and staff at the School of Architecture, I am grateful for your help; for your camaraderie. I could not ask for a friendlier or more inspired community to have worked alongside with.

Melissa, because of you, everything is possible. The greatest treasure has been to share, and learn, and grow, together.

Dedication

To my mother and father, and to my brother Dean, and sister-in-law Candace,
without whose love and support this work would not have been possible.
Thank you.

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All photos taken by Nikola Nikolic and Melissa Ng, unless otherwise noted:

Figures 204, 205, 206 by Rachel Novak

Figures 238, 248 by Jeremy Carson

Figures 281, 282 by Jana Carson

Introduction

standing on the shoulders of giants

India. Second millenia BCE: Jain, and Buddhist stonemasons carve religious sanctuaries into the sides of mountains. Although plenty of natural caves exist; the sacred act of carving into living stone mirrors a spiritual awakening; "opening the mind to cosmic enlightenment" (Crouch and Johnson 9).

Japan. Sixth-century: Cutting down a tree is an act of moral significance. A carpenter will repay their debt to nature, by way of exacting and beautiful workmanship; honouring the life of the tree and assuring its continued existence "as a thing of beauty to be treasured for centuries" (Brown 21).

Mali. Sixteenth-century: The Bambara craftsman's knowledge is tied to "the mystery of the primal cosmic unity . . ." and their work is "considered to be the embodiment of a particular aspect of the cosmic forces . . ." (Hampâté Bâ 14).

contact and continuity

This document represents a personal exploration of the culture of craft and embodied learning. What follows is a record of a sustained attempt to think about architecture with my entire body, in an act of building. As a guide, I have looked to technical, historical, and philosophical texts, and to the works of those who came before me. I owe a great deal to the masters of a bygone era, for they have shown me a way. Although we may never repeat their customs, we would do well to take their values to heart, because they are human.

During the course of this work, I was driven to make beautiful constructions "to be treasured for centuries". However, the reader should consider them neither coherent architectural statements, nor strictly formal objects, in and of themselves, but as open ended experiments. Much attention was given to their fit and feel in relation to the body. First and foremost, the reader should consider the works to be an embodiment of a slow, repetitive, and often messy process, which I have attempted to portray here in the form of a photo essay.

Building a Harvest Table

Anyone who has only been shown how to force a piece of wood against a mechanized saw will have learnt very little, but if [they] have had to saw that piece of wood by hand [they] will be more likely to know that much more about it, [they] will have greater respect for it and will understand in greater depth the problems that will have to be faced in its manipulation.

Ernest Joyce,
The Encyclopedia of Furniture Making

August 2011: beginnings

Having acquired a few dozen reclaimed timbers in the summer of our first year of graduate studies, my partner Melissa and I endeavoured to make a harvest table. With what little construction experience and woodworking ability there was between us, we could not have known what an act of building would do to challenge our assumptions, and shape our values.

We were taken by the age of our timber, more than a century old, covered with dust, and plaster. Because the boards were pierced with nails, we could not rely on power tools to dress them. Using reclaimed wood required working by hand, with hand-tools. We sought guidance from craft traditions and found inspiration in the work of the late masters George Nakashima and Wharton Esherick, among others. The ancient art of wood joinery provided us a template for almost every possible type of wood construction, and building traditions offered a return to the fundamentals of architecture: to material, to the body, to the earth.

As a compliment to working by hand, Melissa and I decided to avoid, wherever possible, the use of adhesives and mechanical fasteners. More an opportunity to learn about wood than a matter of principle, relying on wood joinery as a means of assembly, we hoped to broaden our understanding of how things were built, and exercise our capacity to visualize complex details.

In any wood construction, one must consider the movement of wood with changes in humidity. In glued-up assemblies, components generally expand and contract as one unit, and quality glues will expand and contract in joints that change shape over time. Depending on the species of wood used and the type of construction, wood movement in glue-less assemblies is often more difficult to manage.

right:
Melissa, next to a stack of floor joists, salvaged from a century-old stone building.

figure 1

To accommodate dimensional changes in our tabletop, we looked to the eighteenth-century American door, which employed a rigid perimeter frame, grooved on the inside face, to carry a floating panel—often divided in two with a rail—made up of smaller tongue-and-groove boards that would expand, and contract, freely. In the construction of our table, a rigid frame would also allow us to maintain an undressed edge along the perimeter of the tabletop: a design detail we had decided upon after our first encounter with the reclaimed timbers.

Work commenced with a general cleaning. We removed metal fasteners and other debris embedded in the boards, before planing them flat, to the correct thickness and width. Each each face was made true (to meet the edge of an adjacent face at a ninety-degree angle). During the course of this process Melissa and I became familiar with basic tool use and wood properties.

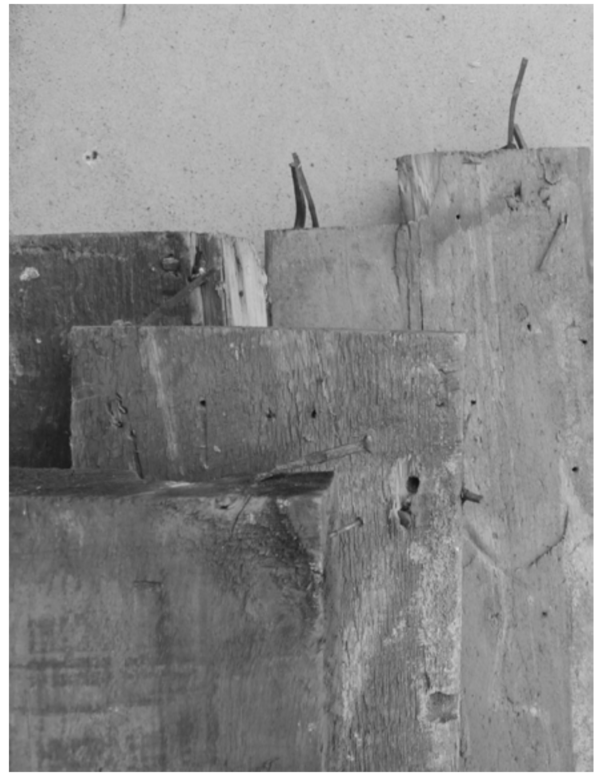


figure 2

figure 3

Halfway through the process of thicknessing, truing, and jointing our boards, Brad, a friend and colleague (and professional woodworker) visited us in the workshop. He lifted a handful of shavings cut from the boards we were planing up to his nose, and with a breath identified the genus and species to be eastern white pine. “The species of wood can even be identified by its flavour”, he said. In the weeks up to this meeting, Melissa and I had been comparing pictures of wood grain, attempting, unsuccessfully, to identify what we were working with. Brad’s display was an inspiring reminder of the power of the human body; of the role the craftsman’s senses play in embodying and reading the material environment.

above:
Our boards, riddled with iron nails.

eastern white pine

Pinus strobus, or eastern white pine, the provincial tree of Ontario, is a moderately hard conifer native to eastern North America. White pine wood is lightweight and straight of grain, and exhibits a creamy-white to yellowish-brown colour that darkens considerably when exposed to light. Fresh white pine has a pleasant, bitter-sweet scent, not quite lemony-mint. White pine constitutes a major portion of the lumber produced in its native area. Because it was straight grained, free of knots, and easy to work, old growth white pine was traditionally used in colonial homes for floor boards, panel siding, and furniture; the tallest specimens, which often had no extending branches under a hundred feet, were used as ship masts. First nations peoples of eastern North America, ingested parts of the white pine for nourishment.

above:
Using a magnet to find the location of embedded iron spikes.

figure 4

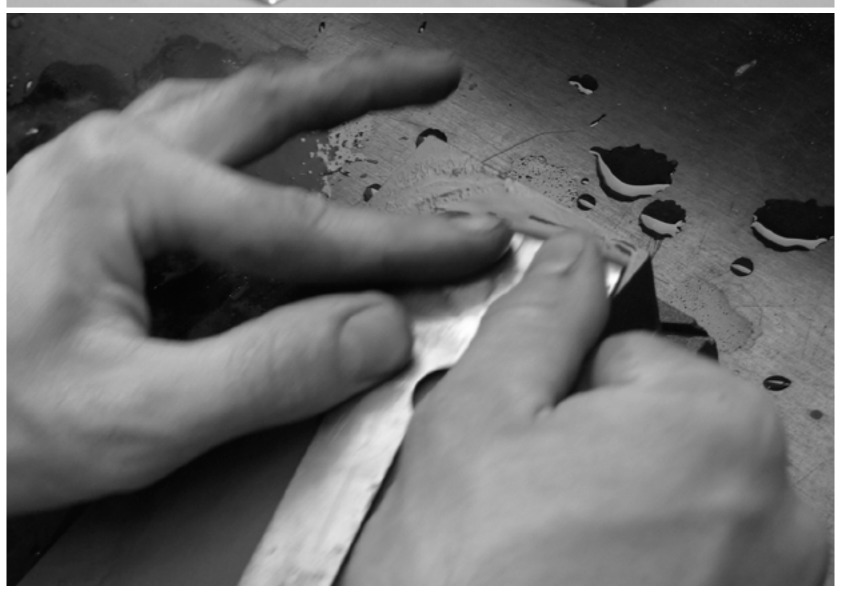


figure 5

hand-tools in woodworking

Hand tools must be wielded with care, and understanding for work to progress efficiently. With patience, and practice, the craftsman learns to think and feel through their tools, which become extensions of their body. In ancient Japan, a carpenter did not work with mere tools, but with *dõgu*, "instruments of the way". The intense personal relationship between a craftsman and their tools is compounded when the tools a craftsman uses are of their own making.

Although woodworking tools number in the hundreds, only a few are needed to perform a wide variety of tasks. Nonetheless, the learning curve is high. Close to half of the time Melissa and I spent building was dedicated to calibrating, maintaining, and learning to use our tools properly.

left:
Preparing our first hand-plane for use.

figure 6

figure 7

top:
"Scrubbing" with a modified jack-plane.

bottom:
A not-so-efficient attempt at thicknessing.

hand-planes

Using a hand-plane to dress wood can yield a surface of unparallelled quality. There is no other tool that can come close, except perhaps the Japanese *yari kana*, "spear plane", which has fallen out of regular use for at least a thousand years.

Hand-planes work by cleanly shearing a layer of wood fibres with a steel blade held at a consistent angle and depth. A properly calibrated plane will leave behind a smooth surface characterized by its clarity and depth, especially when compared to a sanded surface. Sandpaper abrades the surface of wood, tearing at, then filling in the opened pores with dust produced by every pass. The damaged cell structure of a sanded surface appears muddled, and is more susceptible to water damage than a properly planed surface.

While the plane blade is the heart of a hand-plane, the body, in addition to providing a comfortable hand-grip, and holding the blade in place, performs several important functions. The area of the sole pressing down on the wood in front of the cutting edge prevents fibres from shearing out ahead of the cut. The long sole of a jointer plane helps flatten a board as it rides across crests until they are planed down to a uniform level. The short sole of a smooth plane allows for easy manipulation, while the narrow blade and sole of a scrub plane minimizes friction.

right:
Thicknessing with a scrub-plane.

figure 8

Whether the body is made of metal, or wood, is also a consideration: many carpenters claim that wood planes produce a nicer finish as a result of the burnishing action of wood on wood, while others prefer the durability and weight of a metal plane, especially when working hard woods. The design of a hand-plane reflects its intended use more than a carpenter's preferences however, and planes are made for a variety of very specific tasks, including: scrubbing, jointing, truing, smoothing, and routing.

right:
Deep cuts left by the convex blade of a scrub-plane.

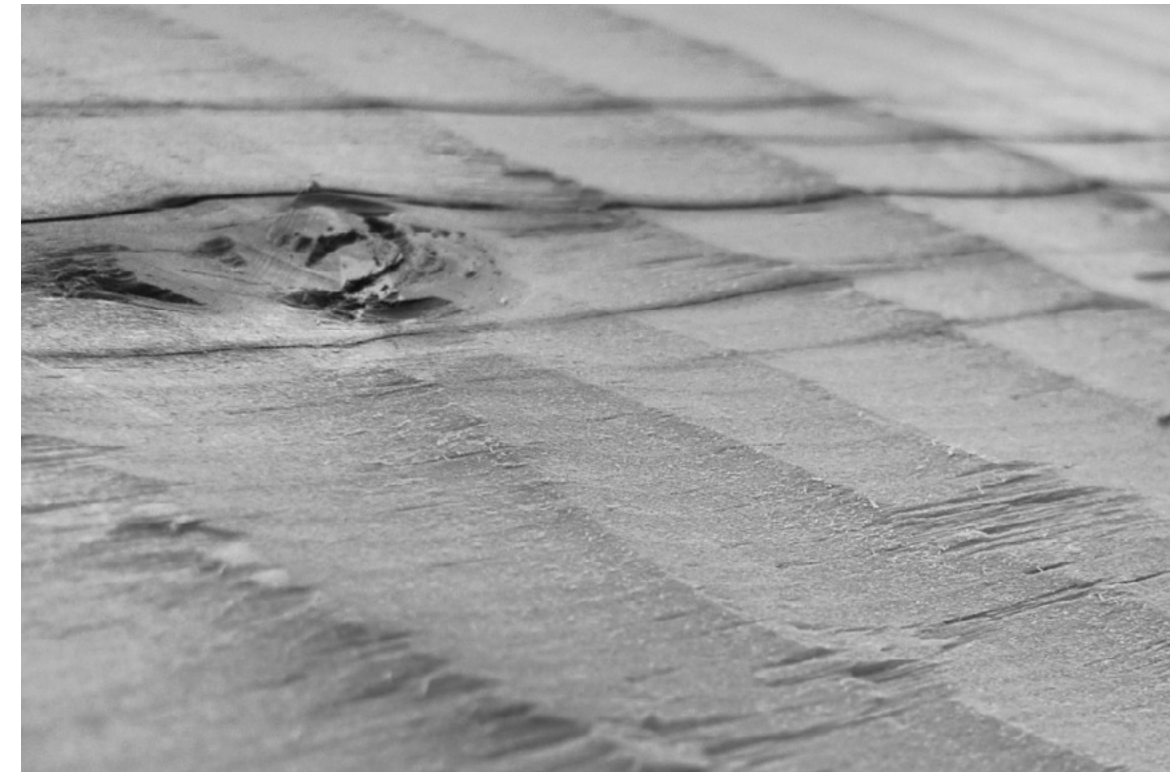


figure 9

wood grain

Wood grain is directional. Except when removing large amounts of wood with a scrub plane, truing end grain with block plane, or rabbeting end grain with a rabbet plane, one should always move in the direction of overlapping grain. Planing in the wrong direction will result in broken or torn fibres. There are several visual cues that can be used to determine the directionality of wood grain. Except in burls and around knots, grain on the outside face (bark-side) of a board overlaps in the direction of growth, from bottom to top, and top to bottom on the inside face (pith-side). Growth rings can be used to distinguishing the inside face from the outside face of a board. Growth rings near the crown of a tree are less dense than at the base of the trunk, which must be strong to support massive loads. The orientation of grain around knots signal the direction of tree growth, as do ray and vessel cells, which are easier to spot in hardwoods like oak, walnut, and butternut. Only the most experienced woodworkers can read wood grain with confidence.

figure 10

figure 11

figure 12

above:
Melissa, sighting crests and valleys, along the length of a board.

above, left:
Using a jack-plane to flatten a scrub-planed surface.

above, right:
A spirit-level eases the task of assessing how true a board is.

figure 13

figure 14

steel in woodworking tools

Steel technology makes woodworking as we know it, possible: it is the interface between maker and material. Steel is an alloy that contains iron, carbon, and other elements. The alloy ingredients of a particular steel, and the methods employed in the fabrication of that steel might make it suitable for one task, but not another. A basic understanding of the properties, and characteristics of common tool steels is vital, if the woodworker wishes to use them properly.

above, left:
Using a water-stone to sharpen a plane blade.

bottom, left:
Melissa, sharpening.

Sharpness is of great concern to the woodworker. How sharp a blade can be made, how long a blade stays sharp, and how easily a blade re-sharpens is determined by the grain, structure, and hardness of a particular variety of steel. When steel exhibits a small and uniform crystalline structure, it is considered to have a fine, even grain, and—depending on its composition—will sharpen very well. Properly formed carbon steel can be made very sharp, but it is often too brittle on its own to be of any use. Elements like chromium, which are used to harden steel, make very strong bonds with the carbon atoms present in the alloy, resulting in a larger, durable, but often less uniform, crystalline structure.

The structure of steel is also a result of the forging process. It is claimed that hand-forged steel is superior to drop-forged or hot rolled steel produced in a factory. A reason why this may be true, is that the process of hammering red hot steel into its rough shape causes the crystalline structure to break apart, and realign more tightly, in the direction of the steel flow. Provided this is done properly, an experienced blacksmith can often produce a finer grained steel by hand-forging than through other processes.

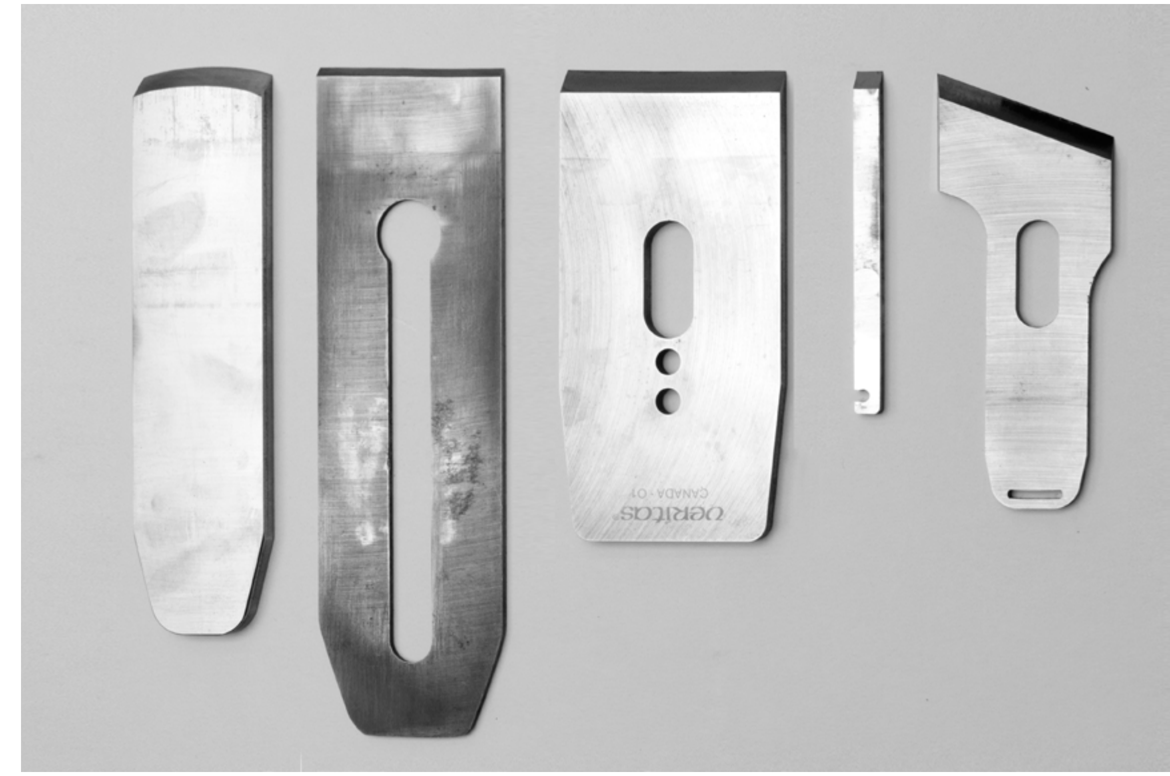


figure 15

In practice, a high concentration of chromium in A2 steel, improves the durability of a plane blade, but also compromises its ability to take on a very sharp edge. This may be fine for working hard woods but is less than desirable for softer woods. O1 steel is less durable, but easier to sharpen because it contains far less chromium. The addition of tungsten imparts a tighter grain to O1 steel, that can be made sharp enough for general use with softer woods, but not quite as sharp as a fine grained, hand-forged, carbon steel blade: the ideal candidate for smoothing soft woods. Hand-forged carbon steels made by early American, and traditional Japanese master smiths, were often laminated with a ductile backing steel to produce a durable blade, capable of taking on a very keen edge.

above:
A variety of plane blades, each suited for a particular task.

figure 16

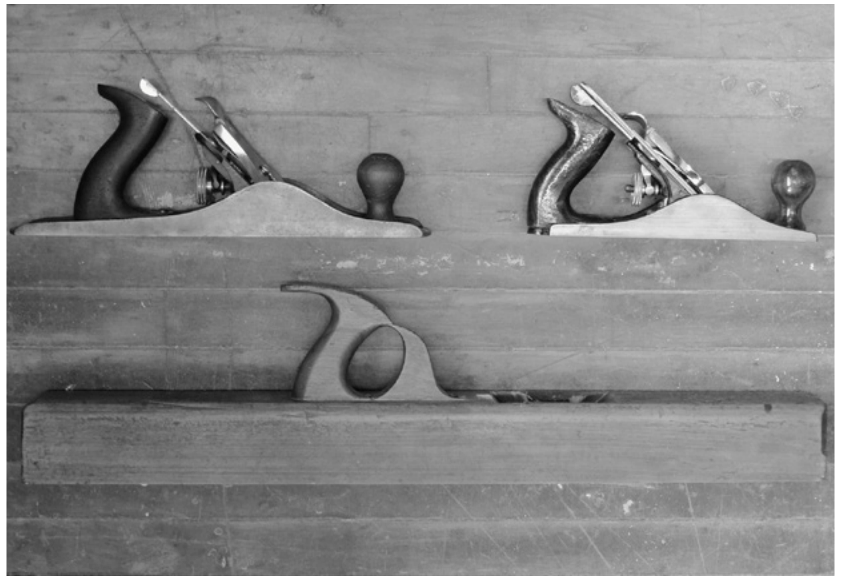


figure 17

figure 18

above, left:
Scrub, jack, and jointer-planes are used in combination to effectively thickness, true, and square a board.

bottom, left:
The long, flat, sole of a jointer-plane.

above:
Because of its length, the jointer-plane is indispensable when truing long boards.

right:
Cutting our boards to size
with a ryoba saw.

figure 19

handsaws

Handsaws are usually designed to cut parallel to wood grain (rip cut), or across wood grain (cross cut). The teeth on a rip cut saw are sharpened to a square or chisel-like profile and are deeper and fewer in number than the teeth on a crosscut saw, which are shallower, more numerous, and sharpened to a knife-like profile to prevent tearing out end grain. The set describes the width of the blade at the cutting edge, or, kerf. The set is made wider than the rest of the blade by bending every other tooth outward, away from the centre of the blade. The set relieves friction caused by wood bearing against the sides of the saw blade, that would otherwise lead to binding. The profile, set, number of teeth per inch (TPI), and thickness of the blade are a few of the considerations that go into the design of a saw, and will vary depending on the nature of the material and cut.

The traditional Japanese ryoba saw is an fine example of these design considerations in a simple form, that, to the layman, belies its sophistication. A ryoba saw can accommodate rip cuts and cross cuts because of its double edged blade, which is hand forged from the highest quality alloys. Good quality blades have minimally set teeth, taper from haft to tip and from the edges to the centre, to further reduce binding. Even higher quality blades are thinner at the tip than at the haft (where the teeth are finer to facilitate starting a cut) and thickest at the shaft, where the blade meets the handle.

The unassuming handle of a ryoba deserves special attention. Because of its length and elliptical cross section, it can accommodate hands of all shapes and sizes. In ancient Japan, the tools of war and trade were often made by the same master smiths and woodworkers, and the shape of sword and saw handles developed in parallel.

figure 20

In The Book of Five Rings, Miyamoto Musashi describes the proper technique for holding a sword, a technique that applies equally well to holding a Japanese pull-saw: ***"…hold it rather lightly with the thumb and the index finger, neither firmly nor lightly with the middle finger, and firmly with the ring and little fingers"*** *(Musashi 38).*

Most Japanese handsaws, the ryoba saw included, cut on the pull stroke. This distinction carries several advantages over handsaws that cut on the push stroke. Because a pull saw acts in tension, its blade can be made thinner, and can therefore accommodate finer cuts. Pulling down through a cut, one expends less energy by relying on gravity, and pulling toward the body while cutting allows for a greater degree of control than pushing away from the body: this is why Japanese hand-planes are also designed to be pulled toward the body.

above:
A ryoba saw.

figure 21

figure 22

above:
Our boards, cut to length
and planed flat on one side.

above:
Using a jointer-plane to
square the edge of a board.

figure 23

above:
Scribing with a marking gauge.

figure 24

above:
Marking over a scribe line for better visibility.

figure 25

figure 26

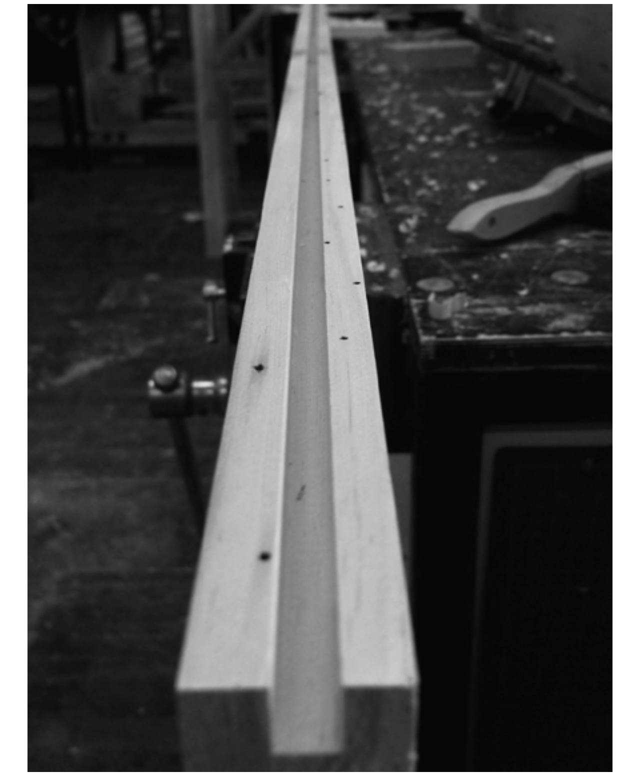


figure 27

above, left:
Cutting a groove along the edge of a board with a plough-plane.

above, right:
Using a rabbet-plane to cut a tongue.

above:
A nine-foot long groove.


figure 28


figure 29


figure 30

top, left:
Fitting our first tongue-and-groove joint.

middle, left:
Tongue-and-groove, detail.

bottom, left:
Tabletop, beginning to take shape.

figure 31

practice

The one who practices consciously, listens and adapts: sensitivity is increased through careful repititon; improved technique and intuition follow. The one who relies on force, practices aimlessly. In woodworking, the practice of sharpening a tool blade is paramount: it is a foil for every other task, and a measure of care. There is no short-cut, no formula for mastery. I am only beginning to understand this. The majority of my sharpening attempts have been characterized by overexertion: too much pressure, too quickly. Gradually, I have learned to slow down, to practice sharpening softly, to listen. A slow, careful approach has always resulted in a sharper blade.

left:
Sharpening.

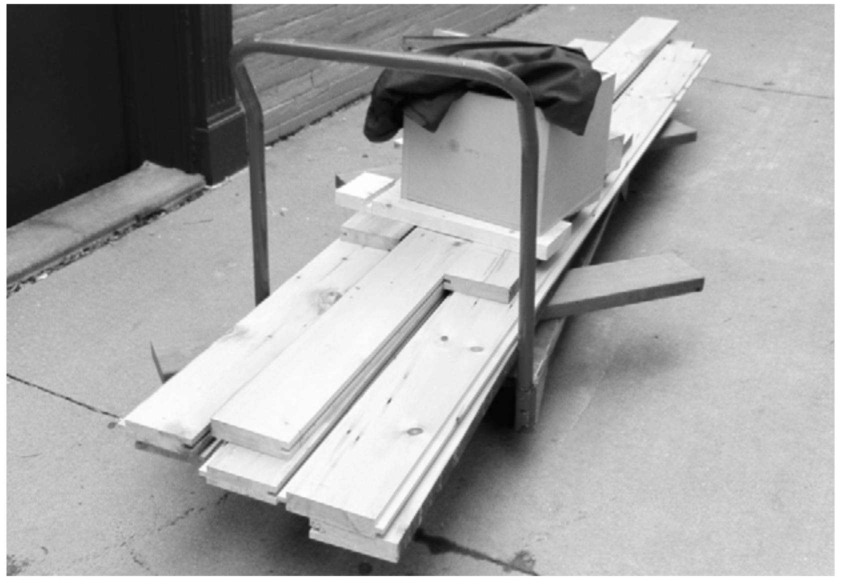


figure 32

figure 33

top, left:
Relocating.

bottom, left:
Setting up shop at home.

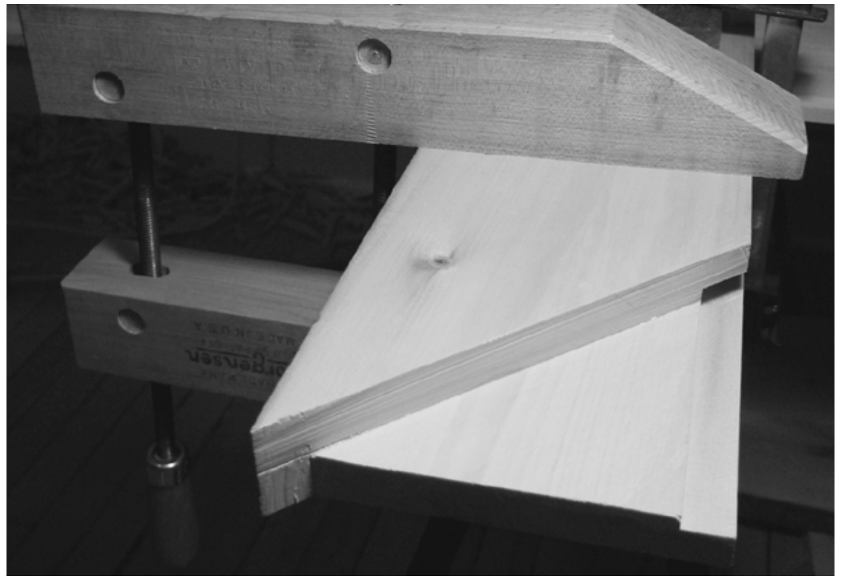


figure 34

figure 35

top, left:
A mitred lap-joint.

bottom, left:
Using a dozuki saw to cut a mitre.

overleaf:
Our tabletop, serving as a temporary work surface.

figure 36

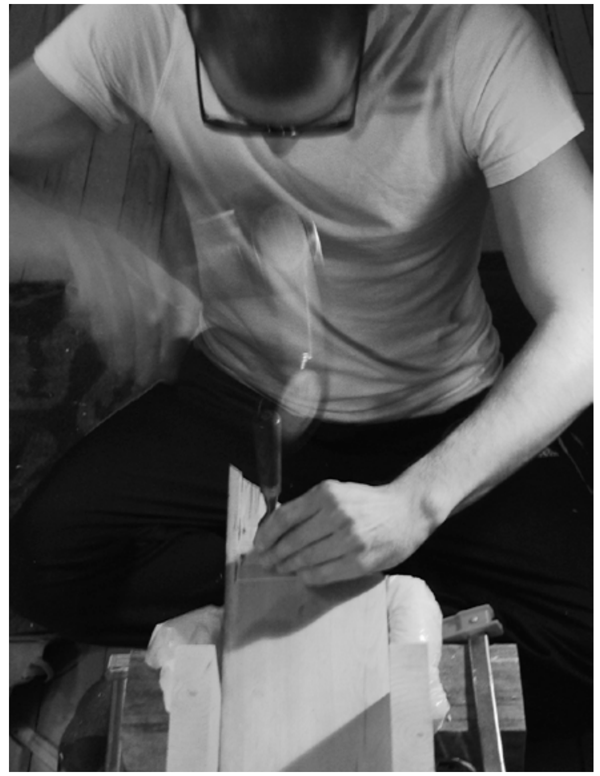


figure 37

figure 38

figure 39

above:
Using a mallet and chisel.

above, left:
Finding creative ways to restrain our workpieces.

above, right:
Paring down a housed, half-lap joint.

figure 40

figure 41

above:
Attaching the mitred breadboard.

above:
A housed, half-lap mitre at the breadboard.

figure 42

figure 43

above, left:
Table panel and frame, fully assembled.

above, right:
Testing the strength of the tabletop.

the primacy of touch

The immediacy and intimacy of touch are among the more rewarding aspects of furniture making. The sensory feedback a craftsman receives from prolonged contact with tools and materials in an act of making, alters their physiology, and psychology. For the designer, the effects, and affects of touch can positively aid the development of problem solving skills, especially those relating to the many issues surrounding material constructions. It is for this reason that architects in some traditional craft societies were, as a rule, master craftsmen; masters of touch.

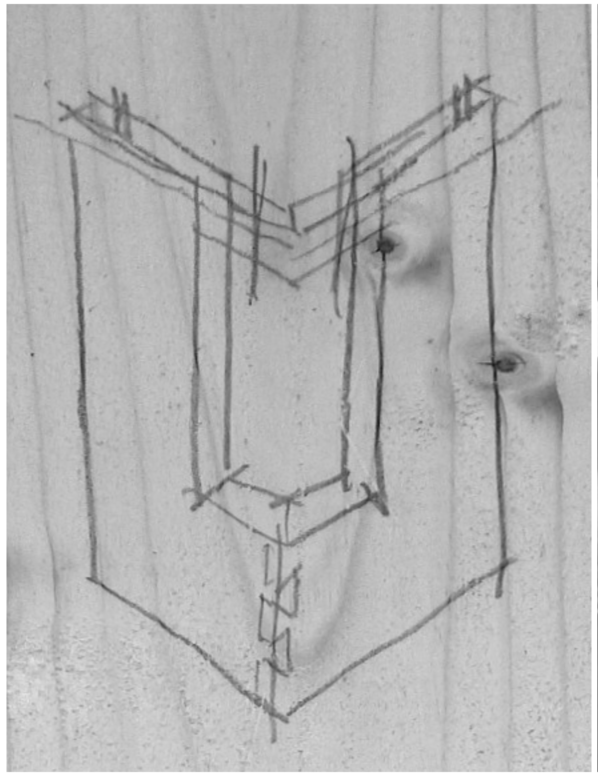


figure 44

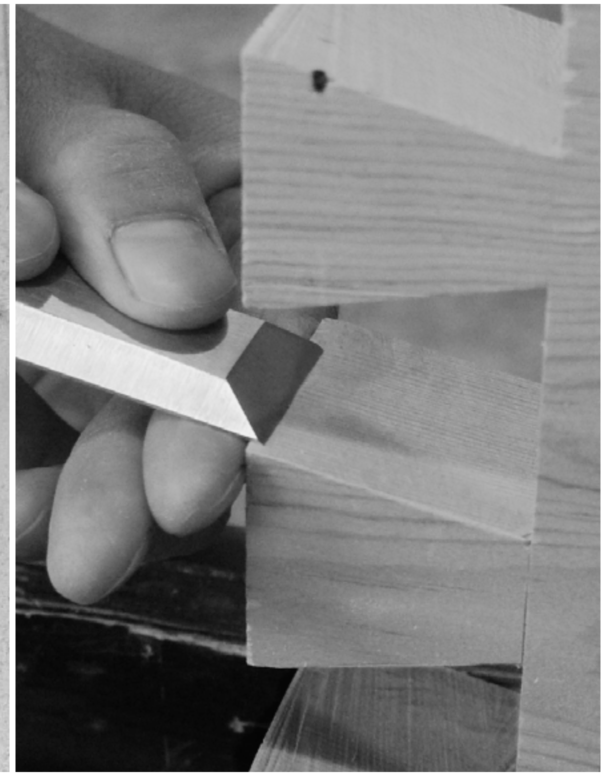


figure 45

The role touch plays in the evolution of intelligence is not fully understood. Many neurologists believe that early hominids, using their hands to make and use simple tools for the first time, affected the growth of more complex neural passageways in their brains, allowing them to think through more complex problems, and in turn, to develop even more complex tools. It is thought that, over a period of several millennia, this process led to the development of language, and later, civilization. In "The Hand", neurologist Frank R. Wilson posits that even during the span of a single human life, the use of our hands and whole body in highly skilled applications, can positively affect our overall psychology.

above, left:
Table leg, concept sketch.

above, right:
Slowly feeling through a cut:
a dovetail takes shape.

In "The Senses of Touch: Haptics, Affects, and Technologies", Dr. Mark Paterson, studies the affective nature of touch, and maintains that touch can communicate an array of emotions, including aggression, and love. Craftsmen have long depended on the emotive capacity of touch to convey meaning in their work. When a person responds to the feel of something that is handmade, or finely crafted, they are responding to the touch of the maker. A designer or craftsman, touching and working closely with materials, may even begin to care for those materials as if they were a loved one, and their sense of care—or lack thereof—is invariably embedded in the things they design and make.

figure 46

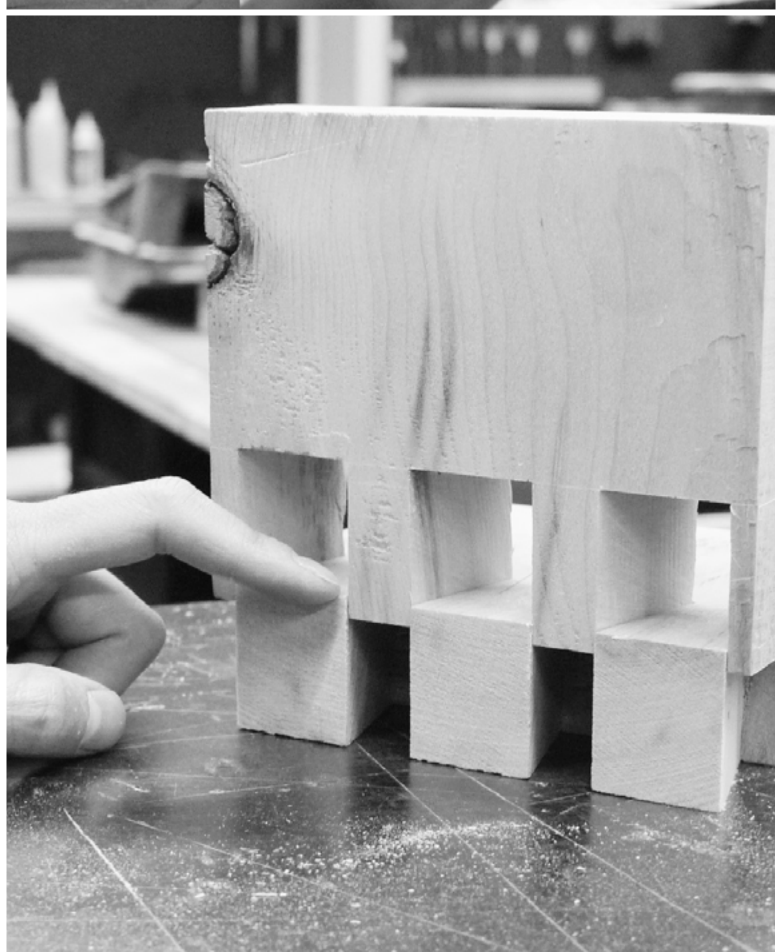


figure 47

above, right:
Butt-chisels are easy to manipulate, and are well suited for precise work.

bottom, right:
One of several practice dovetail joints.

figure 48

figure 49

above:
Full-scale mock-up of the leg assembly; in search of a comfortable proportion.

the body, and full-scale prototypes

In addition to aiding a performative analysis of a construction detail, full scale prototypes allow a designer to use their entire body as a measure of form, and function—both of which contribute toward an overall aesthetic. Although aesthetic concerns in design are usually associated only with a subjective appreciation of beauty, or appearance, it is important to remember that aesthetic derives from the Greek word aisthētikos, which refers to perception by the senses. In design, notions of beauty can be informed by more than sight, and reason alone.

Working with full scale mock-ups, Melissa and I tested a number of proportions for the assembly of the trestle leg, and ultimately rested with one that would support our feet most comfortably while sitting in a reclined position.

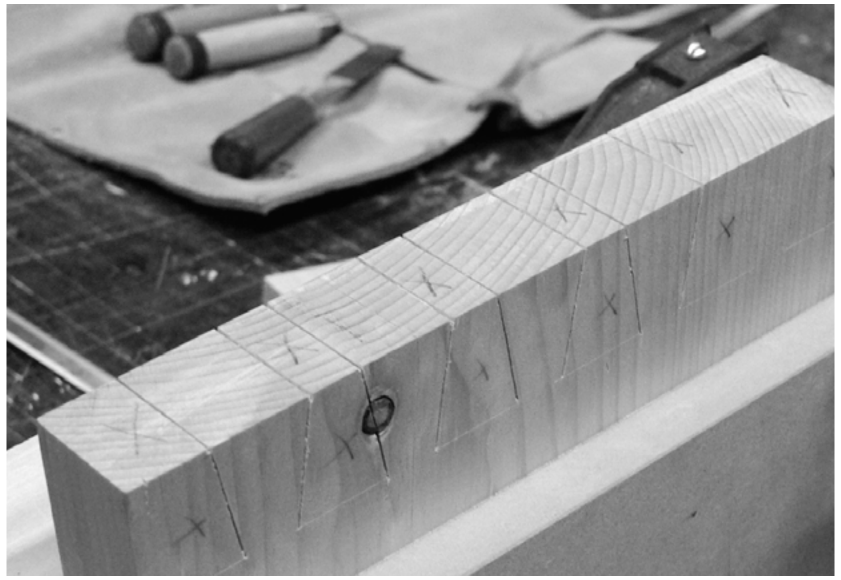


figure 50

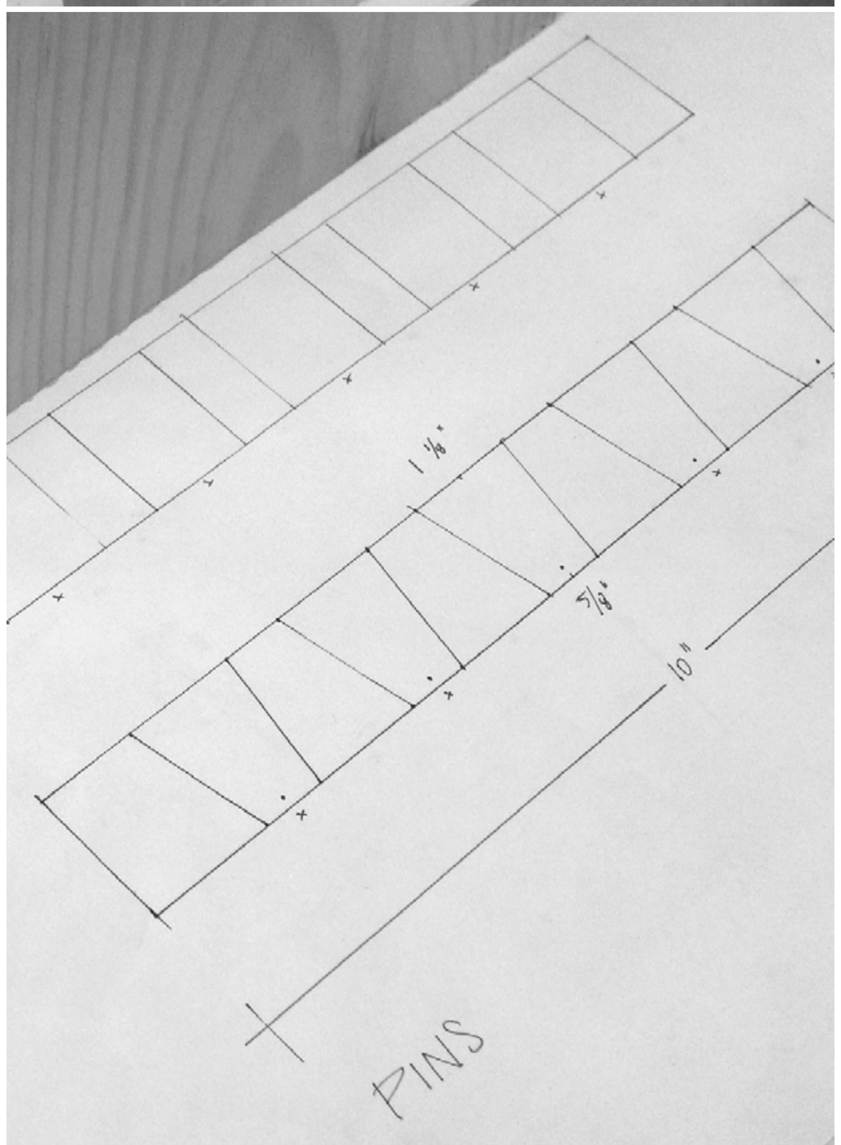


figure 51

above, left:
"X" marks the waste to be removed with a chisel.

bottom, left:
Laying out the final dovetail joint.

overleaf, top:
Almost ready to assemble.

overleaf, bottom:
A poorly designed connection: a tongue and groove with a modified bridle joint.

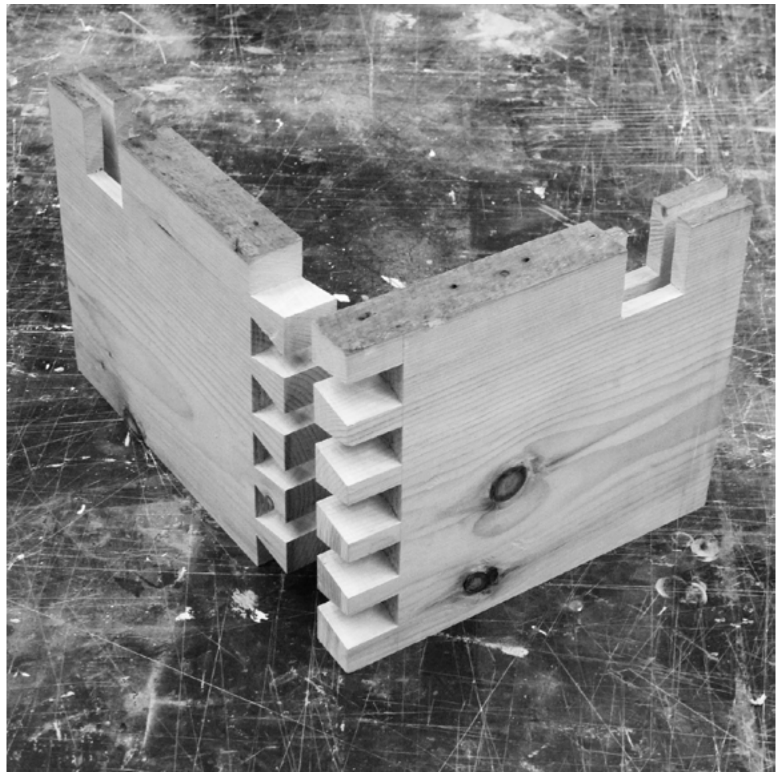


figure 52

figure 53

some mistakes are easier to make on paper

Full scale prototypes can reveal errors made during the conceptual stages of design. Designing on paper, or on the computer, in a material-less, scale-less, virtual environment, it can be difficult to account for the physical properties of materials, and the myriad forces acting upon them.

In the design of a modified bridle joint *(figure 53)*, Melissa and I neglected to accommodate the direction of wood grain. As a result, a joint that appeared fine on paper, was, in reality, susceptible to shear failure due to short grain, near base of the bridle connection.

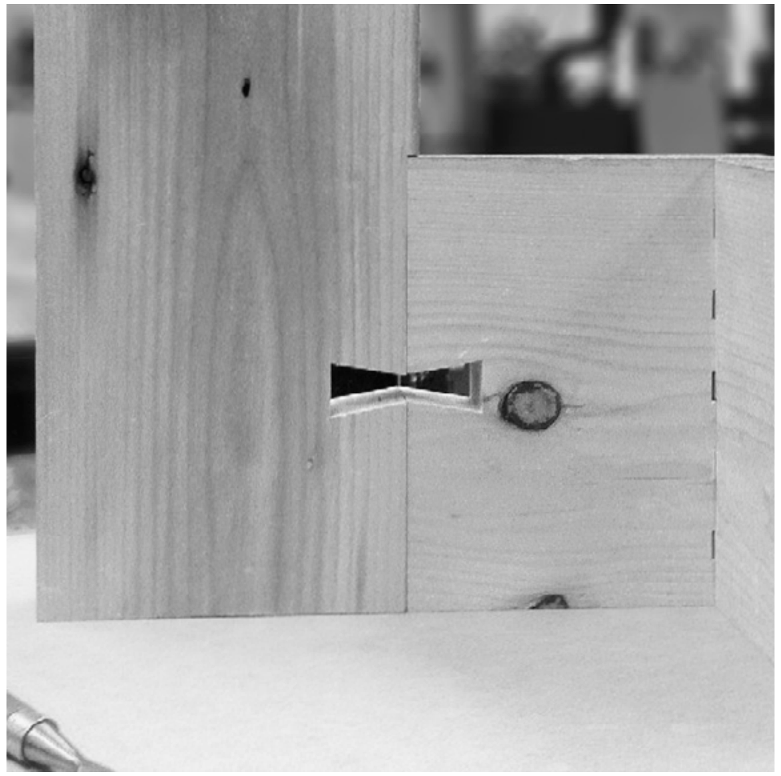


figure 52

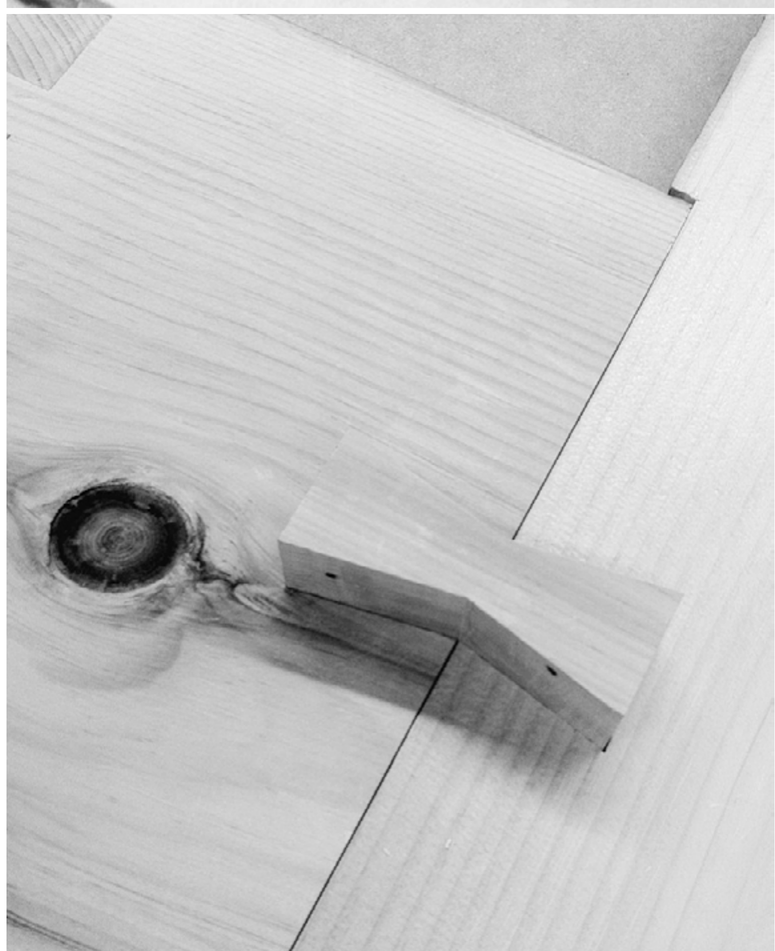


figure 53

top, left:
A poor joint made better...

bottom, left:
A tongue-and-groove
secured with a bow-tie pin.

right:
A glue-less assembly.

figure 56

figure 57

figure 58

above:
Planing a bevelled edge.

above:
A tapered spacer attached to the fence of a rabbet-plane produces angled cuts.

above, right:
Flat head screws with countersunk washers secure a triangular support structure...

bottom, right:
...designed to attach the trestle legs to the underside of the tabletop.

figure 59

figure 60

above, right:
An improved trestle leg-to-table top connection provides support across the entire width of the table.

bottom, right:
The support plank adds rigidity to the legs and is a means of attaching the legs to the tabletop.

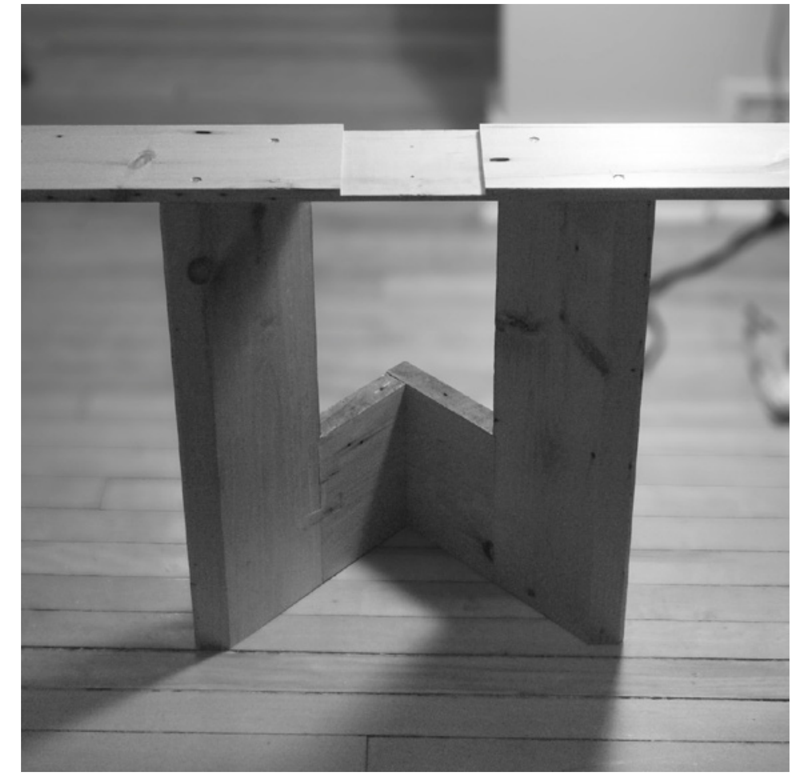
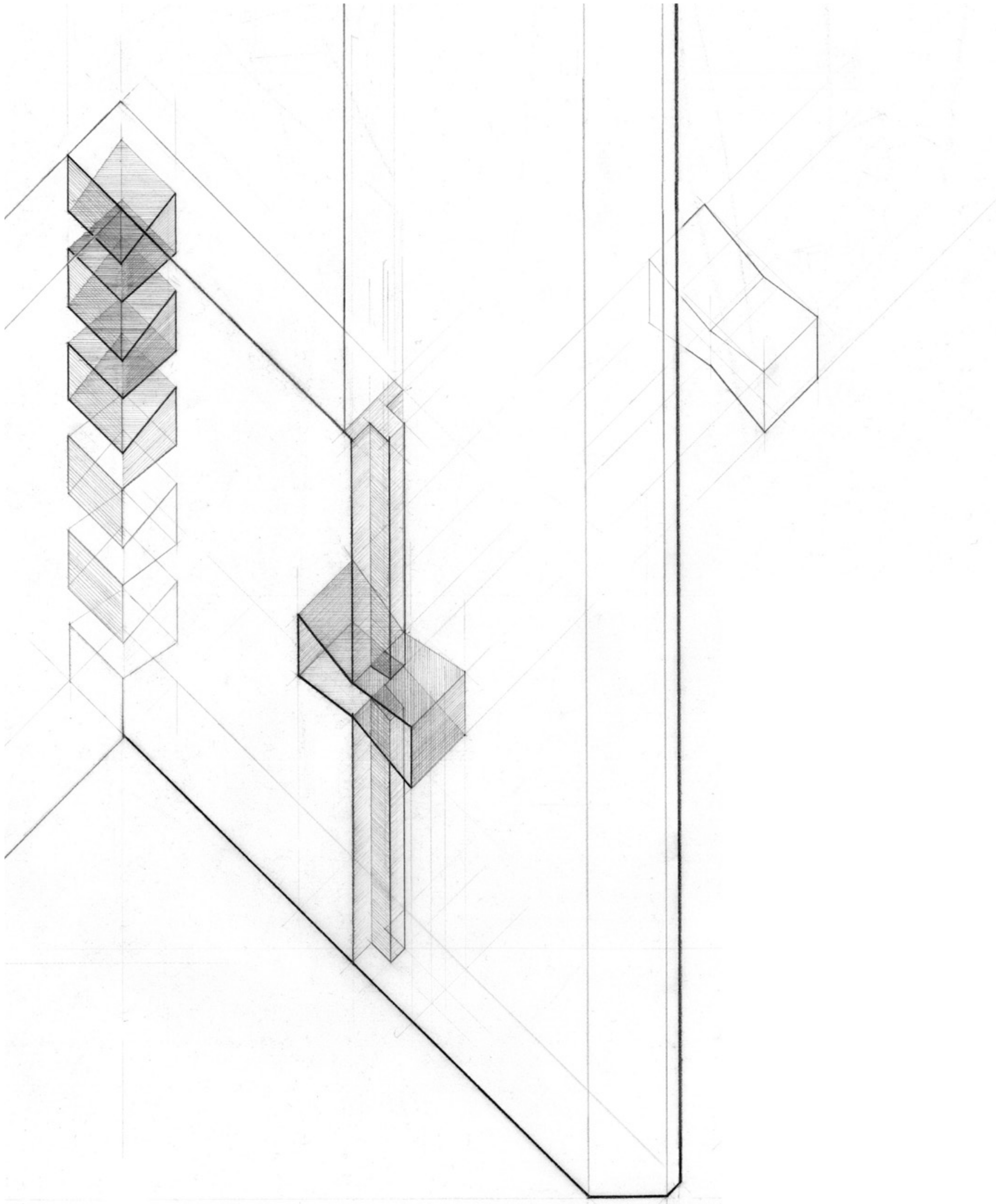


figure 61

figure 62



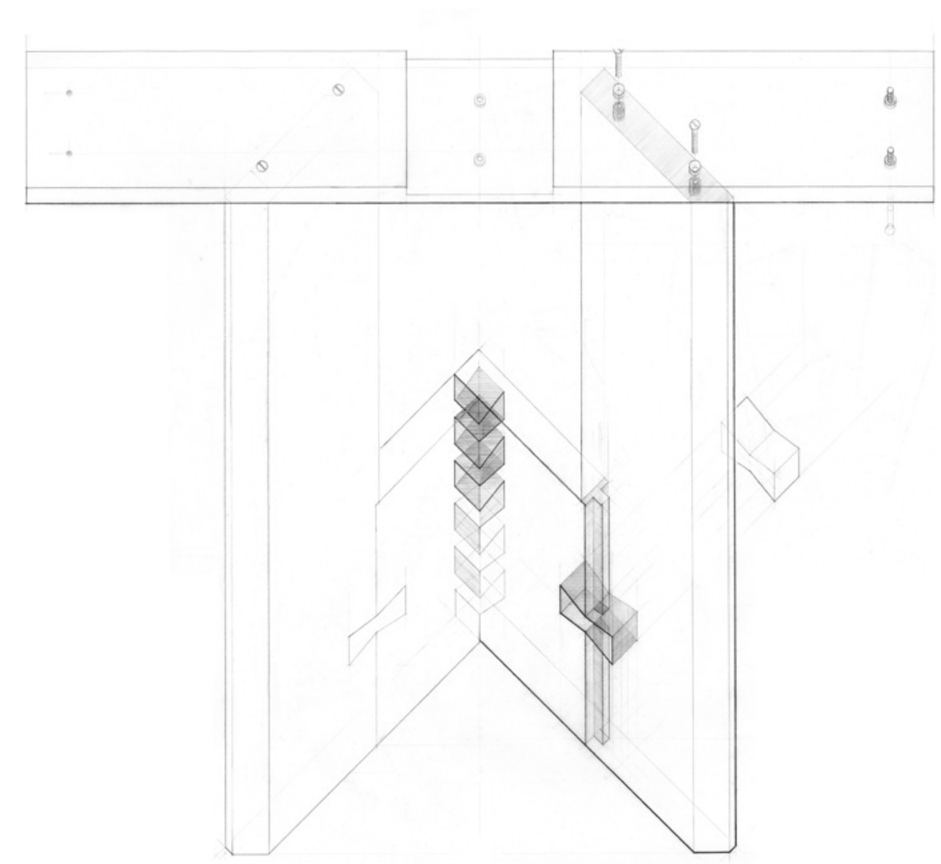


figure 64

above:
Trestle leg. Isometric.

figure 62, left:
Dovetail, and tongue and groove with bow-tie pin.

figure 65

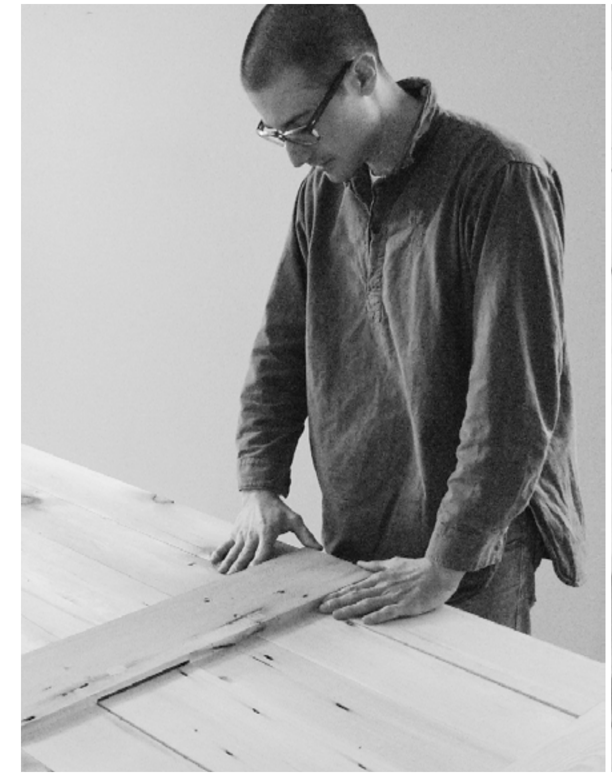


figure 66

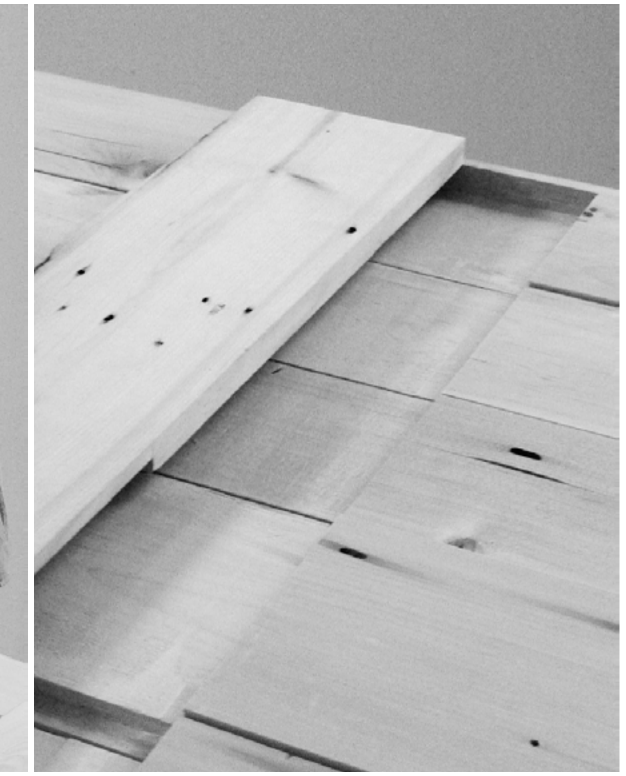


figure 67

above:
Trenches on the underside of the tabletop receive the trestle leg support.

above, left:
Assessing the fit of the leg support-to-table joint.

above, right:
ibid.

figure 68

figure 69

above:
Our table, assembled for the first time.

above:
Trestle leg-to-table top connection.

figure 70

above:
The iterative process at work: a tapered trench holds an additional rail support, without fasteners.

the iterative process is a natural, skill-developing mechanism

Referring to the contemporary disconnect between head and hand in "The Craftsman", Richard Sennett reminds the reader that "Going over an action again and again . . . enables self-criticism", and that "Afraid of boring children . . . the enlightened teacher may avoid routine—but thus deprives [them] of the experience of studying their own ingrained practice and modulating it from within". "As a person develops skill, the contents of what he or she repeats, change" *(Sennett, 21)*.

The results of this practice are unsurprising: after making the leg-to-table rail supports, which are mechanically fastened to the underside of the table, Melissa and I developed a tapered, trench detail to receive a third, central rail, held in place with no fasteners at all *(figure 70)*.

Less obvious are the obstacles inhibiting the iterative process in contemporary education. Architectural pedagogy is encountering an unprecedented wave of automation and digitization that promises precision, and efficiency by reducing the time spent on manual labour. "Yet machinery is mis-used when it deprives people themselves from learning through repetition". "The smart machine can separate human mental understanding from repetitive, instructive, hands-on learning" warns Sennett. "When this occurs, conceptual human powers suffer" *(Sennett, 22)*.

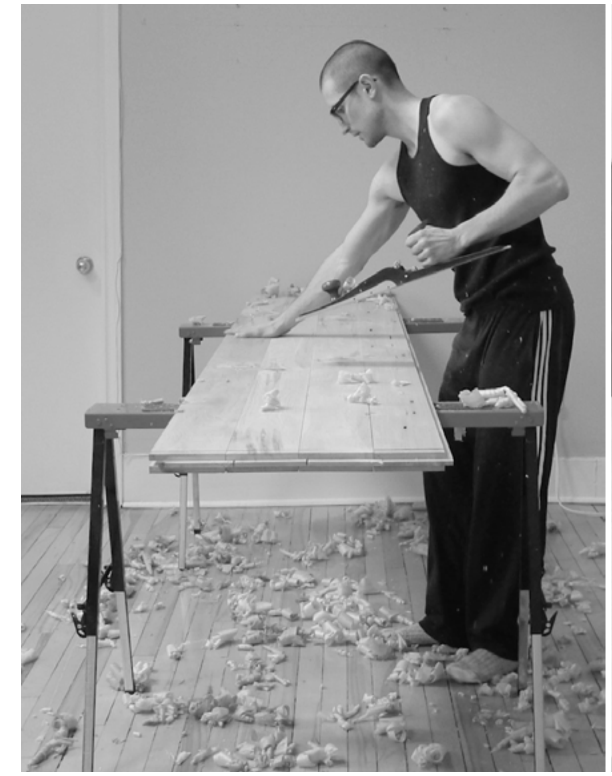


figure 71

figure 72

above, left:
Preparing the table top for oiling.

above, right:
Taking very fine shavings with a jointer-plane.

figure 73

a most profound lesson

Early on during the table build, I was quick to impose upon Melissa, my opinion. I would attempt to *correct* her technique, offering advice on how to best grip and use a particular tool—not appreciating the fact that what felt comfortable and right to me, may not have been to her. The physicality of building together reminded us both that our bodies move and grow differently. Physiology plays a large role in the development of personal preference; comfort is not simply a matter of opinion. This is very easy to take for granted, and it has profound implications in the field of design.

I return to this experience often, and am reminded to listen; to listen with every sense; to sense empathetically.

left:
Melissa and me, smoothing
with a Japanese block-plane.

figure 74

above, left;
In time and effort, the finishing process is often underestimated.

above, right:
A plastic drop cloth is used to create a dust-free environment for oiling.

figure 75

in time and effort, the finishing process is often underestimated

The treatment, or finish, can preserve and elevate the appearance of wood—or ruin it. Although there is a tremendous variety of wood finishes to choose from, most will fall under oil, water, wax, or resin based finishes that are naturally derived, synthesized, or a combination of the two. Each will offer unique advantages; each is suited to a particular context.

In the context of finishing our pine table, Melissa and I desired an all natural, oil based finish, that would provide a beautiful yet durable, food-safe, waterproof surface. To this end, pure tung oil is without parallel. Tung oil is derived from the nut of the tung tree, native to southeast Asia. Tung oil hardens to a transparent film when exposed to air, creating a protective layer in and around the wood being treated. Depending on relative humidity, pure tung oil can take two or more weeks to harden between coats, which is why it needs to be applied thinly. For heavy use surfaces, such as a table, up to ten coats are needed. After two months of oiling, Melissa and I settled with six: enough to cause water to bead.

right:
The harvest table, after finishing.

overleaf:
The harvest table in use.

figure 76

figure 77

Learning from the Past

In order to know what should be built . . . it was first necessary to observe what already existed. What was worth preserving? What sense, what atmosphere, should be duplicated in a new construction? It is possible for a code or formula to be followed to the letter and yet result in a work devoid of life, inert. This is the meaning of tradition: not formulae, but innate sense; not "design," but patterns of action and use. Only this can result in the preservation of those fragile constructs we call "culture."

Azby Brown, paraphrasing Tsunekazu Nishioka
The Genius of Japanese Carpentry

experiencing the work of masters

As our table neared completion, our reverence for wood grew. Thriving on the spirit of craftsmanship, Melissa began to experiment with other materials, including paper, and clay, and continued working with wood; building furniture and other craft, centered around the space of the table. I began designing and fabricating a timber frame tree-house; experimenting with wood joinery, and furniture, at a larger scale. We wanted to inform our work, by experiencing the work of a master. Having read about George Nakashima and Wharton Esherick, and having studied photos of their craft, Melissa and I were inspired to drive to Philadelphia, to visit their studios outside the city.

figure 78

figure 79

above:
George Nakashima Woodworker. The Office Showroom.

above:
Office Showroom: south elevation.

figure 80

above:
Furniture made to be touched.

above:
Inside the Conoid Studio.

right:
Conoid Studio, office.

above, right:
Main Workshop.

middle, right:
An organized workspace.

bottom, right:
A record of use.

figure 83

figure 84

figure 85

figure 86

left:
Blanks and spindles, stacked
for future use.

figure 87

left:
An old cherry tree features
prominently on the grounds.

right:
A cedar gate with buried
wood posts.

figure 88

above, right:
The Wharton Esherick Museum. The building at rear was designed in collaboration with Louis Kahn.

bottom, right:
Formerly a log cabin garage, the visitor's center features a hyperbolic roof.

figure 89

figure 90

left:
Wharton Esherick's studio.

right:
A grand view overlooking the valley.

right:
Seasoning lumber.

figure 93

Building a Tree-House

a new project

I became acquainted with Gregoire shortly after work on the harvest table had commenced. Greg asked me to design a tree-house, that would be located in a maple tree on his property, in Waterloo, Ontario. Greg wanted a tree-house for his grandchildren, Grace, and Nolan, who were six, and four years of age respectively.

Nearly a year passed before any serious work on the tree-house began. After having completed the table, awakened to the potential of wood as a building material, I considered the tree-house an opportunity to apply what I had learned investigating the relationship between furniture and the body, material and craft—at a larger scale. With the harvest table as a precedent, I made arrangements with Greg so that I could design, and then build the tree-house. In the time leading up to this arrangement, Greg had decided to move the build site from within the maple tree, to a place beside it, on the sloped part of his yard, at the rear of his property.


figure 94


figure 95

In the interest of preventing unnecessary damage to the maple, and to ensure some longevity to the build, Greg wanted the tree-house to be a freestanding pavilion, capable of accommodating his grandchildren through childhood, into young adulthood. We agreed that the pavilion should be intimate and playful enough for a child, spacious enough for an adult, and comfortable to both.

above:
Gregoire's yard, which backs onto Breithaupt Park, in Waterloo, Ontario.

above:
An old maple, at the rear of the yard: the initial site.

figure 97

figure 96

above, left:
Local sources of inspiration:
the Historic City Hall...

above: right:
...the Fire Hall...

figure 98

Experientially, we wanted the pavilion to retain the feel of a proper tree-house. I felt the design should inspire wonder in a manner suited to the larger scale and longer lifespan of the build, and to the sensibility of the owners, and neighbourhood. It seemed appropriate to adopt a gazebo typology, and to reference to the rich local vernacular; I was inspired by the towers and roof-scapes characteristic of the 19^{th} century Waterloo, Cambridge, and Galt landscape.

above:
...and the old Galt Post
Office, in Galt, Ontario.

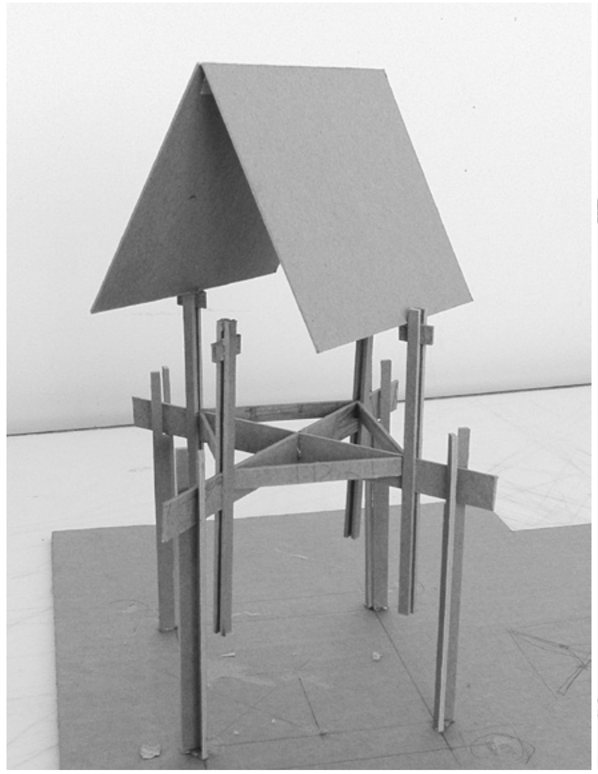


figure 99

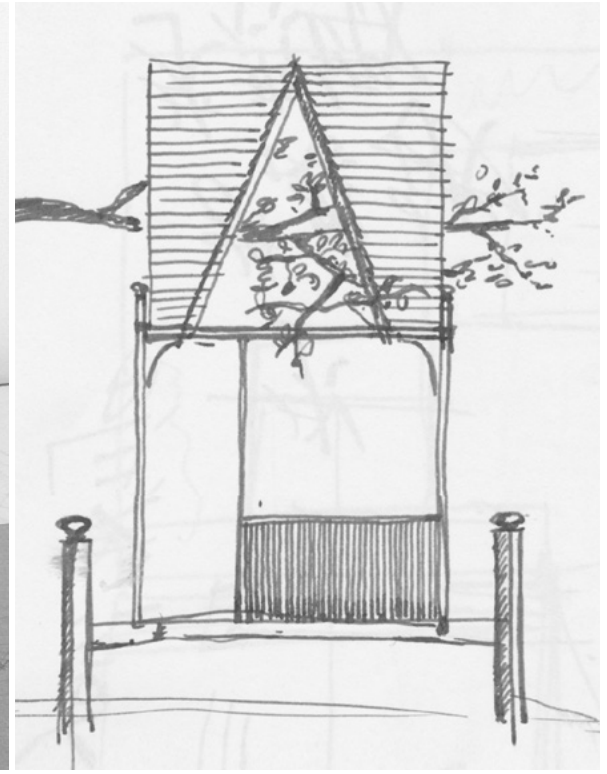


figure 100

figure 101

After a number of exchanges, Gregoire and family, and I agreed upon a concept design, *(figure 101)* in which the floor, supported above the ground and inside of the footings, lends a feeling of suspension. A tall, pyramidal gable roof harbours one of the boughs of the maple, a leafy canopy furthers the sensation of being in the tree, and vertical elements that are accentuated to imply an upward rise take a cue from the Gothic revival common in the Tri-City area.

above, left:
An early concept model.

above, right:
A tall pyramidal gable
harbours a leafy canopy.

Because the tree-house would be inhabited by children, it had to be designed to work. A square form showing symmetry would make the structure easier to resolve, easier to construct, and would allow some freedom in the expression of individual members and joints. The chosen design would make an excellent testing ground for sustainable building practices in the form of pre-fabrication, timber-frame construction, and natural materials and finishes.

above:
A covered platform on stilts
gives the impression of
being suspended.

figure 102

above:
These timbers were once used to house tractor equipment shipped from Germany.

scots pine

Pinus sylvestris, or scots pine, is a lightweight, moderately hard conifer native to Europe and Asia. Scots pine was introduced to North America in the 15th century, but does not grow very well there, due in part to adverse soil conditions and poor diversity in the initial seed stock—making it susceptible to damage by pests. Scots pine wood is similar in appearance and smell to other pine woods. It is a major source of lumber in its native area because it grows straight and tall, and is used in all manner of constructions, most notably in the stave churches of Norway, where the tree was once an important resource in the pine tar industry.

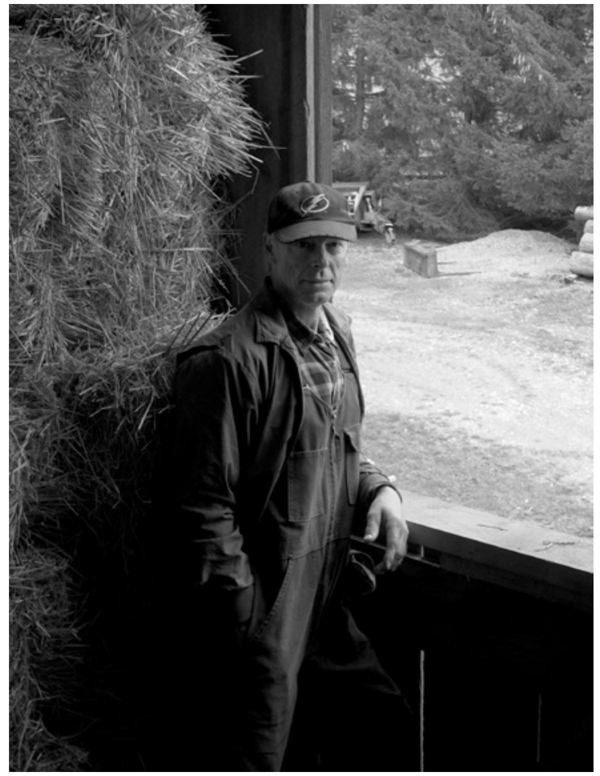


figure 103

figure 104

white oak

Quercus alba, or white oak, is a dense hardwood native to eastern North America, where it is one of the most prevalent hardwoods. White oak heartwood is brown to light-brown in colour, with sapwood that is noticeably lighter. White oak is prized for its durability and rot resistance: a result of its closed cell structure, making it ideal for use in applications susceptible to damage by water. The *USS Constitution*, a frigate of the United States Navy, was famously nick-named "Old Ironsides" after the war of 1812, because her white oak hull and masts proved exceptionally durable.

above:
This is Bill. He runs an independent mill in Granton, Ontario.

right:
Bill sold me choice pieces of air-dried, quarter sawn white oak for two dollars a board foot.

overleaf:
Bill's Barn is more than a century old, and still bears all the original members, including the pine cladding.

figure 105

figure 106

above:
The resiliency of timber-frame construction keeps this barn standing, despite its dilapidated state.

timber frame construction

It was not until the widespread use of iron tools that more complex forms of wood joinery would have developed, around 200 BCE. By the middle of the 1st century, Buddhist carpenters spread out from India and into China via central Asia, disseminating their knowledge of wood construction, which, by the time it had reached Japan in the 6th century would already have been highly developed. Because of environmental and cultural factors, timber frame construction and wood joinery flourished in Japan, resulting in what many consider to be the epitome of wood architecture. At the height of their craft, Japanese carpenters, driven by intense rivalry among guilds, produced in the order of seven hundred unique joints of varying complexity, four hundred of which are still in use today.

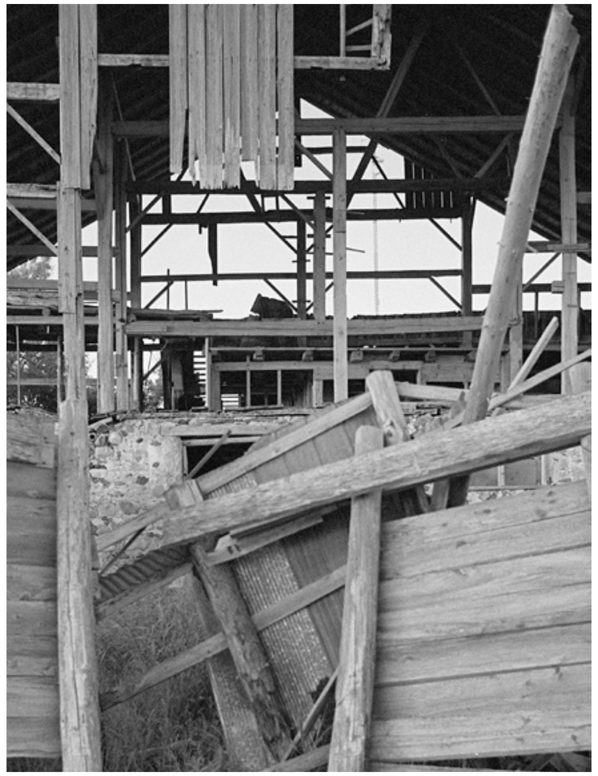


figure 107

In Europe, then Scandinavia, timber frame construction developed somewhat later, maturing into a sophisticated and refined craft responsible for the ornate roof trusses that we still admire, in the many churches, cathedrals and palaces throughout those regions.

Early European colonists, setting foot in North America for the first time, pressured by harsh weather and a need for shelter, adapted their ornate woodworking traditions toward the utilitarian, and developed an efficient structural system, comprised of a series of cross-sectional frames, or "bents"— joined together with beams to form an enclosure. This stripped back, functional vernacular, characterized much of the wood construction that followed. We can still witness the remnants of this craft in the many barns that proliferated across the continent.

above:
Several layers of timber-frame "bents"

Timber frame construction began to fall out of favour when it could not keep up with the pace of industrialization. By the 20th century, stud frame construction had largely replaced the slower, but otherwise superior, timber frame tradition. More recently, people are returning to timber framing for its structural efficiency, beauty, and comparatively low embodied energy. With the adoption of engineered lumber, and advances in manufacturing, we can expect to see timber-frame technology re-entering the construction industry in a big way.

figure 108

above:
Planing bench and covered outdoor workspace.

September 2012: fabrication commences

I constructed a temporary work shelter out of doors so that I would have enough space to joint, thickness, and true the lumber that would become the structure of the tree-house. Given that several of the structural members would end up six to thirteen feet in length, I also made a work bench, loosely influenced by traditional Japanese planing benches, and the Ruobo bench: a European design dating back to the 18^{th} century. While I was open to utilizing both hand and power tools, the limitations of the machine tools available to me meant that I would have to dress the largest members by hand.

Building my own bench allowed me to experiment with, and monitor the performance of, common timber-frame joints, in the months leading up to the installation of the tree-house.

above, right:
Cutting an angled mortise that will receive the hind trestle leg.

bottom, right:
A trestle with an angled leg helps stabilize the bench.

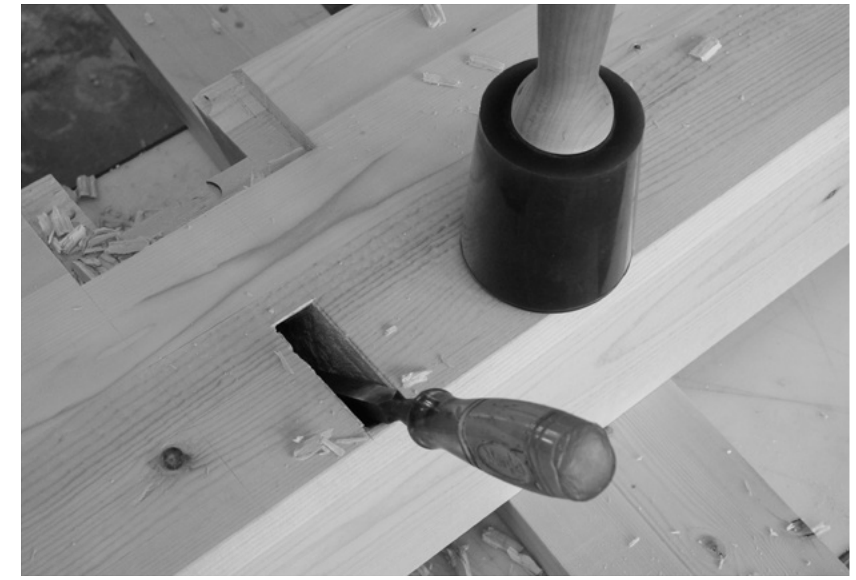


figure 109


figure 110

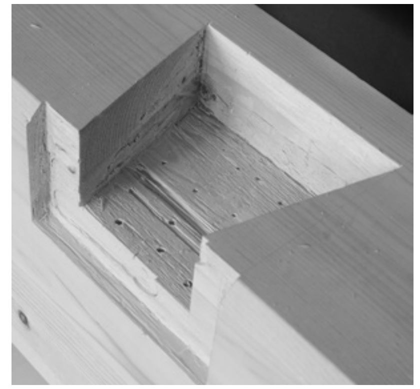


figure 111

figure 112

top:
A shouldered, half-lap dovetail...

bottom:
...joins the front leg to the bench top.

figure 113

above:
A shallow ledge keeps tools close at hand.

right:
Truing and squaring a cedar post: one of four cedar wood footings.

figure 114

above, right:
Trued and squared footings are set into excavated post holes...

middle, right:
...made plumb with a spirit level, and braced into position.

bottom, right
A laser pointer helps establish the elevations of the footings relative to one another.

figure 115

figure 116

figure 117

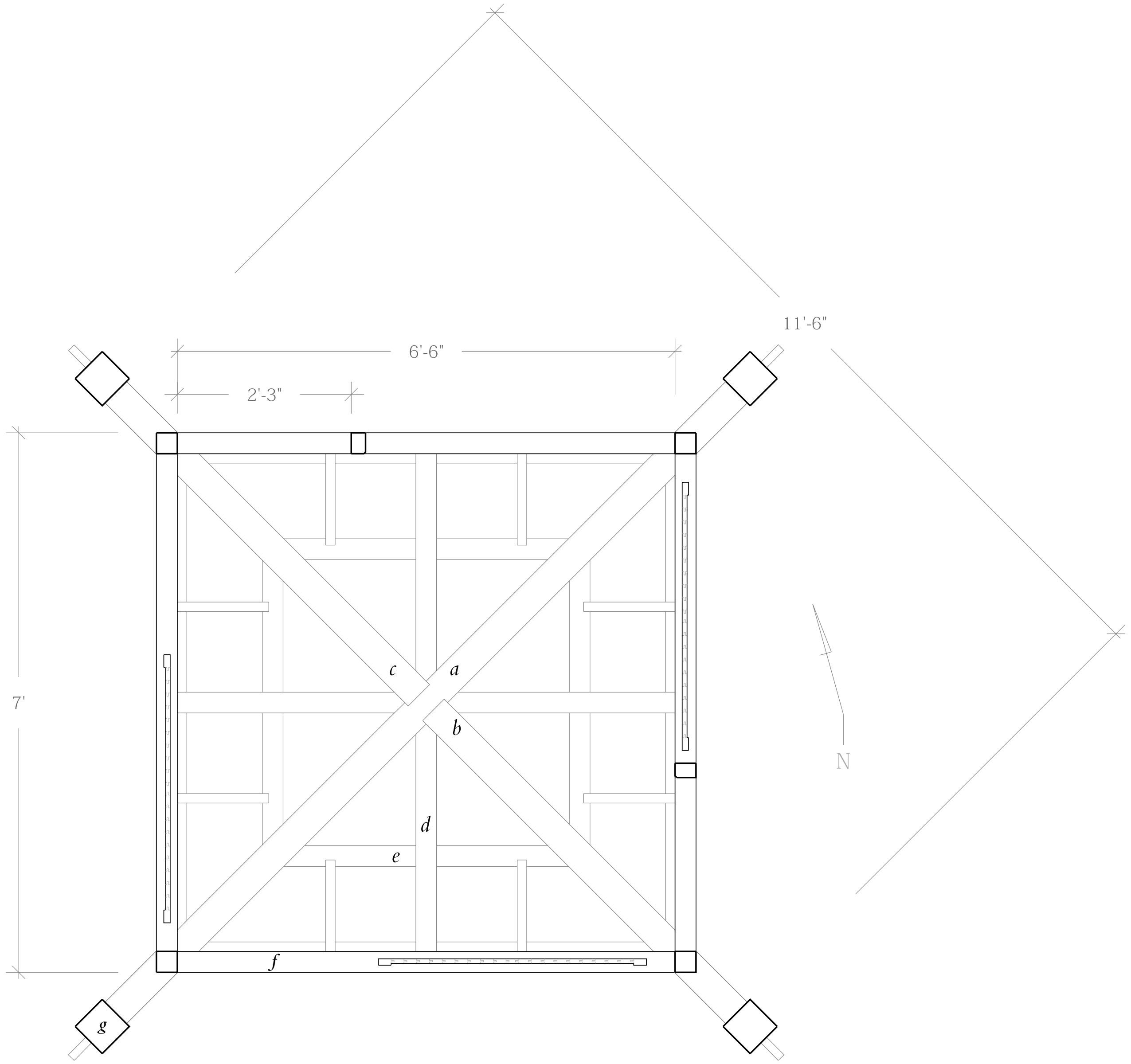


figure 118, above:
Structural Floor Plan.

innovation

After the post-holes had been excavated and the footings marked, I began work on the floor assembly. With total span of 12 feet and an effective depth of 5 ¾ inches, the primary floor beam, *(figure 118, **a**)* exhibited a substantial amount of deflection under load. In traditional Japanese timber construction, the span of a floor beam is often broken up by a post, with a dado with cross-tenon lap joint, *(figure 132)*. I adopted the dado with cross tenon lap joint in the connection of the primary and secondary floor beams *(figure 118, **a**,**b**,**c**)*. The absence of a central post, however, necessitated the development of a unique structural system to diffuse the deflection of the primary floor beam *(**a**)*, to the footings *(**g**)*. I modified the dado with cross-tenon lap joint at center, adding stub-mortises at the junctions of the primary and secondary floor beams *(**a**,**b**,**c**)*, that receive a lever arm *(**d**)*. The primary floor beam, deflecting under load, thus rotates the lever arm about a fulcrum *(**e**)*, which diffuses the load away from the center of the platform toward the mud-sill *(**f**)*, and out to the primary and secondary floor beams, where they connect to the footings.

figure 119

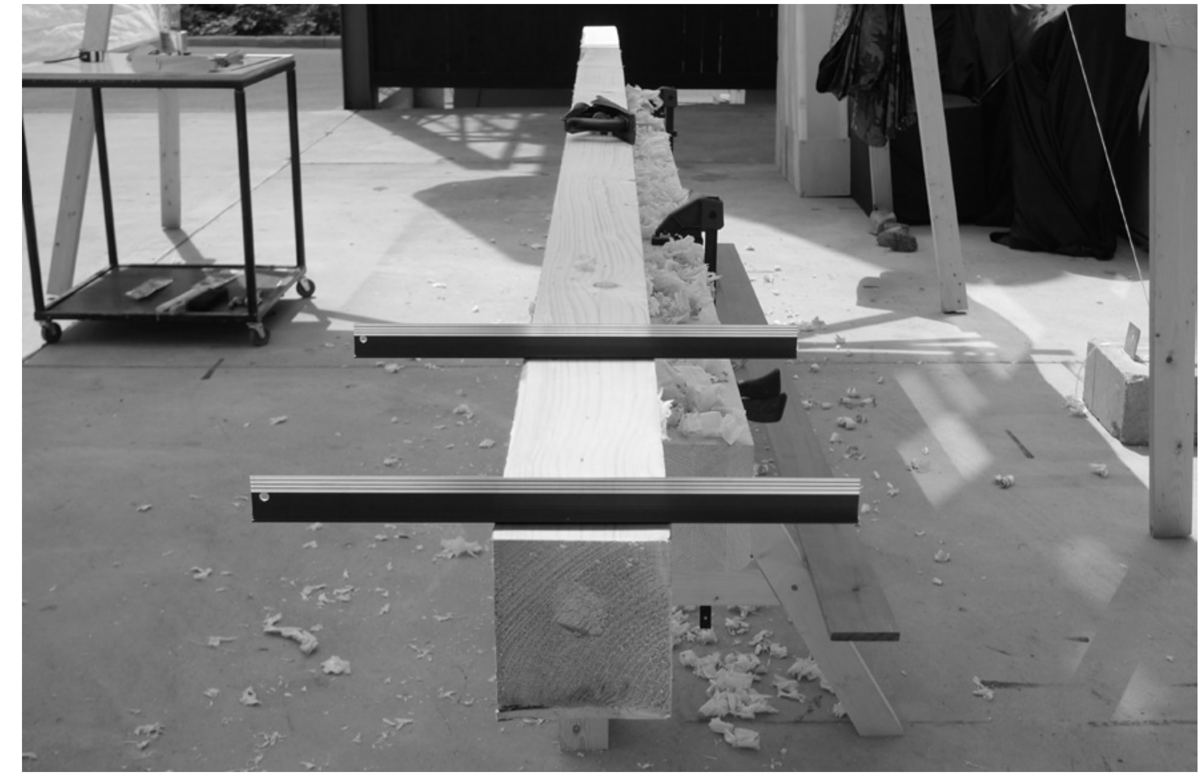


figure 120

above:
A straight edge is a visual aid used to assess the degree of flatness of a board.

above:
Winding sticks—used to gauge the degree of twist in a board—help with truing even the longest boards.

right:
I made this ink-line, which
is similar to a chalk-line, but
more accurate.

figure 121

figure 122

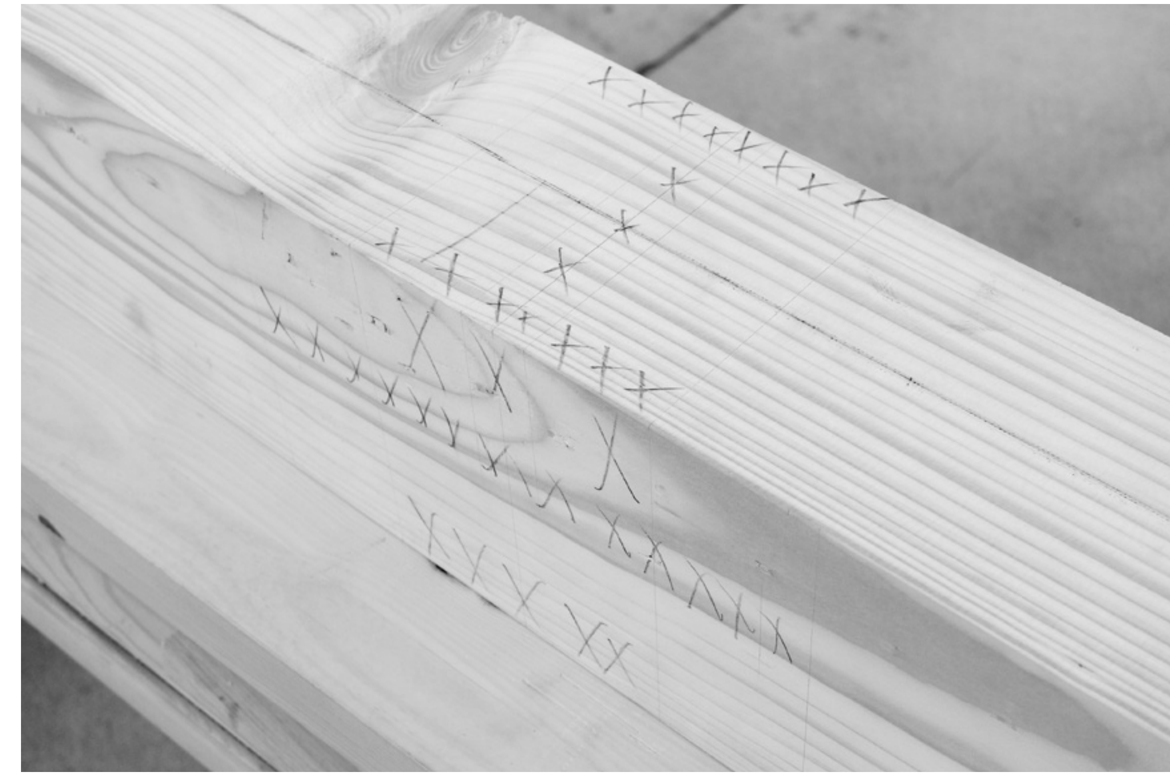


figure 123

above:
An ink line is pulled taught
and snapped to mark a
center line on a major beam.

above:
Joints are laid out relative
to center lines to ensure
accuracy across all
members.

right:
Rip cutting a tenon.

far right:
Wedging-open deep rip cuts prevents the wood from clamping down on the saw blade.

figure 124

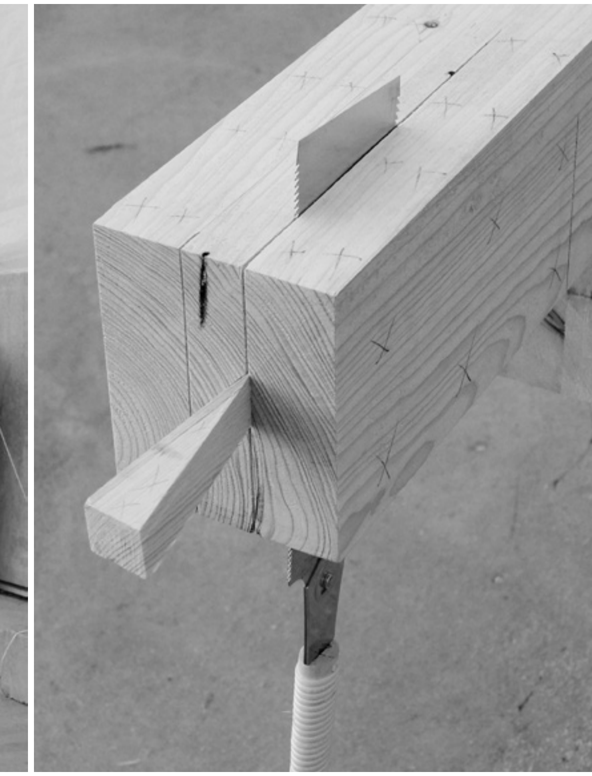


figure 125

right:
A dado and tenon take
shape.

figure 126

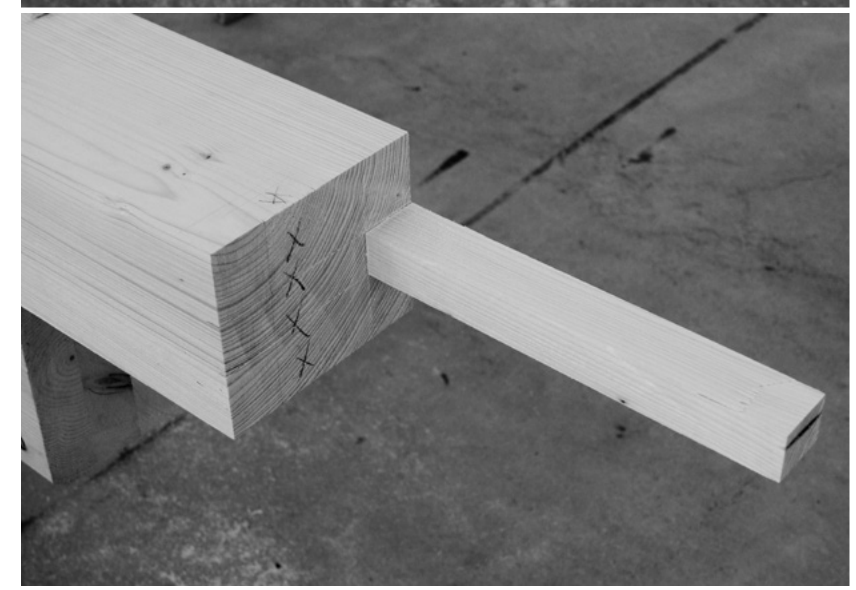


figure 127

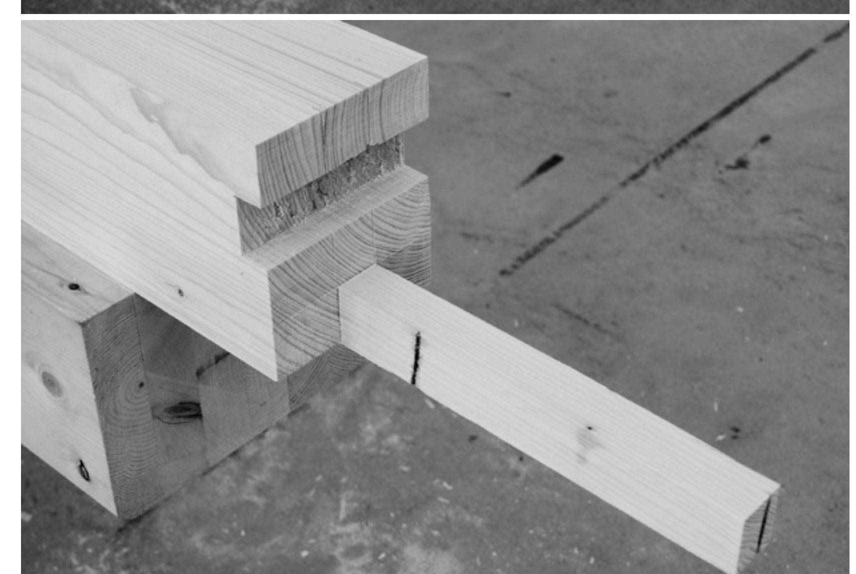


figure 128

right:
A snug fit for a through tenon: the underside of a dado with cross-tenon lap joint.

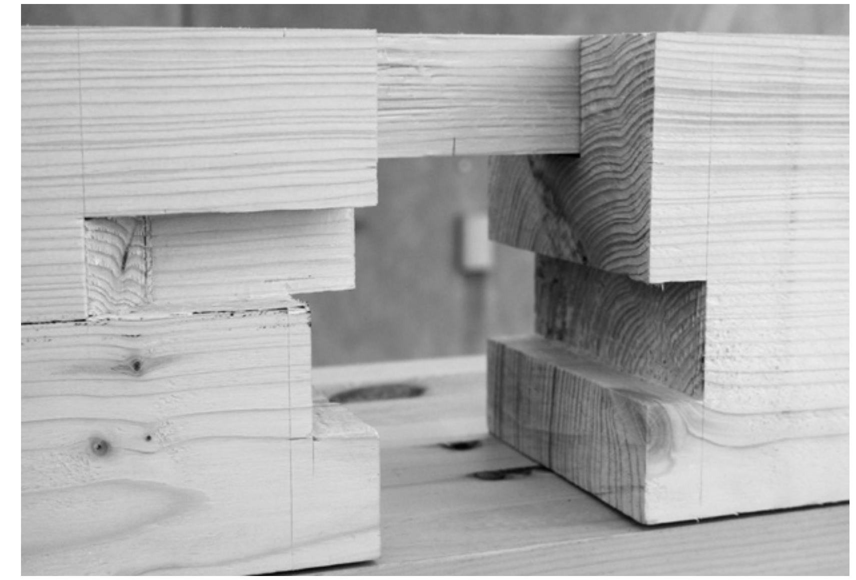


figure 129

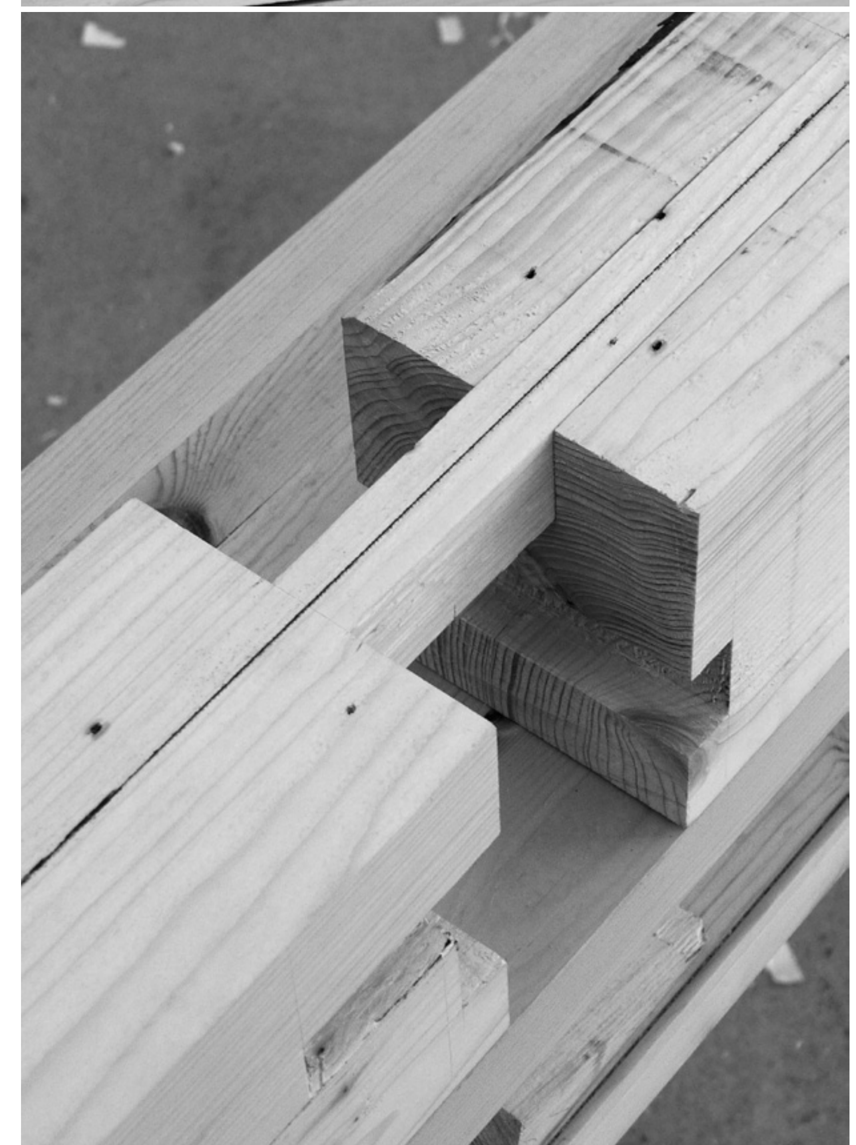


figure 130

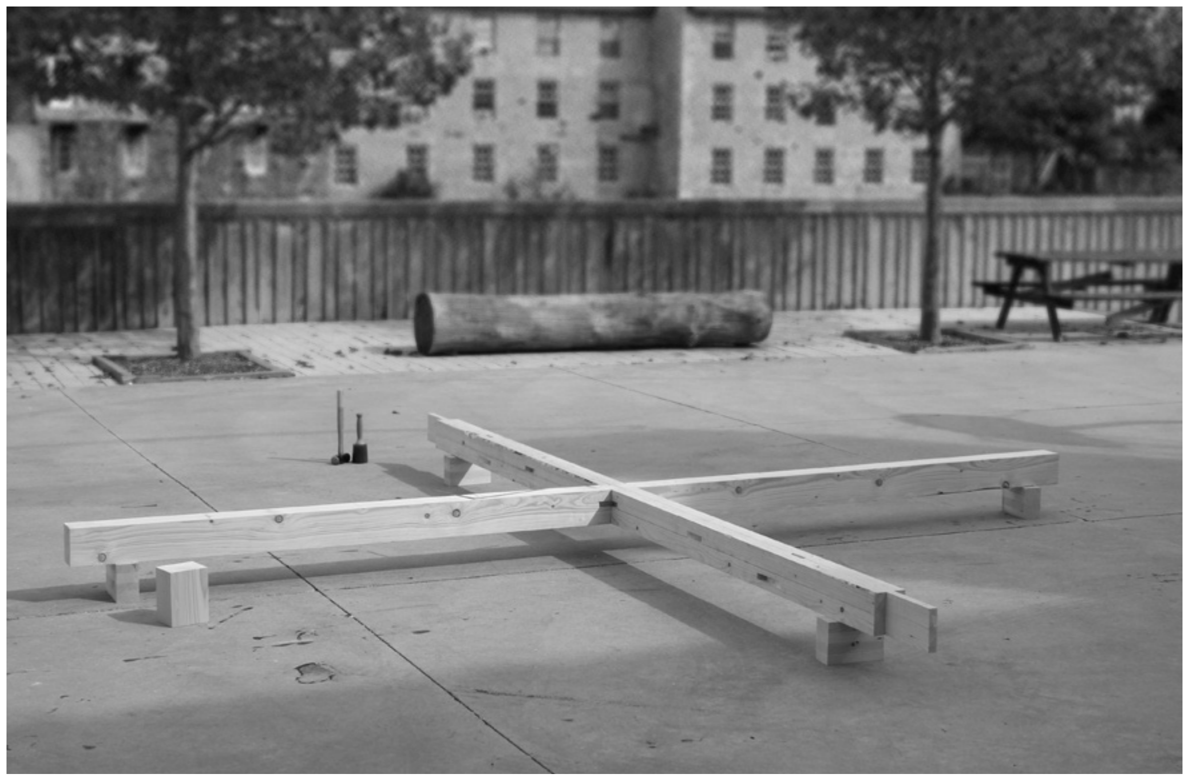


figure 131

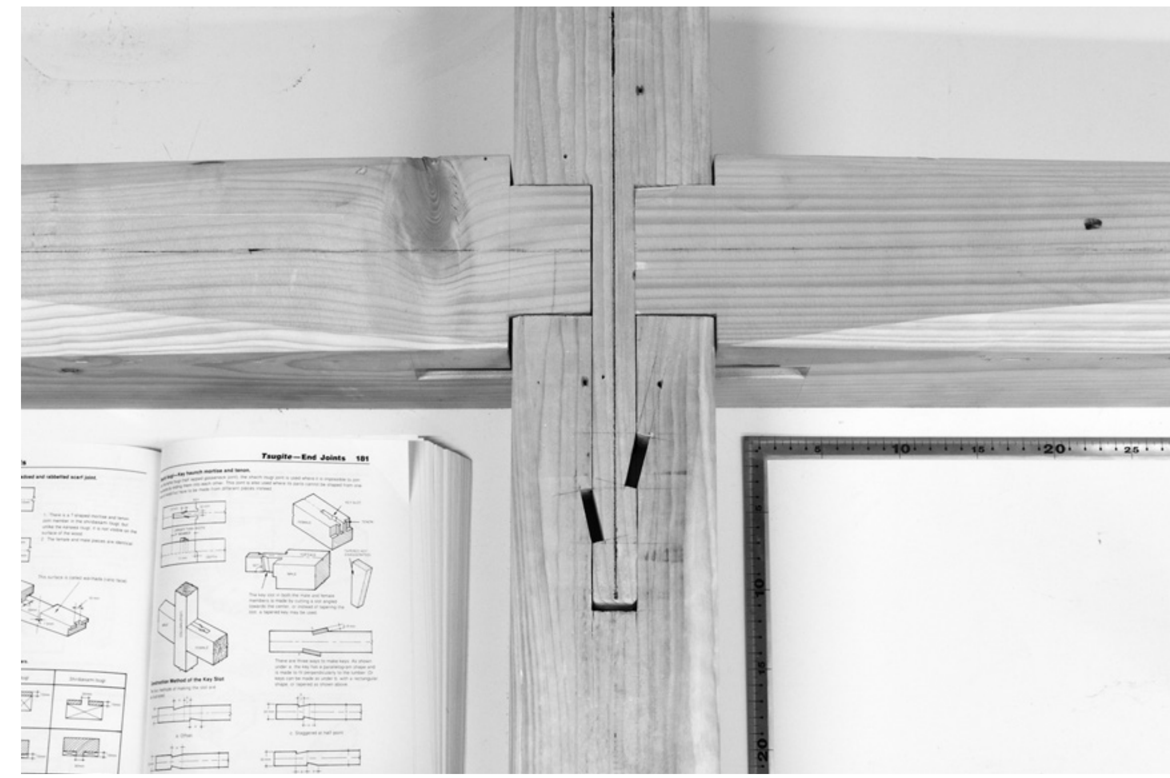


figure 132

above:
A dado with cross-tenon lap
joint, assembled.

above:
The underside of a dado
with cross-tenon lap joint.

above, right:
These mud-sills, roughly two meters long, frame the playhouse floor.

middle, right:
Angled stub-tenon lap joints at the corners...

bottom, right:
...intersect the main cross beam, at the location of the corner posts.

figure 133

figure 134

figure 135

figure 136

left:
Fixing one of many mistakes:
a scarf joint is used to
lengthen a mud-sill.

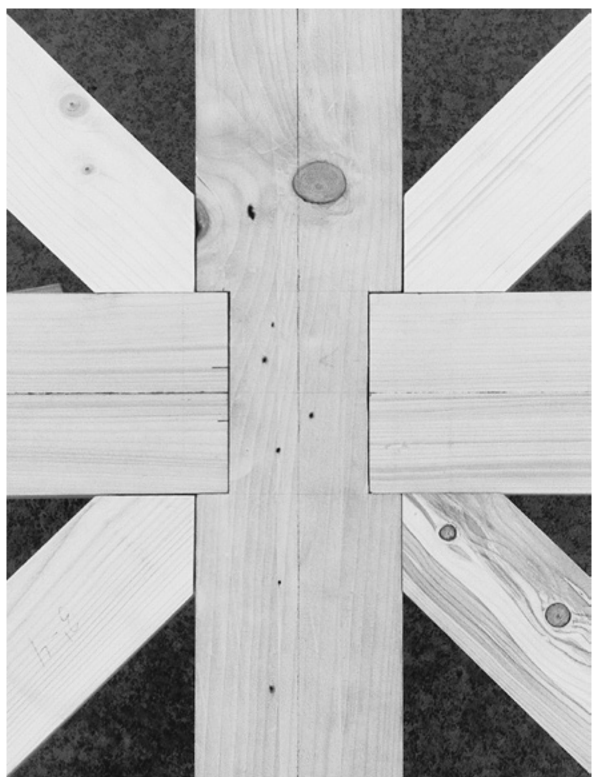


figure 137

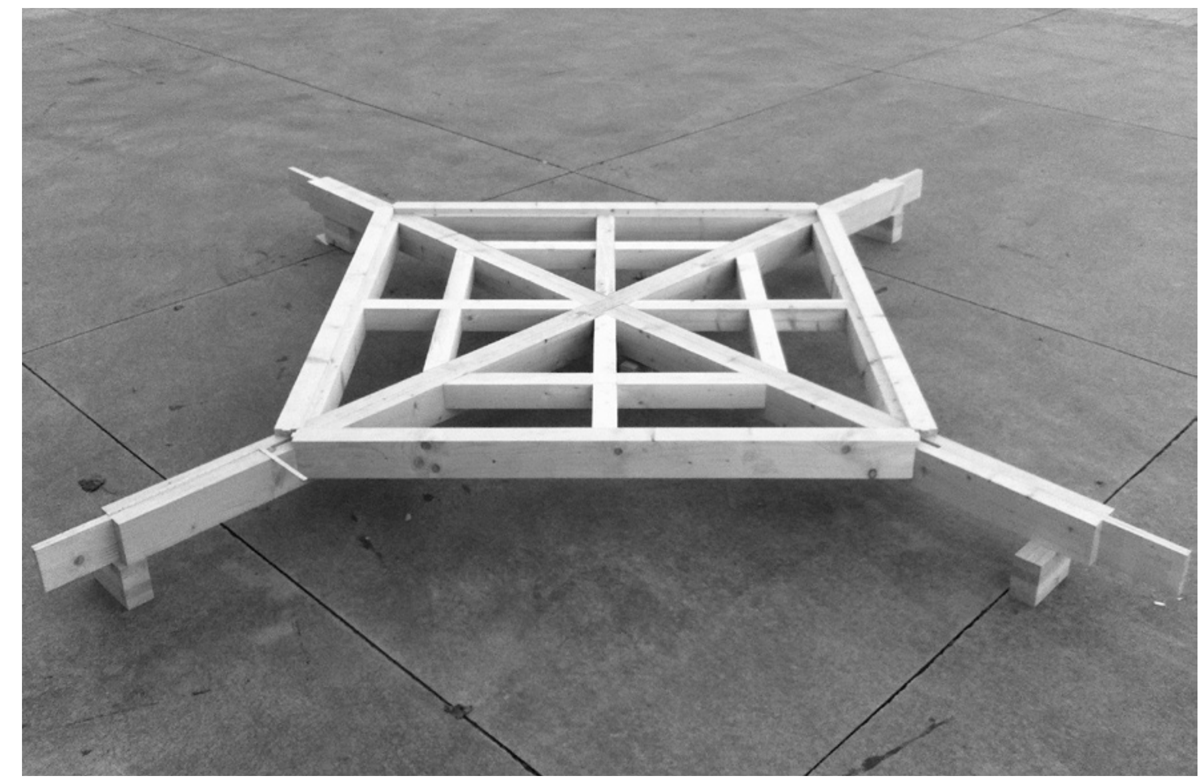
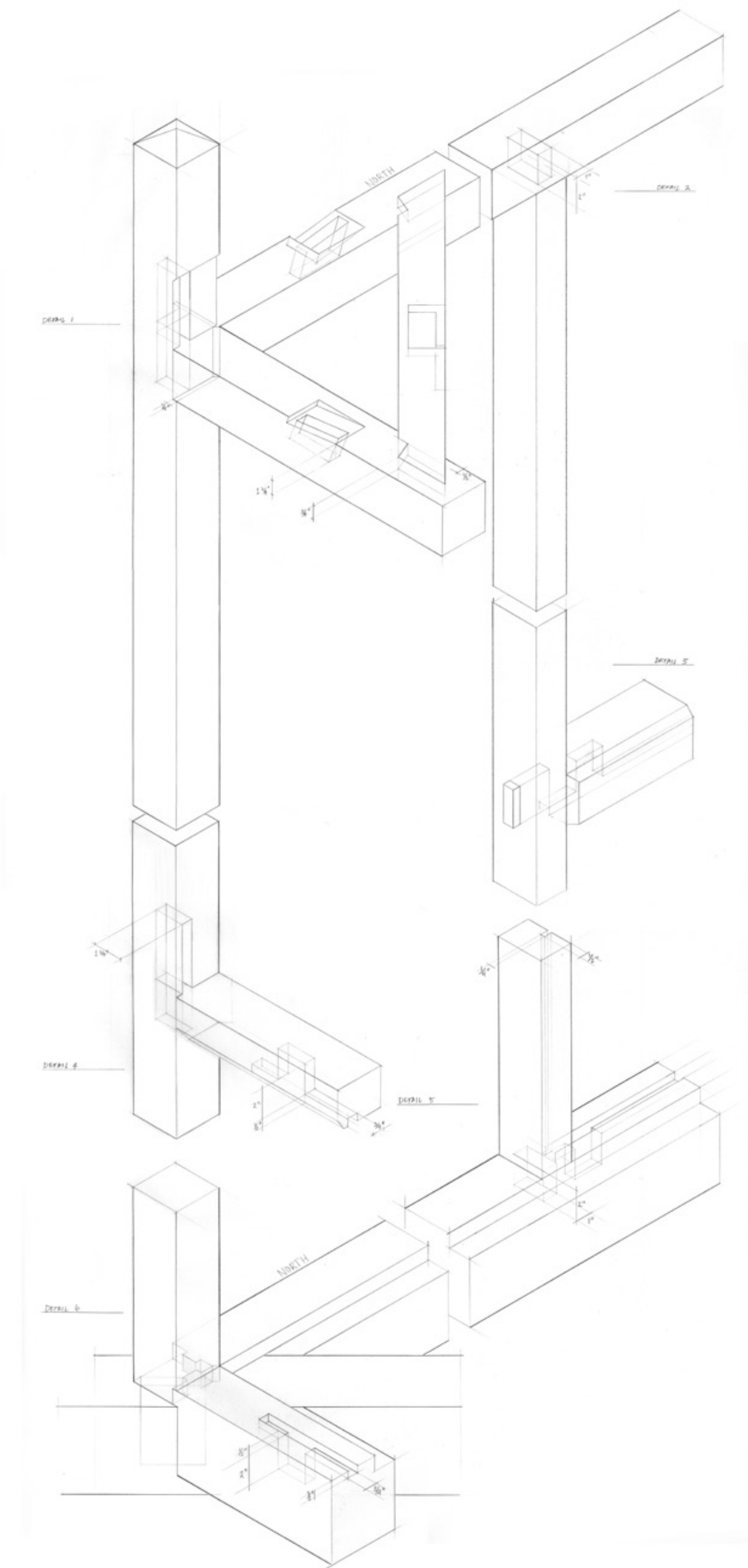


figure 138

above:
A modified dado with cross-tenon lap joint connects the main floor beam to six supporting beams...

above:
...so that bending can be deflected to the mud-sills and footings.

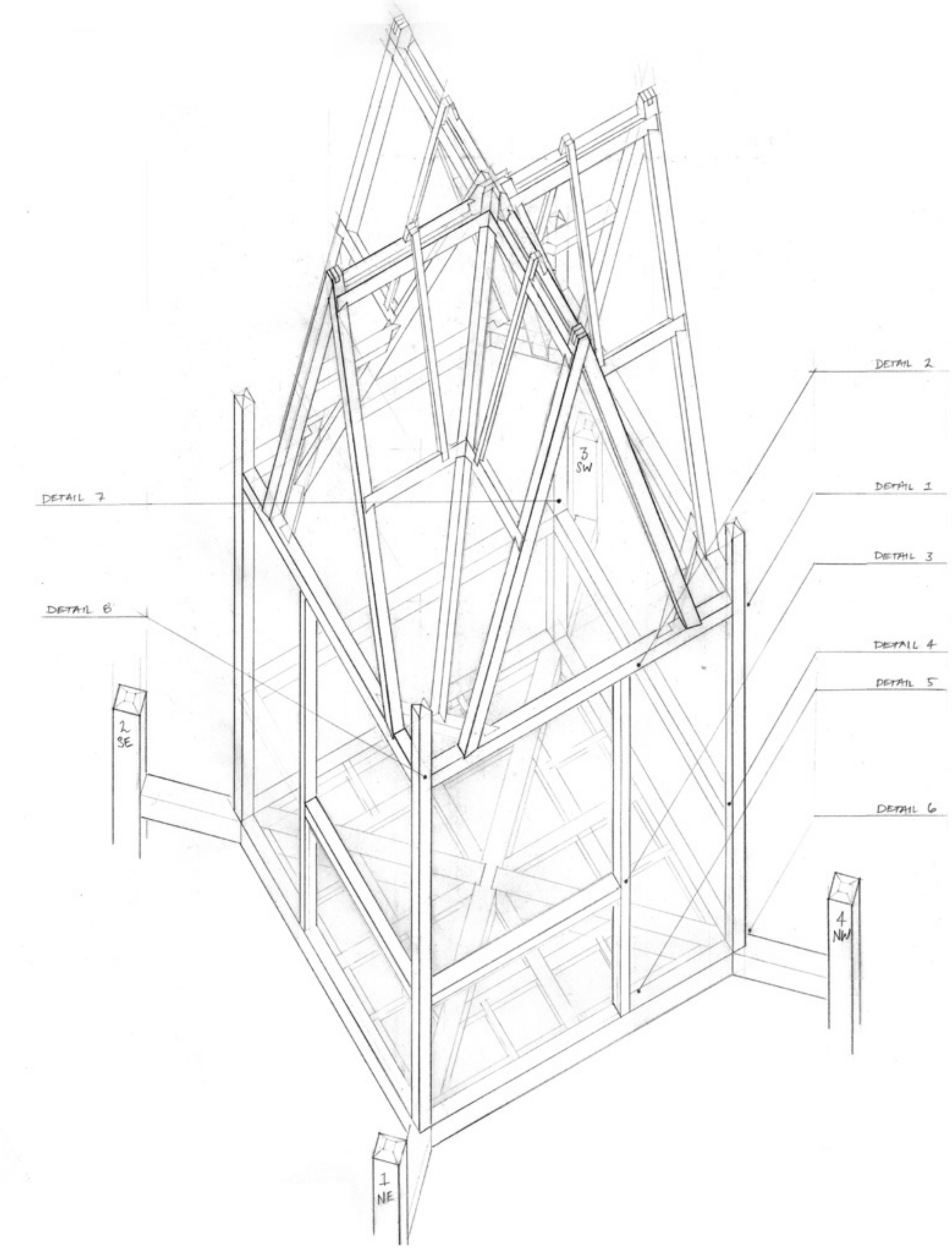


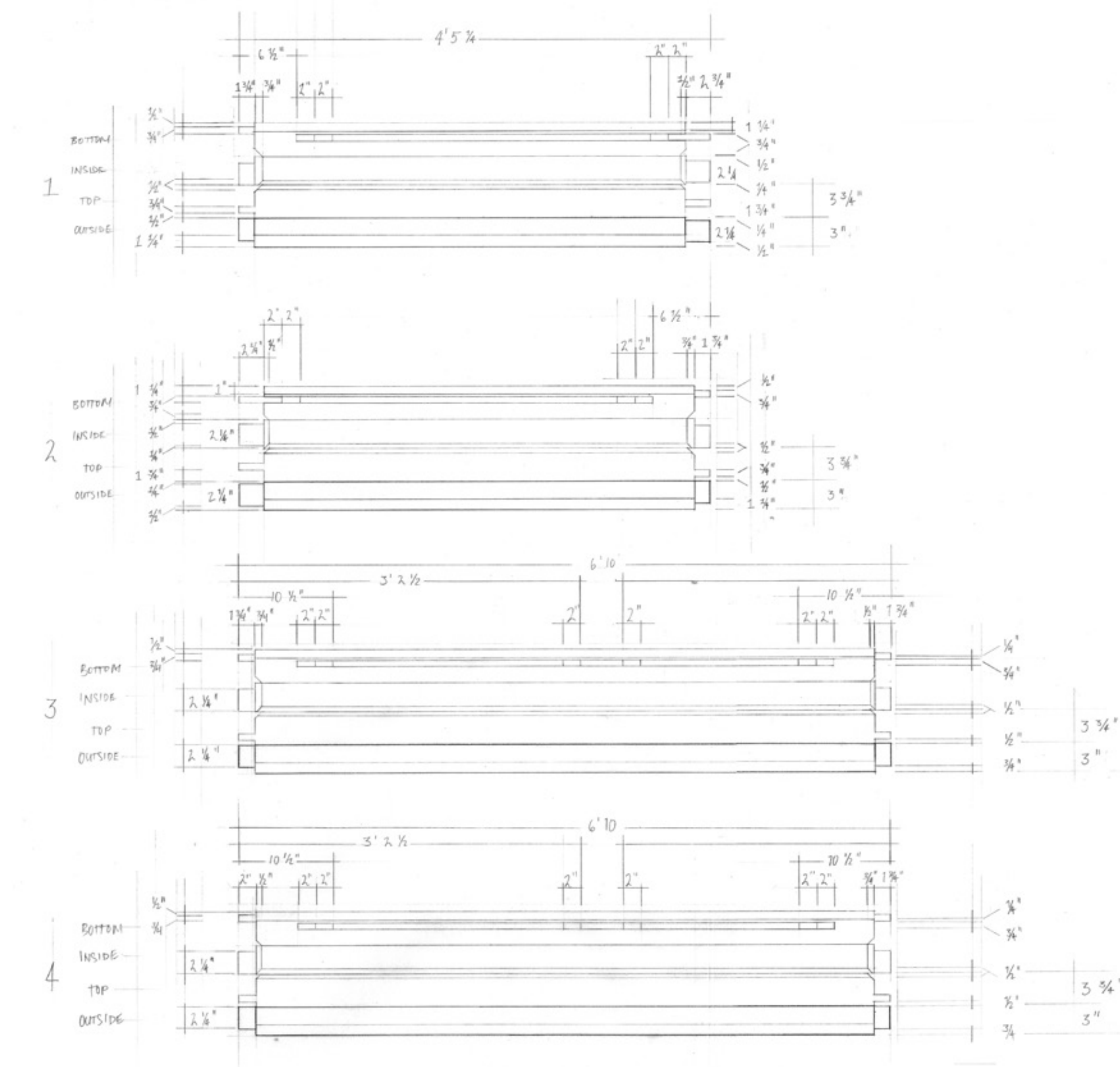
drawing by hand helps develop spacial awareness

During the fabrication of the platform, I had been working from rough sketches of joints, and an accurate and complete, computer model. Nonetheless, I found it difficult to visualize all of the joints in relation to one another. My "spatial blurriness" was the cause of many errors in measuring, and cutting. I needed to internalize the project in order to reduce human error. I took the time to draft all key details by hand, and produced a component schedule inspired by Japanese layout drawings. The physical act of tracing every contour of every joint by hand, familiarized my body to the landscape of the project. Drawing in two dimensions forced me to visualize the construction in three dimensions. During this exercise, I redesigned several joints after realizing they would be impossible to assemble.

figure 136, left:
Post, beam, sill, railing, and brace details at entrance.

right:
Structural axonometric of the playhouse. Refer to Appendix C .





right:
Railing layout diagram. Every component is drawn unfolded, to facilitate locating joints relative to each face.

Task	Start	End	Time
1.0 - TREEHOUSE BUILD	13/08/03 9:00 AM	14/03/30 5:00 PM	8mo 3w 2d 6h
1.1 - Phase 1: Prefabrication	13/08/03 9:00 AM	14/02/13 5:00 PM	7mo
MILESTONE - 1.1.1 - Dimensioning Begins	13/08/03 9:00 AM	13/08/03 9:00 AM	
1.1.2 - Dimensioning	13/08/05 9:00 AM	13/09/09 5:00 PM	1mo 1w 1d
1.1.2.1 - Dimensioning Principal Rafters	13/08/05 9:00 AM	13/08/09 5:00 PM	1w
- 1.1.2.1.1 - Planing Principal Rafter, block 1	13/08/05 9:00 AM	13/08/05 5:00 PM	1d
- 1.1.2.1.2 - Planing Principal Rafter, block 2	13/08/06 9:00 AM	13/08/06 5:00 PM	1d
- 1.1.2.1.3 - Planing Principal Rafter, block 3	13/08/07 9:00 AM	13/08/07 5:00 PM	1d
- 1.1.2.1.4 - Planing Principal Rafter, block 4	13/08/08 9:00 AM	13/08/08 5:00 PM	1d
- 1.1.2.1.5 - Thicknessing Principal Rafters, blocks 1-4	13/08/09 9:00 AM	13/08/09 12:00 PM	3h
Only on one side.			
- 1.1.2.1.6 - Ripping Principal Rafter blocks 1-4	13/08/09 1:00 PM	13/08/09 3:00 PM	2h
- 1.1.2.1.7 - Thicknessing Principal Rafters, ripped faces, 1-8	13/08/09 3:00 PM	13/08/09 5:00 PM	2h
1.1.2.2 - Dimensioning Tertiary Posts	13/08/12 9:00 AM	13/08/13 5:00 PM	2d
- 1.1.2.2.1 - Planing Tertiary Post, block 1	13/08/12 9:00 AM	13/08/12 5:00 PM	1d
- 1.1.2.2.2 - Thicknessing Tertiary Post, block 1	13/08/13 9:00 AM	13/08/13 12:00 PM	3h
Only on one side.			
- 1.1.2.2.3 - Ripping Tertiary Post, block 1	13/08/13 1:00 PM	13/08/13 3:00 PM	2h
- 1.1.2.2.4 - Planing Tertiary Posts, ripped faces, 1-2	13/08/13 3:00 PM	13/08/13 5:00 PM	2h
1.1.2.3 - Dimensioning Railings	13/08/14 9:00 AM	13/08/20 5:00 PM	1w
- 1.1.2.3.1 - Planing Railing, block 1	13/08/14 9:00 AM	13/08/14 5:00 PM	1d
- 1.1.2.3.2 - Planing Railing, block 2	13/08/15 9:00 AM	13/08/15 5:00 PM	1d
- 1.1.2.3.3 - Planing Railing, block 3	13/08/16 9:00 AM	13/08/16 5:00 PM	1d
- 1.1.2.3.4 - Planing Railing, block 4	13/08/19 9:00 AM	13/08/19 5:00 PM	1d
- 1.1.2.3.5 - Thicknessing Railings, blocks 1-4	13/08/20 9:00 AM	13/08/20 5:00 PM	1d
1.1.2.4 - Dimensioning Roof Beams	13/08/21 9:00 AM	13/08/23 5:00 PM	3d
- 1.1.2.4.1 - Planing Roof Beam, block 1	13/08/21 9:00 AM	13/08/21 1:30 PM	3h 30m
- 1.1.2.4.2 - Planing Roof Beam, block 2	13/08/21 1:30 PM	13/08/21 5:00 PM	3h 30m
- 1.1.2.4.3 - Planing Roof Beam, block 3	13/08/22 9:00 AM	13/08/22 1:30 PM	3h 30m
- 1.1.2.4.4 - Planing Roof Beam, block 4	13/08/22 1:30 PM	13/08/22 5:00 PM	3h 30m
- 1.1.2.4.5 - Thicknessing Roof Beams, blocks 1-4	13/08/23 9:00 AM	13/08/23 5:00 PM	1d
1.1.2.5 - Dimensioning Tie-Beams	13/08/26 9:00 AM	13/08/28 5:00 PM	3d
- 1.1.2.5.1 - Planing Tie-Beam, block 1	13/08/26 9:00 AM	13/08/26 5:00 PM	1d
- 1.1.2.5.2 - Planing Tie-Beam, block 2	13/08/27 9:00 AM	13/08/27 5:00 PM	1d
- 1.1.2.5.3 - Thicknessing Tie-Beams, blocks 1-2	13/08/28 9:00 AM	13/08/28 5:00 PM	1d

time management is predicated on adaptability

There is a reason why a traditional woodworking apprenticeship lasted upwards of seven years—fifteen in ancient Japan: developing skill requires prolonged effort. Lacking a high degree of skill, and an innate sense of discipline, my efforts where slow, and wrought with failure—essential ingredients in any learning process. However, aiming to finish in a reasonable amount of time, in the interest of completing a master's degree in architecture, I created a work breakdown structure, outlining the remainder of the build. A WBS was instrumental in expediting my work-flow. Being able to keep track of a task in relation to all others allowed me to allocate my time and effort more efficiently. Rarely did I meet my projected deadlines. My sense of time adapted whenever I revised my schedule. The final revision of the tree-house WBS revealed eight months of seven-hour work days, five days a week, spent on building alone: this metric does not represent any work done up to the production of the drawing set, or any research and practice carried out in parallel to the build.

left:

WBS, excerpt. Refer to Appendix D

figure 143

figure 144

a sense of scale

A six foot square marked on the ground feels too small. A thirteen foot rise feels too tall. While fabricating the many components that make up the tree-house, I found that an acute sense of scale, like an acute sense of time, remains the most elusive.

above:
Melissa, posing next to a height of four meters: the height of the tree-house.

above:
Assessing the platform width, and floor to ceiling height.

figure 145

figure 146

above:
After the footing joints are located, a power drill with an auger bit helps waste out deep sections of wood.

above:
A hole in this mirror allows the auger bit to pass through; its reflection helps keep the drill plumb.

figure 147

above:
After an initial drilling with an auger bit, a mortise is given shape with a mortise chisel.

figure 148

working across a range of tools

In "The Genius of Japanese Carpentry", author Azby Brown points out that modern Japanese temple carpenters, having access to power tools, must still learn to use traditional hand tools. Being able to work across a range of tools affords the modern carpenter tremendous flexibility. Nonetheless, the modern temple carpenter chooses, whenever possible, to use hand tools for the subtle tactile feedback they provide over power tools.

above:
A paring chisel is used to clean up the inside faces of a mortise.

figure 149

above:
Checking the secondary bevel on a paring chisel.

left:
Lapping a paring chisel on a ceramic water-stone.

figure 150

sharpening

The ability to sharpen well hinges on the development of other skills, including: concentration, patience, and listening. At its most basic, sharpening by hand involves lightly stroking the bevelled edge of a blade across a water-stone—so called because it is lubricated with water—or similar, flat, abrasive surface. Lapping a blade across a series of water stones, each with a finer grain than the last, produces a sharp edge. In practice, one must consider the composition of the blade and what kind of abrasive it is best suited for; one must determine how much sharpening is necessary and be weary of over-sharpening; one must develop good posture and technique for smooth, steady, efficient strokes. With good technique, every blade will produce a unique vibration—a signature tone—and it takes a practiced concentration to grow sensitive to the sound and feel of a steel blade, floating on its bevel across a water stone.

figure 151

figure 152

above, and right:
Custom wood cradles are used to clamp a post at an angle, to facilitate the cutting of a tenon.

Priority is given to instilling in the young apprentice a sense of respect and humility, not merely toward his superiors, but more importantly toward the wood and the work. The first tasks are deceptively simple: sweeping the shop floor, fetching tea, helping lift heavy members. Yet even these seemingly mindless tasks have the potential to teach concentration, exactitude, and teamwork, all of which are absolutely essential for the more complicated work ahead.

Azby Brown,
The Genius of Japanese Carpentry

figure 153

above:
Cleaning up after a day's work.

figure 154

figure 155

August 2013: a change of site

In the summer of 2013 Gregoire and Pat decided they would be selling their house the following year. It made sense to move the installation of the tree-house to their daughter and son-in-law's property nearby. Fortunately, this news came before any building on site had commenced. Because I was nearly a year into the construction of all the components, with only a few pieces that make up the roof structure left to fabricate, there was little room for modifications to the overall design.

A few minor changes included lowering the height of the platform to accommodate a flatter site, and lowering the height of the roof, to comply with zoning by-laws. I also removed a railing side-wall, in order to open up the tree-house to a part of the yard the children frequently play in: a space inhabited by a burning bush that Grace and Nolan affectionately refer to as "The Enchanted Forest".

above:
Jana, Greg, and Melissa, assessing the new site.

above, right:
This burning bush glows bright red in the fall. It is the location of Grace, and Nolan's "Enchanted Forest".

figure 156

above:
Triangulating the locations of the post holes at the new site.

figure 157

above:
A gas powered auger has difficulty dislodging large stones.

figure 158

figure 159

figure 160

when hand is mightier than machine

A foot below grade under a layer of sod and clayish topsoil Gregoire and I encountered a very cobbly but well graded, gravely-sand. The soil promised very good load-bearing characteristics, and excellent drainage, but the amount of cobble (stones ranging in size from a few inches to a foot in diameter) made digging very difficult. After a few rotations, the auger—lodged or floating on stones too large to remove—had to be lifted out so that the offending obstacle(s) could be dislodged, with a shovel, or a crow-bar, or some similar tool. When these tools proved ineffective, I resorted to clawing around the half buried stones, and prying them out by hand.

left:
Dislodging stones by hand.

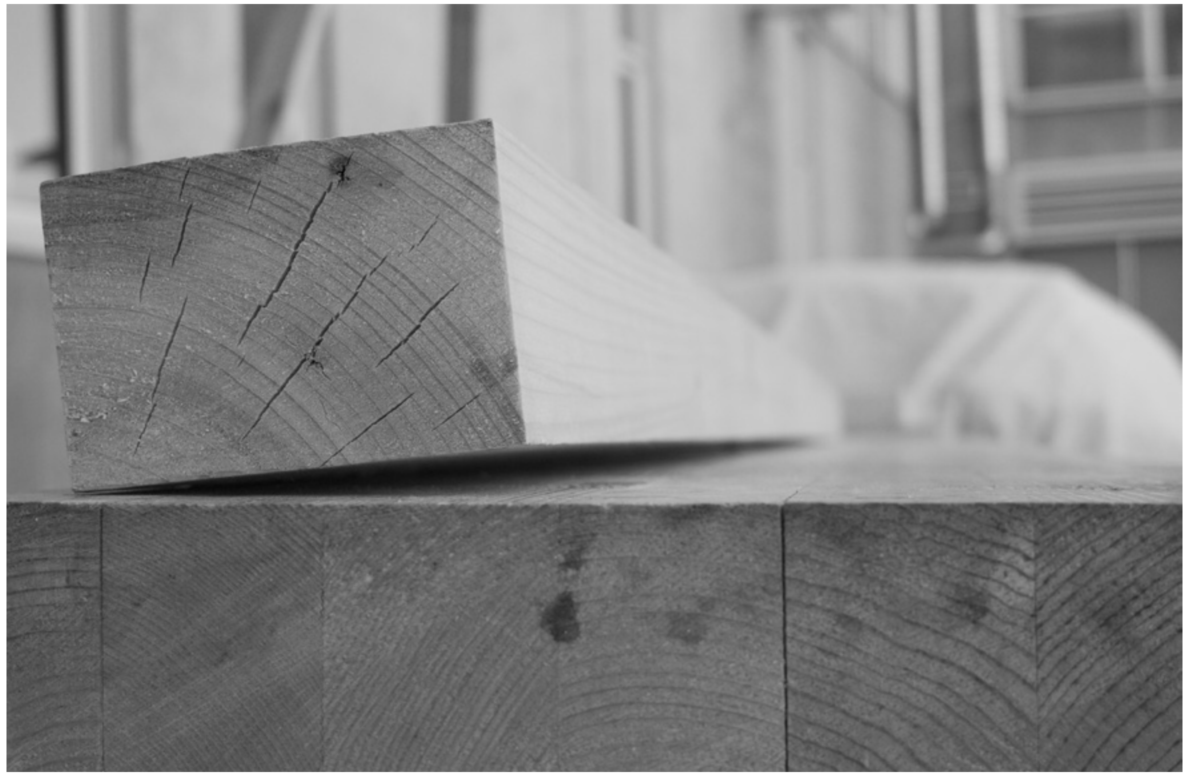


figure 161

above:
Due to substantial warping, this board will be cut into smaller components.

checks, shakes, and wood deformation

The cellular structure of wood absorbs and releases water with changes in humidity. Living wood has a high moisture content that evaporates after a tree is felled, which causes shrinkage, and, depending on internal stresses, deformation. As green lumber seasons, its internal moisture content will come into equilibrium with the moisture content of the air around it. A rapid loss of moisture while seasoning causes differential shrinkage, resulting in checks, shakes, and warping, along the length of a piece of wood. Checks fan out radially from the pith and usually are of no concern. Shakes follow the contours of growth rings, and may signal compromised structural integrity. Wood must be seasoned properly, in a kiln, or covered out of doors, to limit checking, and warping. Warped lumber can be corrected with the correct application of heat and pressure. Steam bending is one way to correct—or cause—permanent deformations in wood, however, lacking the proper equipment, this can be difficult to do with thicker sections of wood.

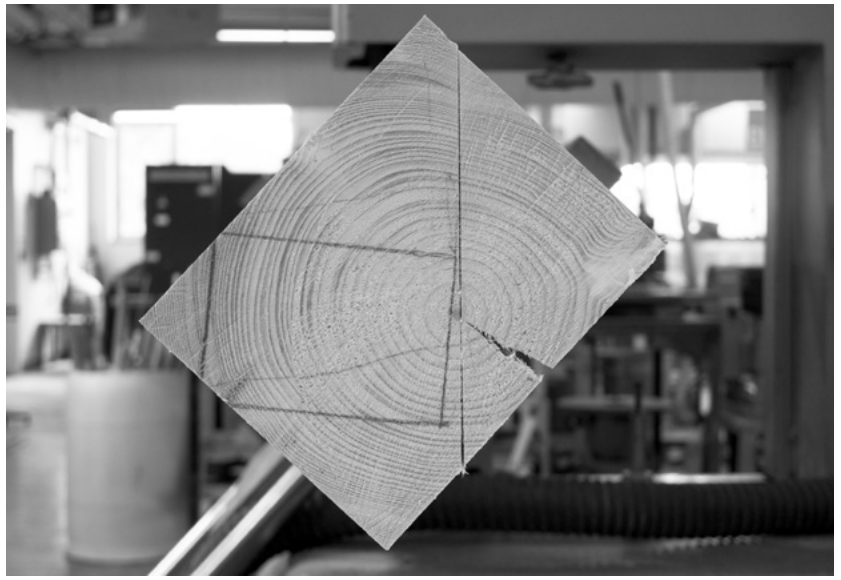


figure 162

figure 163

above, left:
A radially cut board will be less susceptible to deformation.

bottom, left:
Using a band-saw to cut a new principal rafter.

figure 164

figure 165

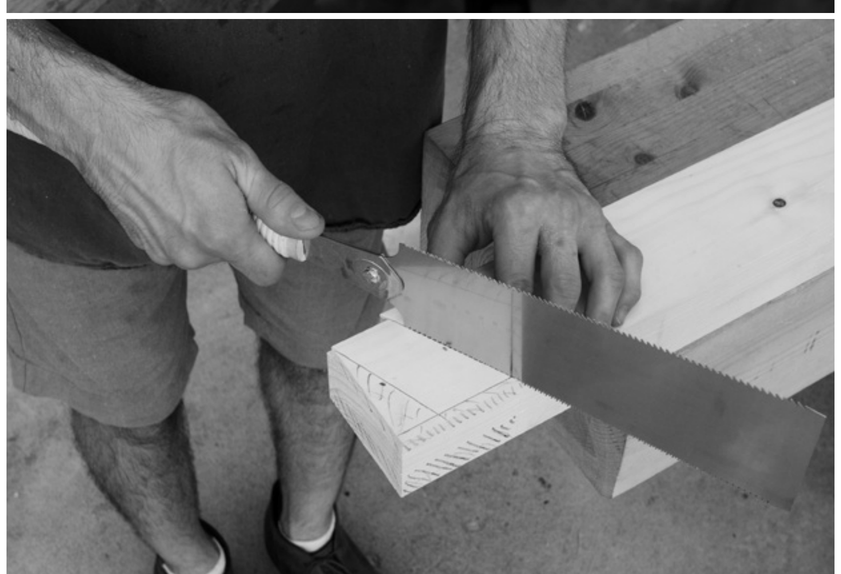


figure 166

the anatomy of a well designed detail

Laying out a joint in timber frame construction, one must consider the steps required in its fabrication. There are several ways to cut an angled tenon; the main difference between them is usually the number of cuts made. The order of operations in fabrication and assembly is one of several factors influencing the design of a particular detail. A joint that is made up of standard angles (30° , 60° , 45° , 90° , etc.), will be easier to lay out, and thus fabricate, because of commonly known ratios and standard tool markings. With any given construction detail, the designer needs to consider performance and appearance in concert with the time needed, and level of difficulty inherent in, its fabrication, and assembly; all of which are related to cost.

left:
Laying out and then cutting a tenon, at the base of a principal rafter.

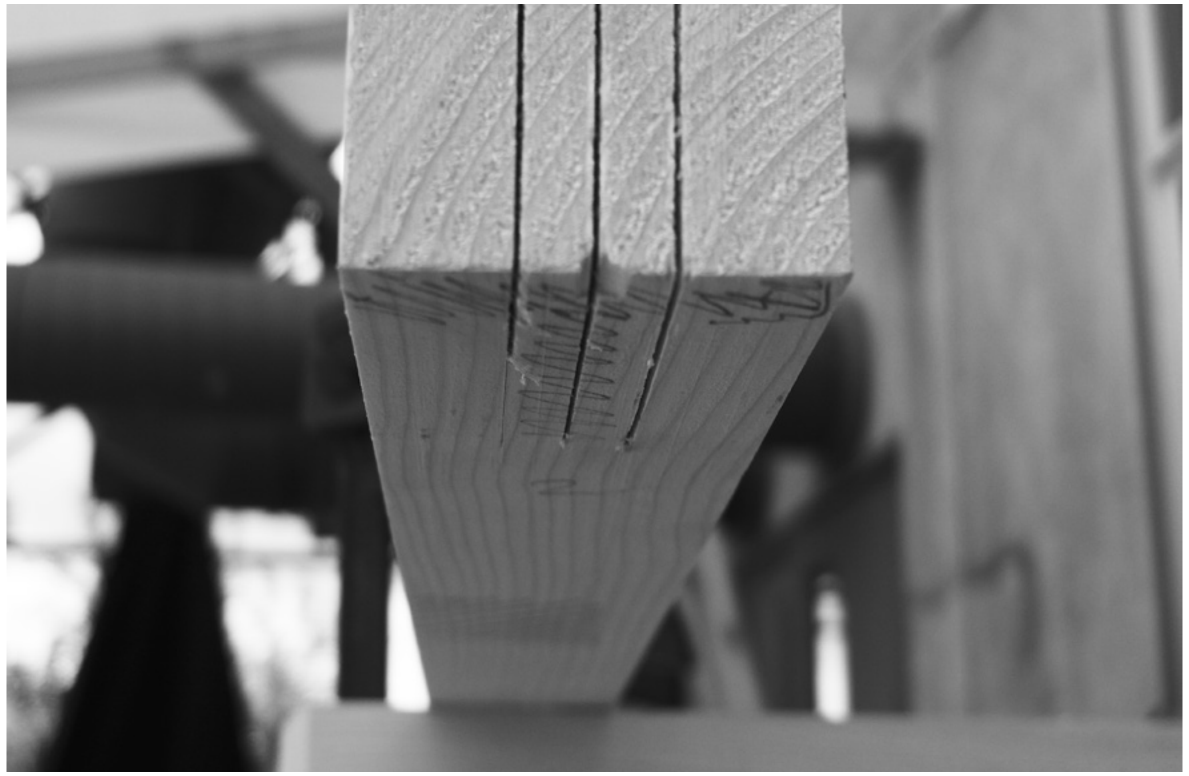


figure 167

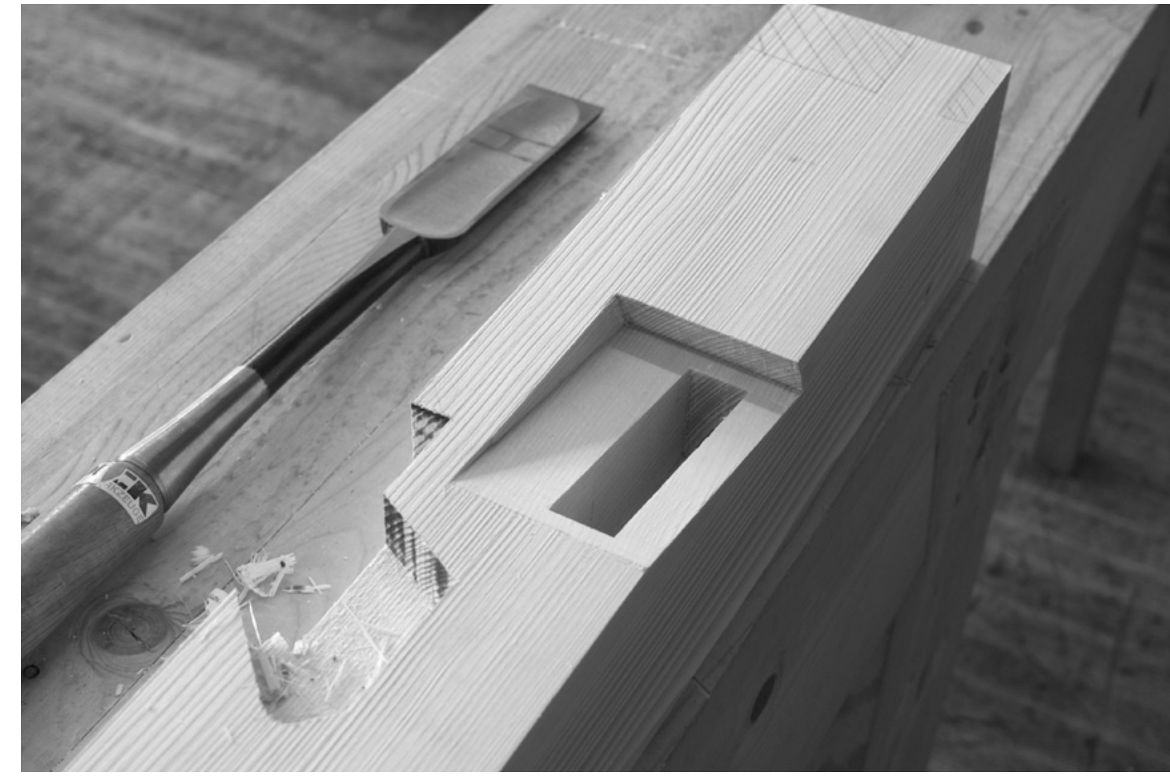


figure 168

above:
"Splitting the line" on the waste side to ensure an accurate fit. Here, a bridle joint is being cut at the top of a principal rafter.

above:
A bird's-mouth mortise in this roof beam will receive the tenon at the bottom of a principal rafter.

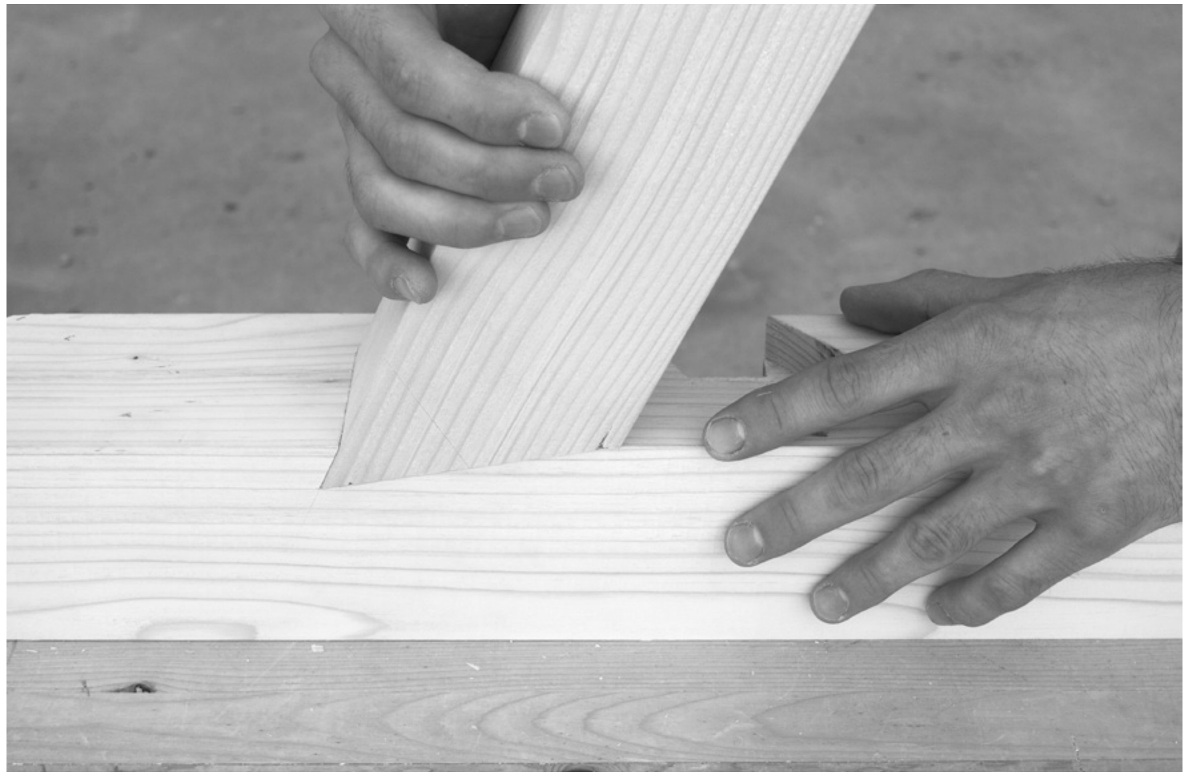


figure 169

figure 170

above:
Fitting a bird's-mouth mortise and tenon joint at the roof beam-to-principal rafter.

above:
A gable assembly takes shape.

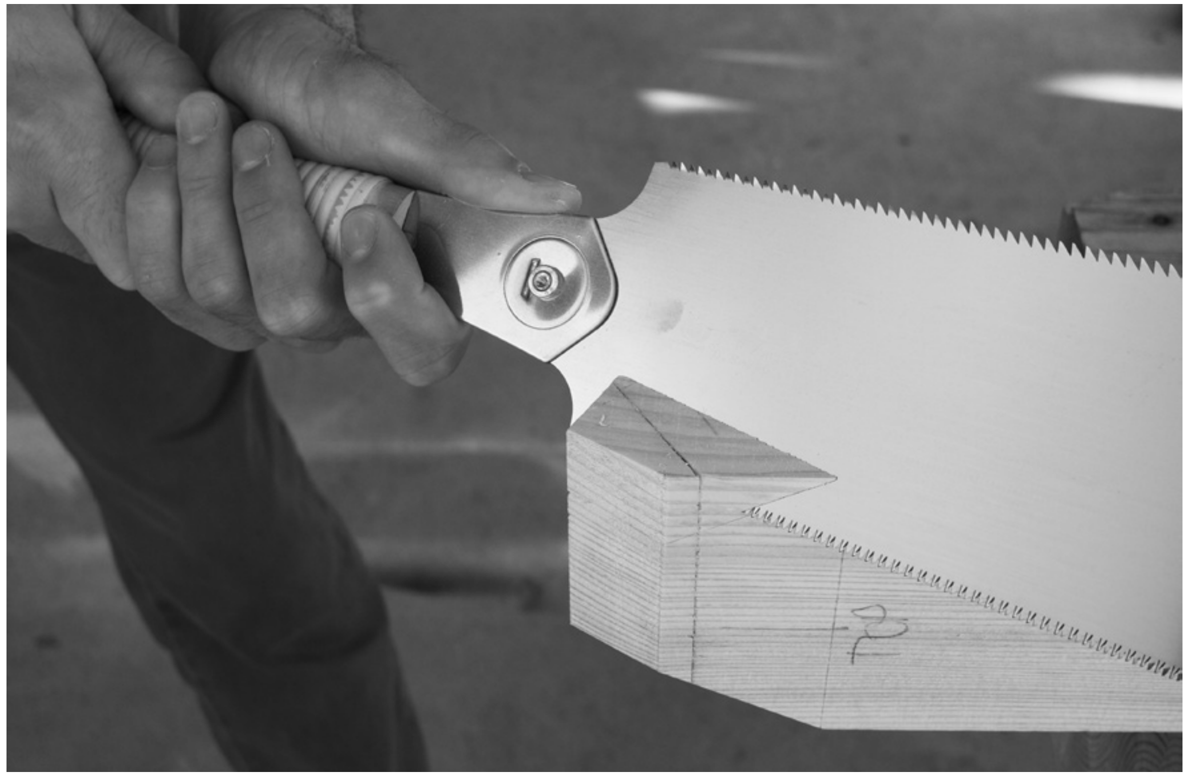


figure 171

figure 172

above:
The valley rafters
were among the more
complicated pieces to make.

above:
Valley rafters, top and
bottom. A table saw, power
drill, ryoba saw, mallet, and
chisels were used in their
making.

right:
Leftover framing lumber,
donated from another
student build.

far right:
Salvaging pieces with
suitable grain.

figure 173

figure 174

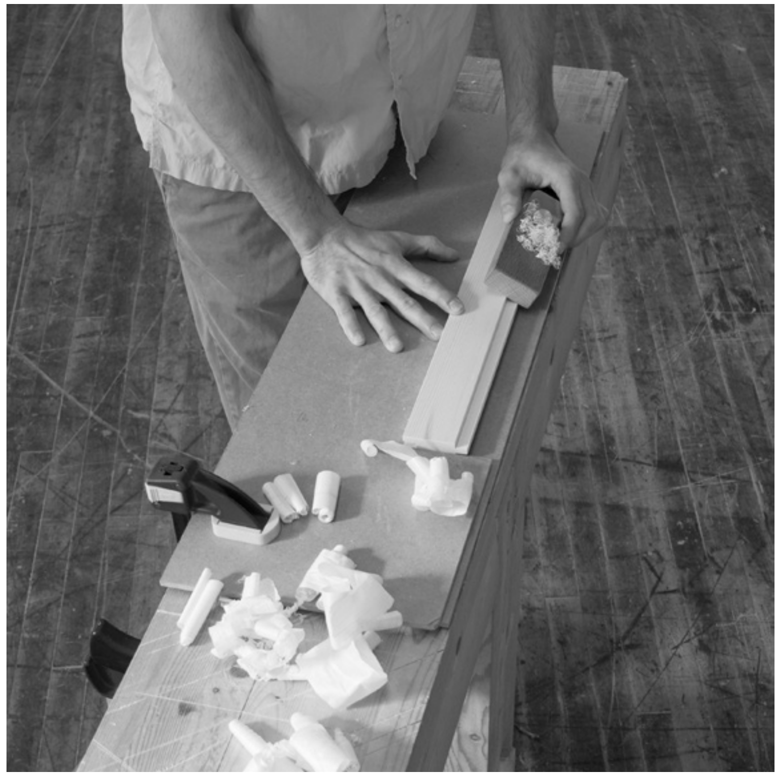


figure 175

figure 176

above:
These tongue and groove pieces are glued together to make a solid panel that...

above:
...is notched into a frame to allow expansion. The white oak rail protects the panel end-grain from moisture and offers increased support.

right:
Once fully assembled, the panel will act as a diaphragm, and should mitigate the need for knee braces at the post and roof beam above.

figure 177


figure 178

above:
This four-foot railing is held sturdy by a mortise and tenon joint.

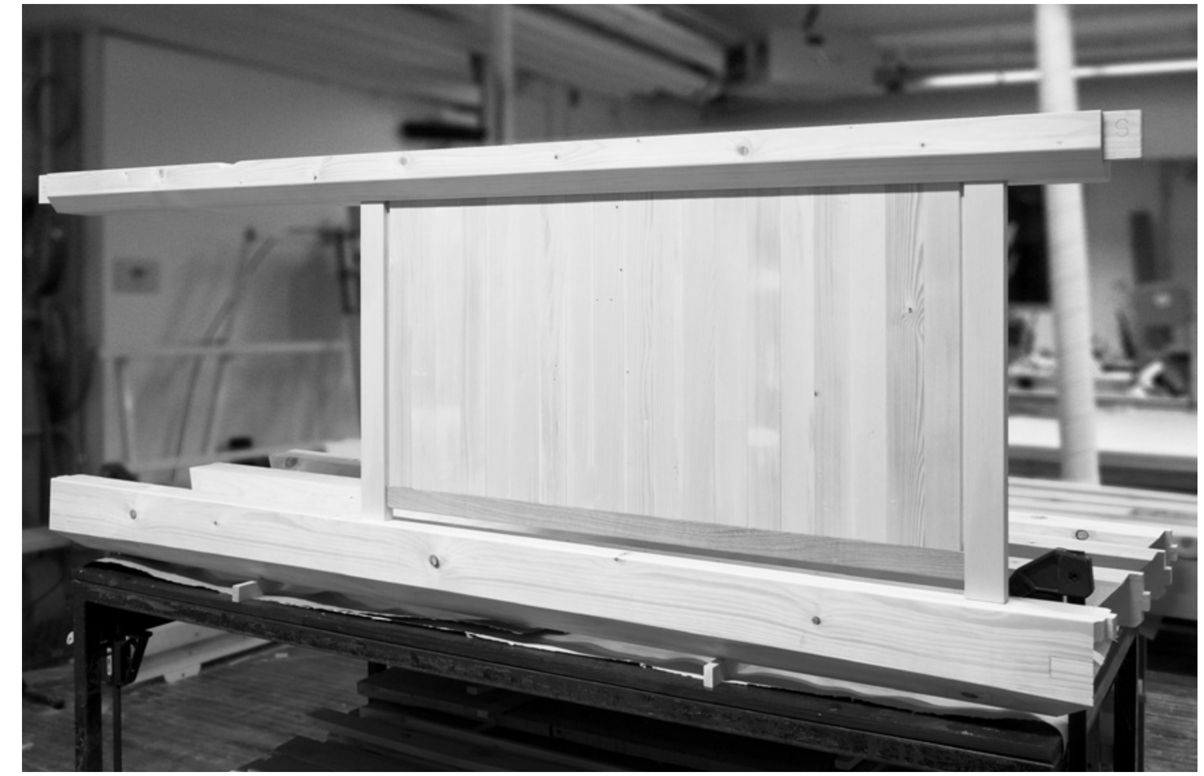


figure 179

the plasticity of wood.

Articulation of the structure is carefully considered. Chamfers contoured to the human hand create shadows and communicate depth; a slight camber is carved into the bottom edge of the mud-sills, lightening their appearance. Eastern white pine can very easily be shaped to convey hospitality.

above:
Mud-sill, wall-panel, and railing assembly.

figure 180

figure 181

above:
Eminently handleable, a draw-knife offers a remarkable degree of freedom in form-finding.

above:
Judging the proportion of a gently cambered chamfer.

right:
After a component is dimensioned and the joints are cut, it is smoothed to the touch.

figure 182

figure 183

above:
One part pine tar to one part linseed oil.

pine tar

On heavily trafficked areas, and for exterior applications, a good finish can drastically improve the durability and lifespan of wood. The heartwood of certain species, including local varieties of white oak, black locust, eastern white cedar, and old-growth douglas fir can be used unfinished, to great effect, in certain applications out of doors. In the right conditions, unfinished black locust fence posts have been known to survive upwards of sixty years. Scots pine (which constitutes the majority of the tree-house structure) is not very resistant to damage from water or insects, once it is felled. Yet scots pine was used extensively throughout Scandinavia, in the construction of stave churches and similar buildings, some of them still intact since the 12th century. The durability of old-growth heartwood, a sophisticated building science, and periodical maintenance have all contributed to the longevity of these buildings. We know that Viking, and later, medieval builders used pine tar as an effective vapour barrier in the preservation of several scots pine constructions.

figure 184

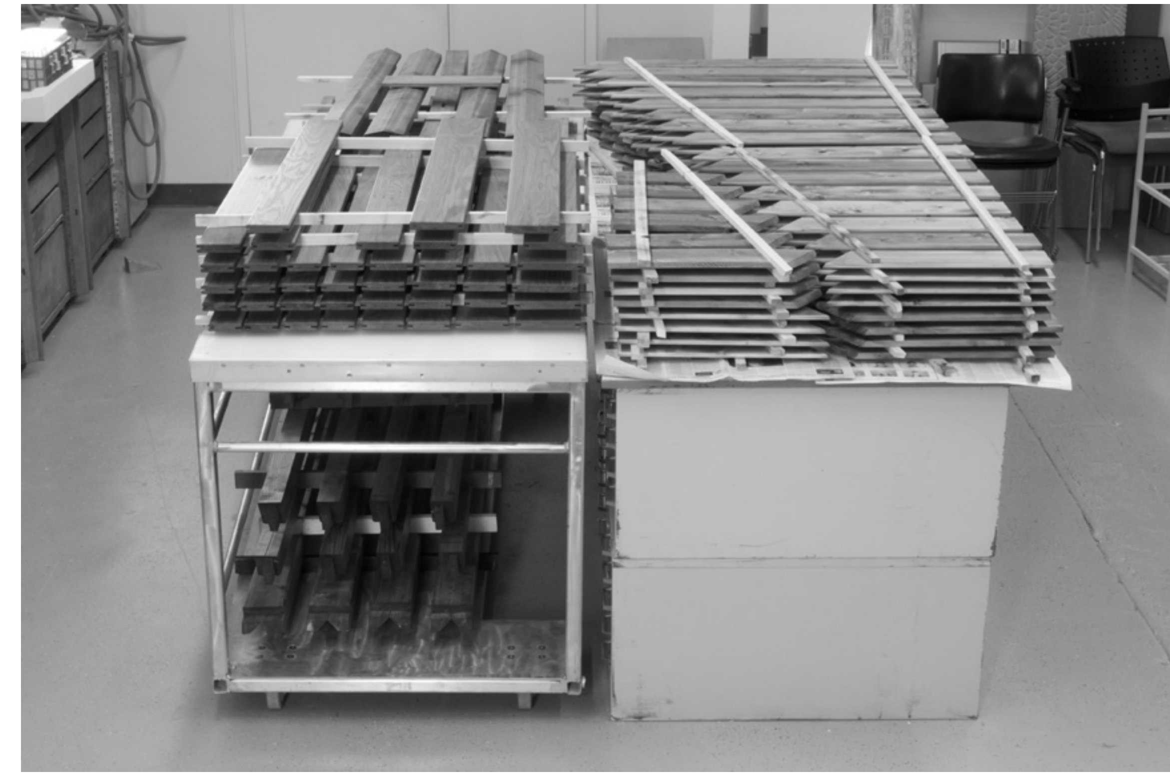


figure 185

Pine tar, a resinous material, is the product of the stump and roots of the pine tree burned at high temperatures, under high pressure, traditionally extracted in built-up mounds. Pine tar was used as a water-proof barrier on wooden buildings, and ships, on steel to prevent the onset of rust, and in pharmaceuticals, as a mild antiseptic.

An ancient recipe of equal parts pine tar and linseed oil should protect the tree-house for three to five years before needing a fresh coat. Linseed oil acts as a thinner and is mixed with pine tar to facilitate absorption. Pine tar has a rich, sweet smell. Applied when warm, it hardens via oxidative polymerization, resulting in an odourless elastic film, that can accommodate movement in wood. Certain grades, and mixtures of pine tar can withstand harsh conditions, without maintenance, for up to 15 years. A high quality pine tar finish is not toxic. Because children will be in contact with the tree-house, health and safety are a primary concern.

I prepared a heavier grade of pine tar for the roofing, decking, and footings of the tree-house, and a lighter grade for the rest of the structure. The undersides of the cedar roof planks are left unfinished, in the hope that the cedar scent might permeate the structure during humid weather.

above, left:
Pine tar is applied warm to facilitate absorption.

above,
716 components make up the tree-house. Oiling 268 of them efficiently requires some organization.

figure 186

above:
The site, cleared of ice and snow.

January 2014: installation commences

Winter had set in when I was ready to begin installing, a year later than I had originally anticipated. The post-holes excavated in the months previous had been covered to prevent settling due to water infiltration. Thankfully, Reuben—a friend and colleague, with construction experience and good sense—had advised me to insulate the post-holes, to prevent the soil exposed to cold air from freezing.

Outside of a few minor alterations completed on-site, the pre-fabricated components came together easily: the installation took little over a month to complete.

figure 187

figure 188

above, left:
Footings and platform
beams are installed first.

bottom, left:
Perfectly level.

figure 189

figure 190

above, left:
The platform structure is pulled together tightly with cable clamps...

bottom, left:
...and checked for squareness.

top, right:
An auger is used to drill a hole through the sills and beam.

bottom, right:
A white oak dowel is used to secure the corner assembly.

figure 191

figure 192

top, right:
A-gravel, sourced from a
local gravel pit.

middle, right:
The post are holes filled a
few inches at a time...

bottom, right:
...and tamped to minimize
settling.

figure 193

figure 194

figure 195

figure 196

above:
Covering up after a day's work.

figure 197

figure 198

above:
Fitting a post, to a roof beam.

above:
An entire elevation—a "bent"—must be assembled before it can be fitted to the platform.

figure 199

figure 200

above:
Finessing the fit of a joint...

above:
...because of expansion
caused by oiling.

right:
Mortises with bevelled
shoulders match the profiles
of the railings.

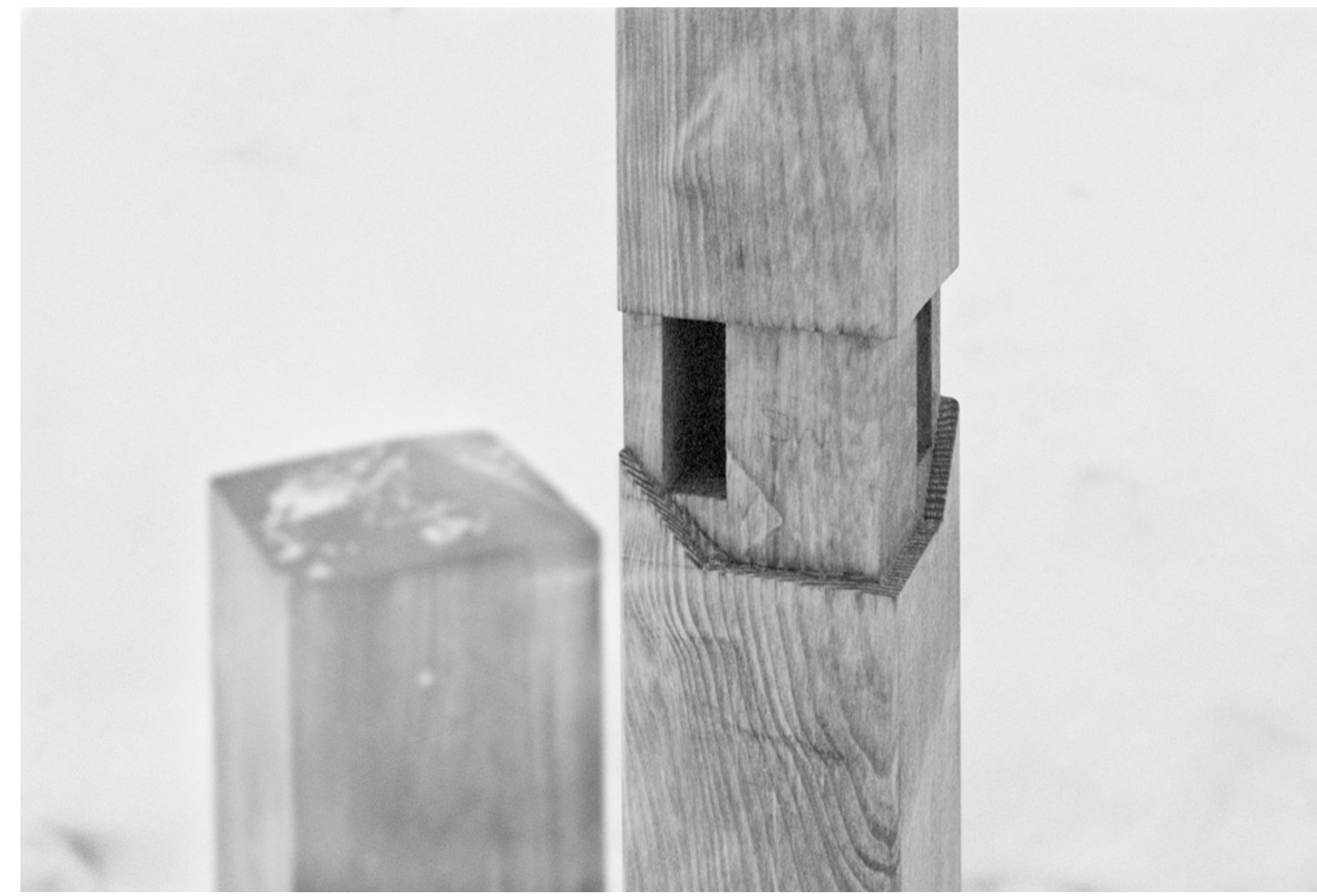


figure 201

figure 202

figure 203

above:
Modifying a tenon with a
ryoba saw.

above:
Tamping a post and railing
assembly into place.

figure 204

figure 205

above:
Because of concealed joinery, the remaining two bents are pre-assembled...

figure 206

above:
...and installed simultaneously. Tall mortises in the first bent accommodate this procedure.

figure 207

figure 208

above:
Using a mortise and chisel
to adjust the fit of a tenon at
the wall-panel.

above:
Installing the horizontal
braces at the post and beam
connections, after the frame
is fully assembled.

figure 209

figure 210

above:
Shouldered, half-lap dovetail joints receive the horizontal braces...

above:
...which carry the valley rafters, and secure the post and beam assembly.

figure 211

figure 212

above, and left:
Installing the valley rafters
and collar-beams.

figure 213

left:
Self-supporting joinery makes the installation process relatively easy.

figure 214

figure 215

above:
A bridle joint joins the tops
of two principal rafters.

above:
The structure provides a
sturdy scaffold.

figure 216

figure 217

figure 218

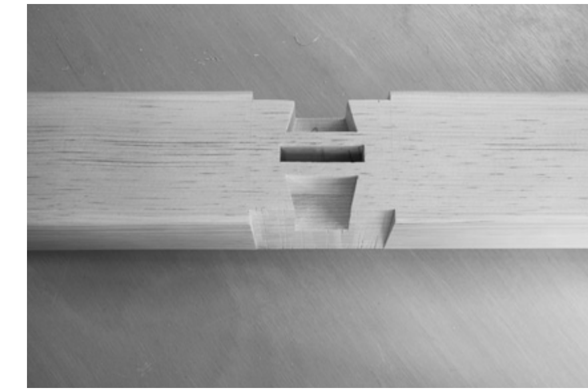


figure 219

top, left:
A tapered cross-dado with a half-lap key joint on the king post secures the tops of the valley rafters.

middle, left:
A mortise in the main collar beam receives a tenon on the king post...

bottom, left:
...which secures the shouldered, lapped dovetail joints on the secondary collar beams.

above:
A mortise with shouldered half-lap dovetails, in the center of the main collar beam.

the kongming lock

The tapered cross-dado with a half-lap key joint at the head of the king post was inspired by the Kongming Lock: a wooden puzzle that Melissa gave me several years ago. The design of this puzzle is attributed to Zhuge Liang, a brilliant strategist who lived during the three kingdoms period of Chinese history, between 181 and 234 AD. An analysis of the puzzle reveals six wooden keys, that, when correctly assembled in two groups of three keys each, will interlock along one axis only.

At the location of the king post and valley rafter connection, I use two interlocking keys, seated in a tapered cross-dado: once installed there is no way for this joint to come apart.

figure 220, left:
The Kongming Lock.

figure 221, overleaf:
Assembly of the tapered cross-dado, with half-lap key joint.

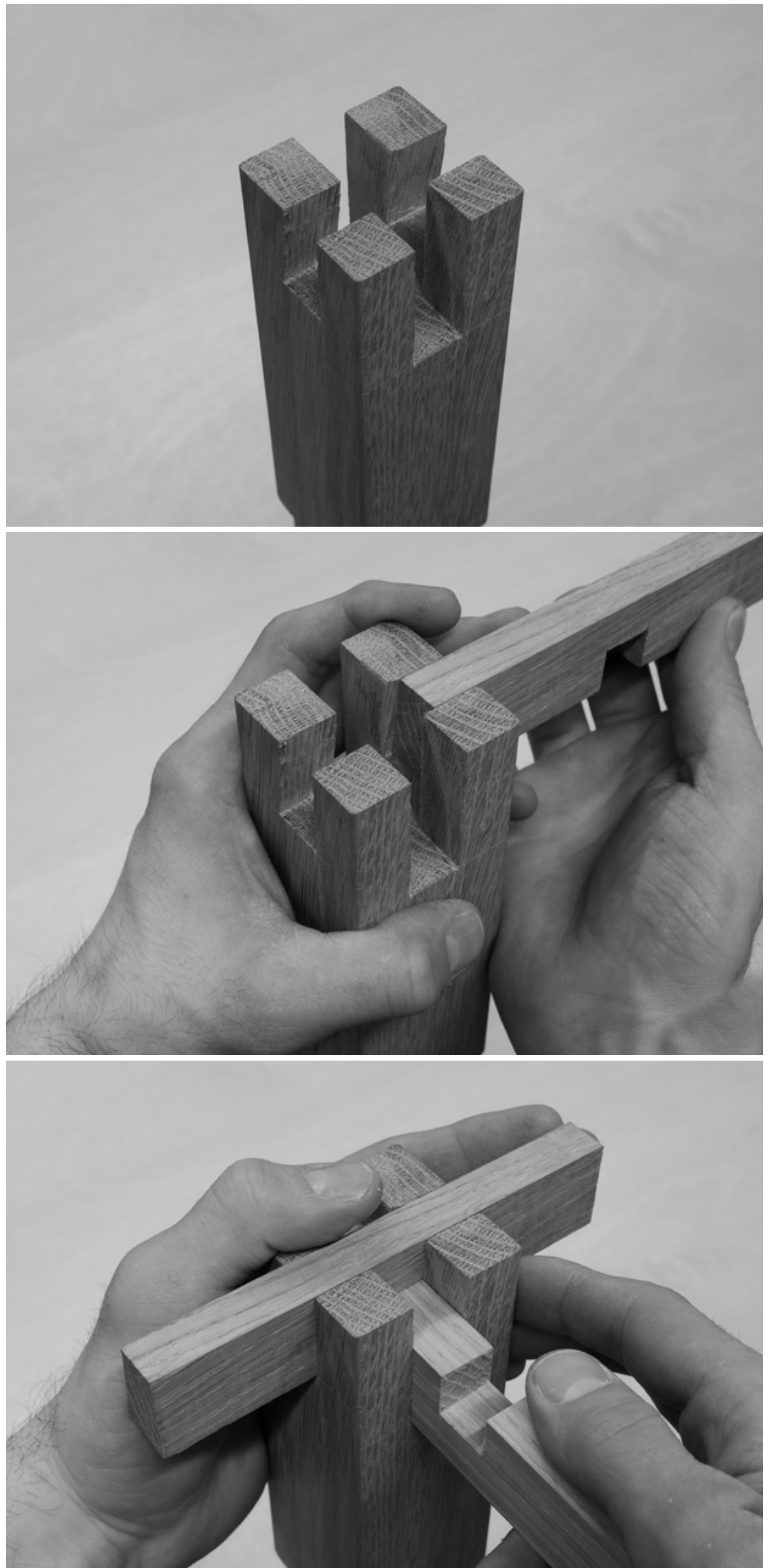
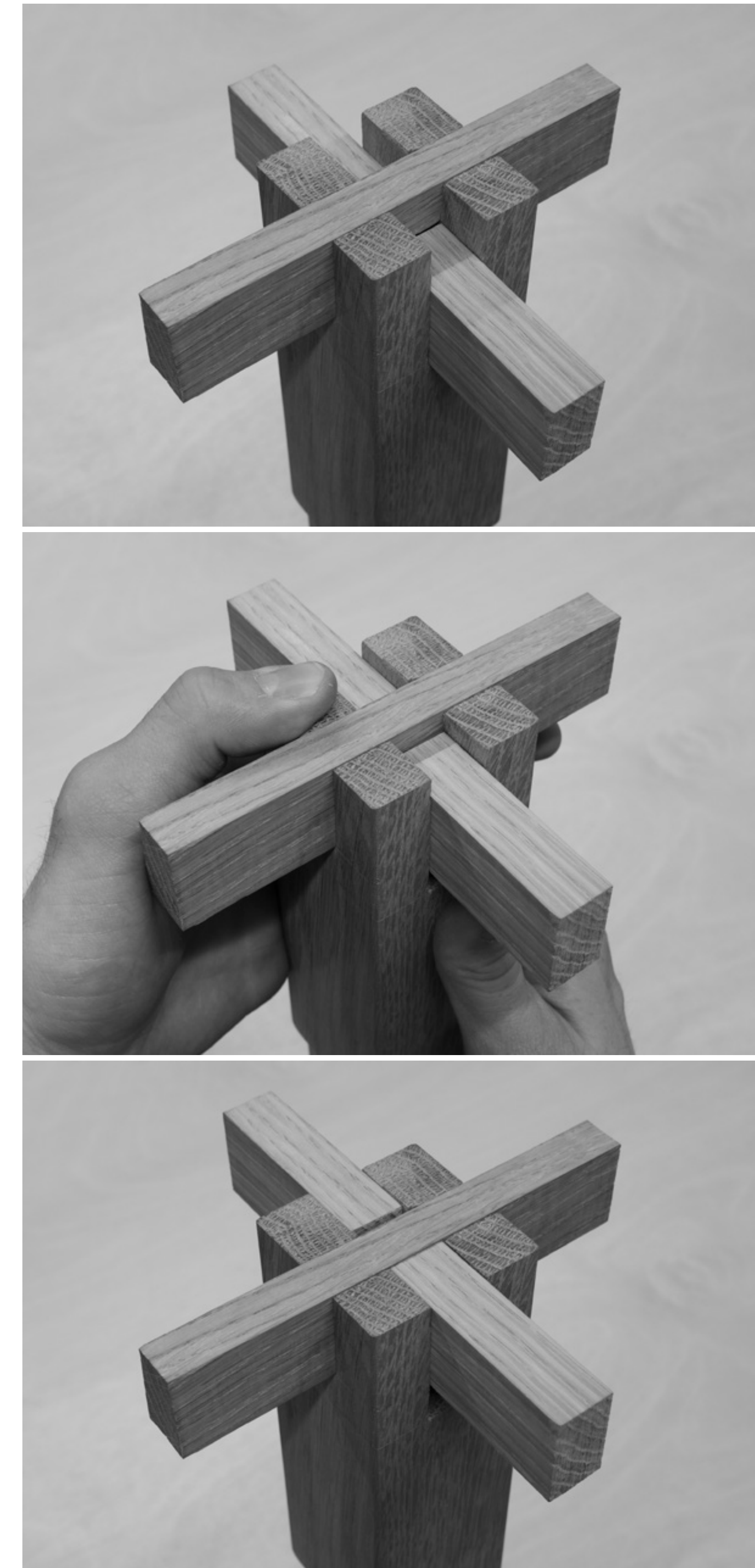


figure 221



right:
Securing the valley rafter-to-king post assembly with oak dowels.

figure 222

figure 223

left:
A feeling of satisfaction.

figure 224

above:
These dovetail notches
receive the roof purlins.

figure 225

above:
A view looking down
through the roof structure.

figure 226

figure 227

above:
King-post, valley-rafter, and
purlin assembly.

above:
A pinned, half-lap joint at
the top of the bridging.

figure 228

topping off

Traditionally, an evergreen sapling is fixed to the peak of a newly completed structure; today, timber framers will "top off" to celebrate a culture of hard work, and to offer thanks to the trees used in the process.

left:
A cedar sapling fixed to the peak of the roof celebrates a newly completed structure.

shortcuts are rarely so

Rather than spend the time needed to fabricate 448 wooden spacers—needed to achieve a desired roof plank spacing—I considered fixing metal braces to the undersides of the roof planks instead. In actuality, screwing 448 fasteners to 176 planks proved tedious. In the absence of a wood spacer, the gap left between plank and rafter exposed the brads used to fasten them. Realizing my mistake, I opted to make the requisite number of wooden spacers.

right:
A poorly conceived detail.

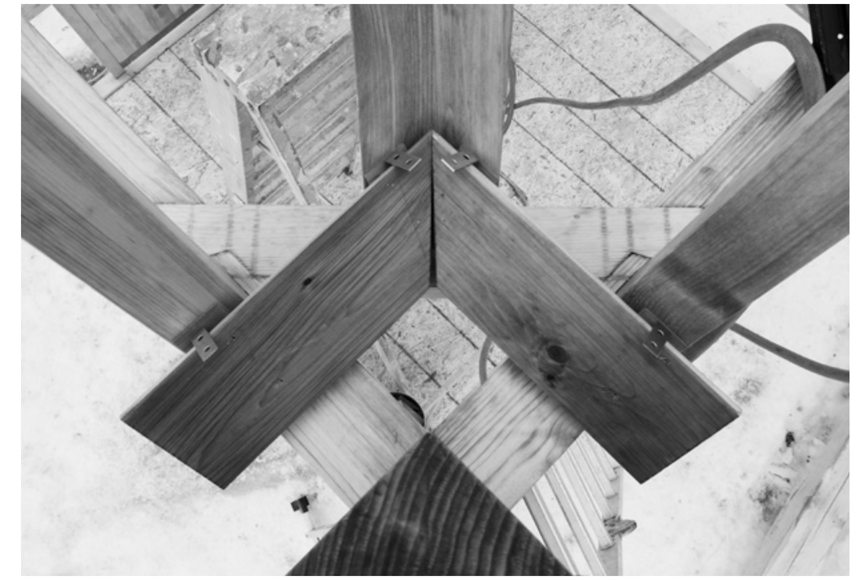


figure 229

figure 230

figure 231

figure 232

far left:
Cedar lumber is jointed, thicknessed, and halved diagonally to create triangular sections...

left:
...that will be cut into 448 triangular spacers.

figure 233

figure 234

a detail is simple only when it is simple to make

It is important to consider the very small, and the very large, simultaneously. A single angled cut—when it is not calibrated to the tools used to make it—necessitates the fabrication of a complex jig, adding time and cost to a project.

above, left:
A handmade jig couples with a table saw...

bottom, left:
...to make an angled cut on a valley rafter spacer.

figure 235

figure 236

above:
Spacers are attached to the bridges and rafters with a brad nailer.

above:
Roof planks are installed from the top-down.

figure 237

figure 238

above:
Roof detail. Early afternoon.

above:
Installing the ridge-caps.

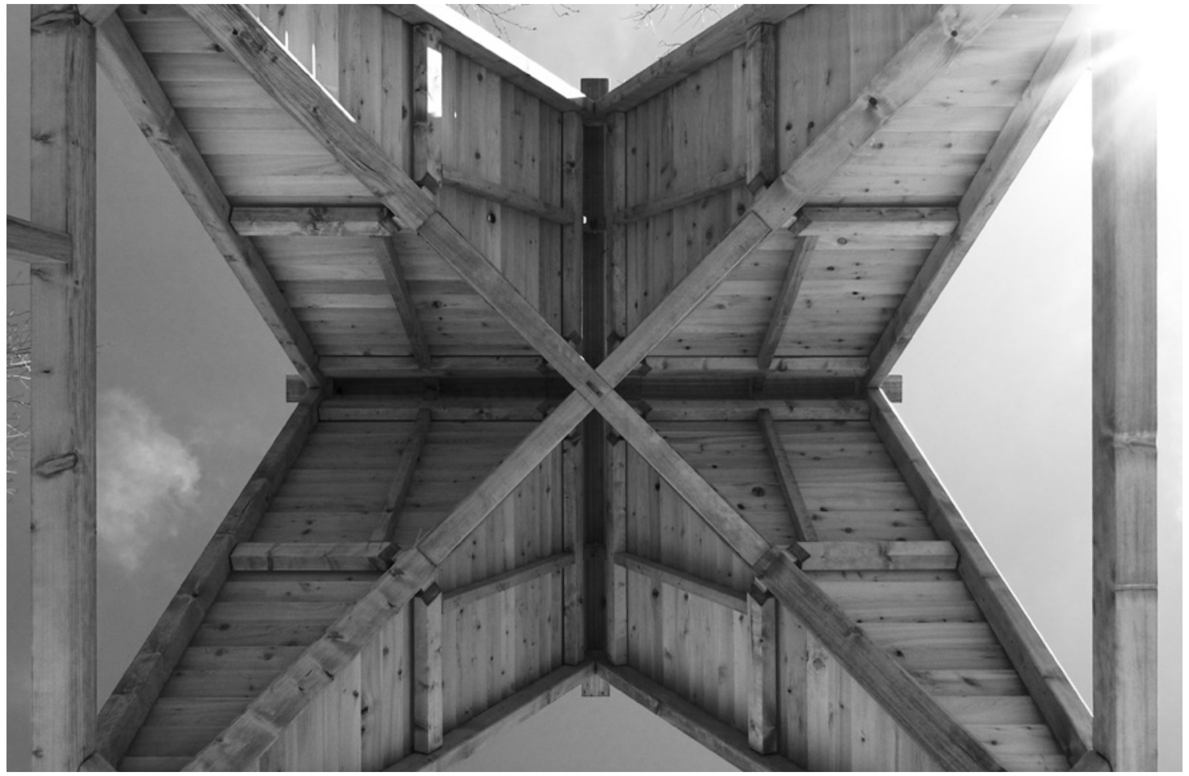


figure 239

figure 240

above:
View of the completed roof from below.

above:
Looking southwest, from the street.

figure 241

figure 242

figure 243

top, left:
Oak dowels, sized with a dowel former...

middle, left:
...are used to pin the major structural joints...

bottom, left:
...securing them in place.

right:
A view of the platform structure, from above.

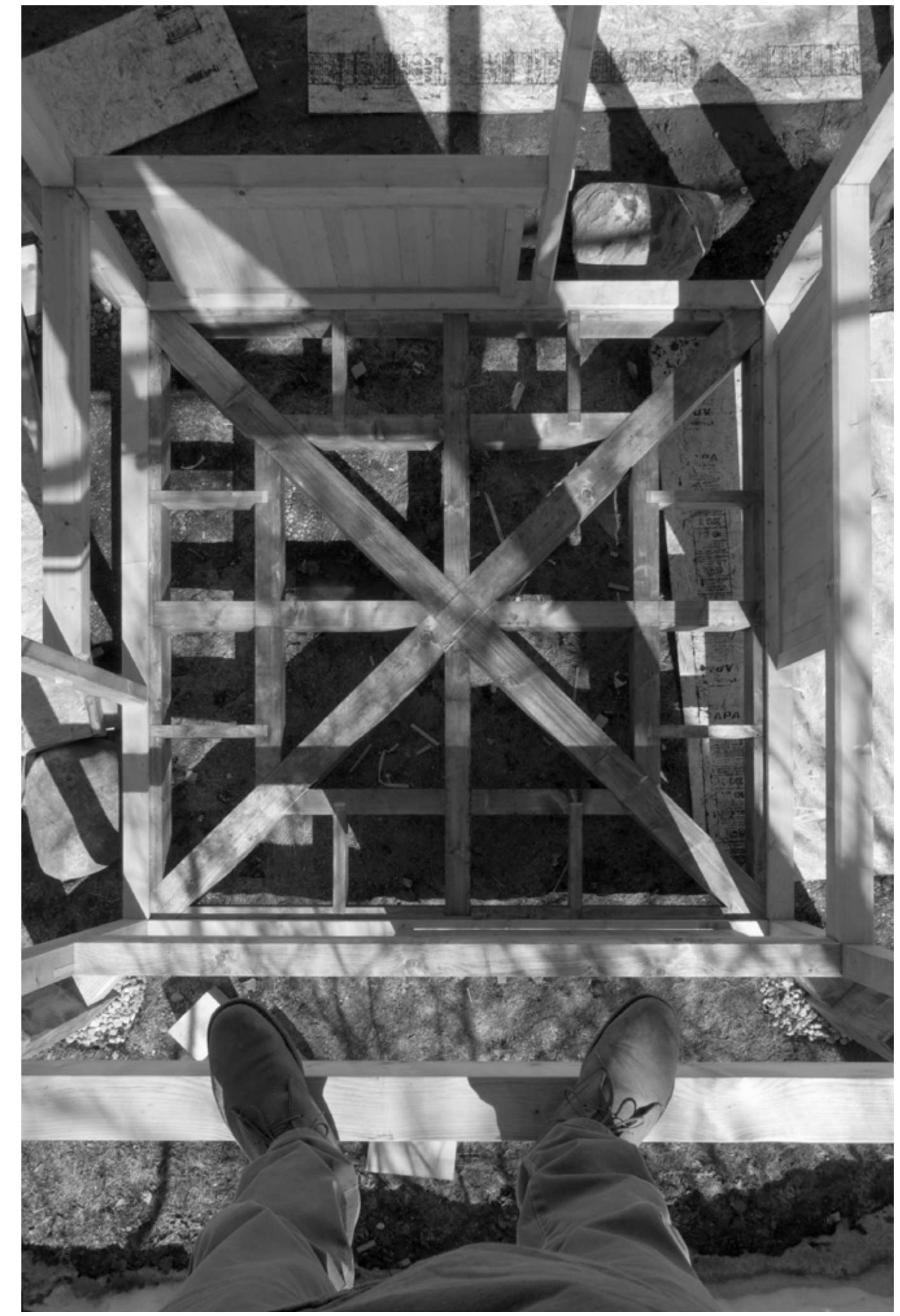


figure 244

figure 245

figure 246

figure 247

top, left:
Hidden deck fasteners secure the decking to the platform, and act as spacers to accommodate expansion in the wood.

middle, left:
The fasteners are inserted into a precut groove on the sides of the deck planks...

bottom, left:
...and zinc-coated screws are screwed diagonally through the fasteners, and decking, into the structure below.

figure 248

figure 249

figure 250

a poorly conceived detail

The continuous groove cut along the edges of the decking made for a quicker installation process, because the hidden fasteners could be placed anywhere along their length. However, when water collects in the groove, the edges of the boards swell. The top surface contracts faster than the still moist underside, causing a visible deformation of the edges. The resultant "cupping" inhibits good drainage and may eventually cause the top edges of the boards to split off or splinter—shortening the lifespan of the deck considerably. It would have been smarter to locate the deck fasteners first, and to cut small grooves at those locations with a biscuit jointer.

left:
Grace and Nolan, helping me
install the decking.

figure 251

figure 252

top, left:
Soft to the touch.

bottom, left:
Grace, trying to stay out of the mud.

right:
The completed deck.
Three, four, five, and six-inch widths make up the herringbone pattern.

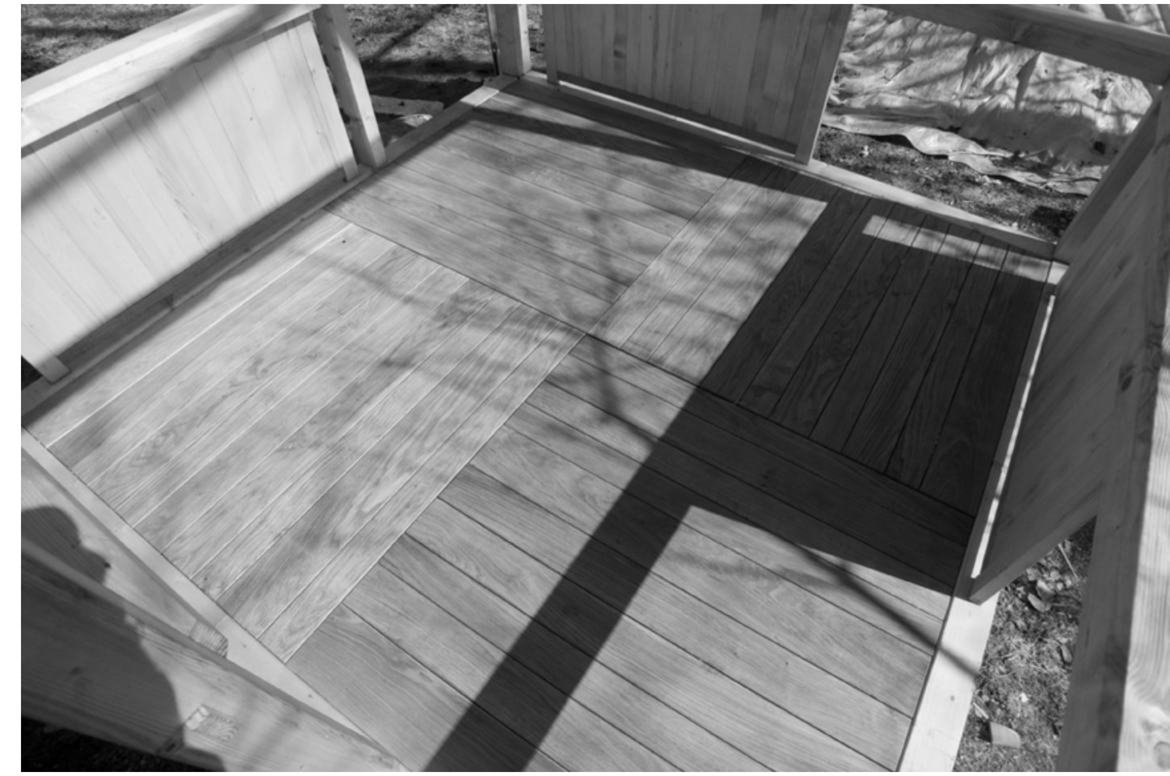


figure 253

figure 254

figure 255

figure 256

top, left:
With the arrival of spring, the edges of the mud-sills at the entrances were beginning to chip.

middle, left:
With a round spokeshave, I carved a deeper chamfer...

bottom, left:
...which will be less susceptible to wear.

made to be touched...

The design and fabrication of the tree-house was largely guided by my sense of touch: it was made to *be* touched. Although photographs cannot substitute the physical immediacy of actual experience, I hope that the following selection might intimate qualities of light, proportion, and patterns of use.


figure 257

figure 258

figure 259

figure 260

figure 261

figure 262

figure 263

figure 264

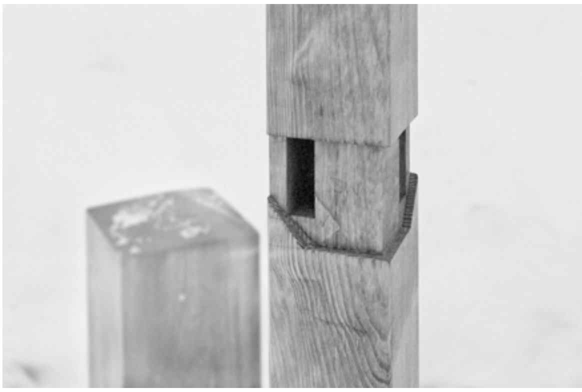


figure 265

figure 266

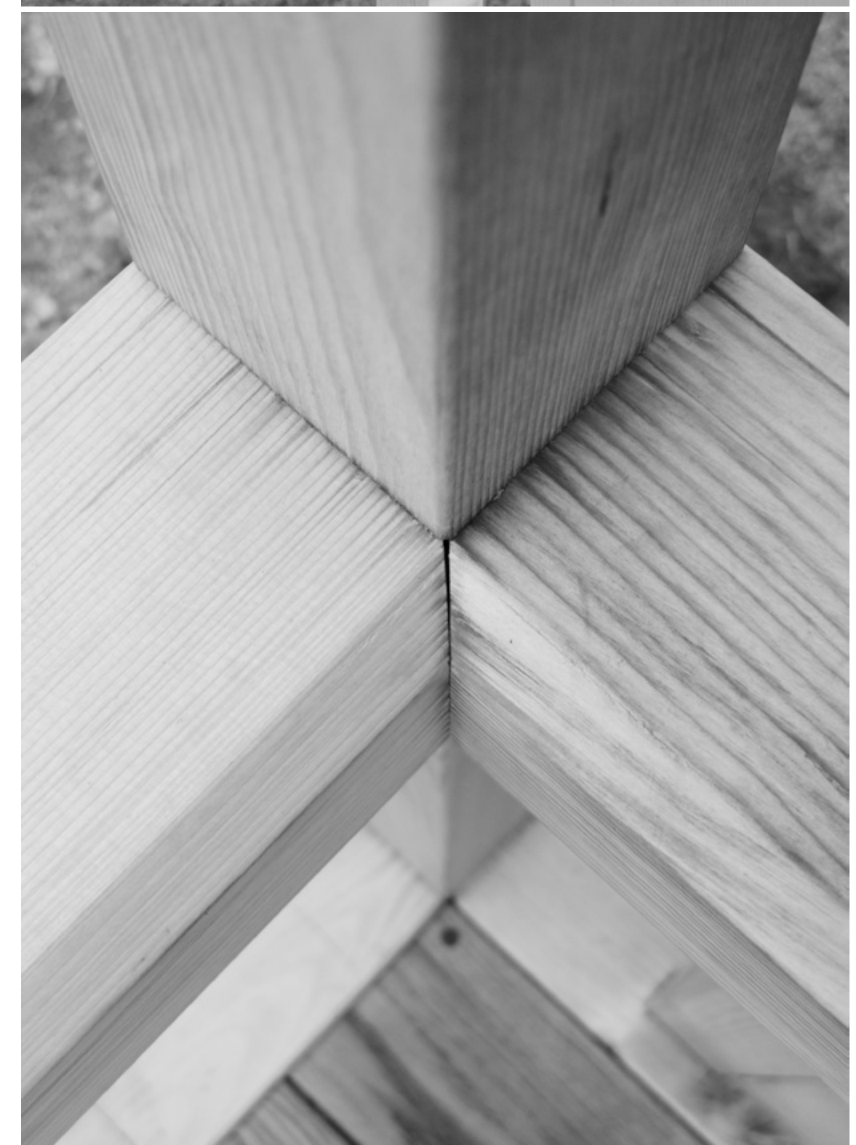


figure 267

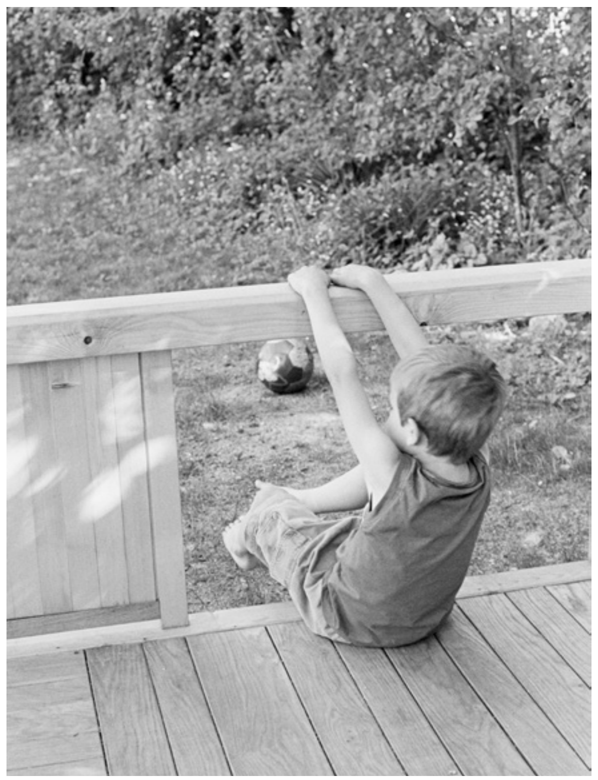


figure 268

figure 269

figure 270

figure 271


figure 272


figure 273

figure 274

figure 276

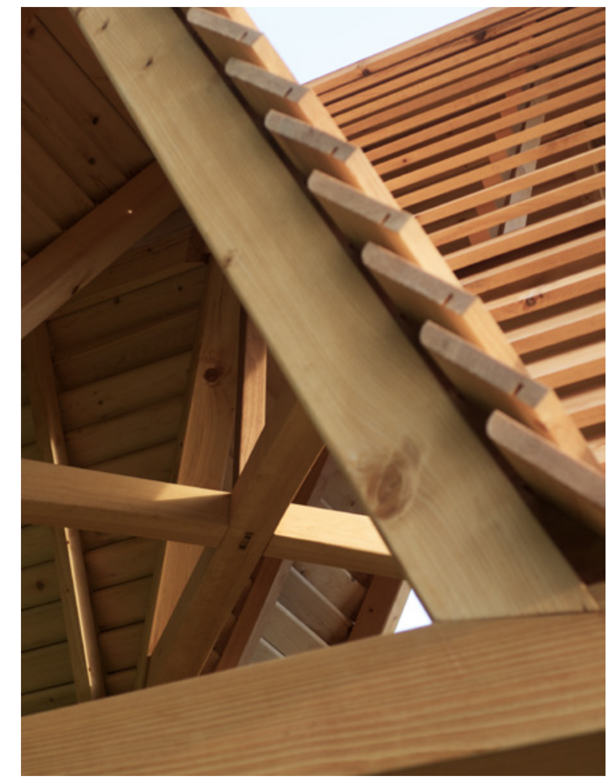


figure 277

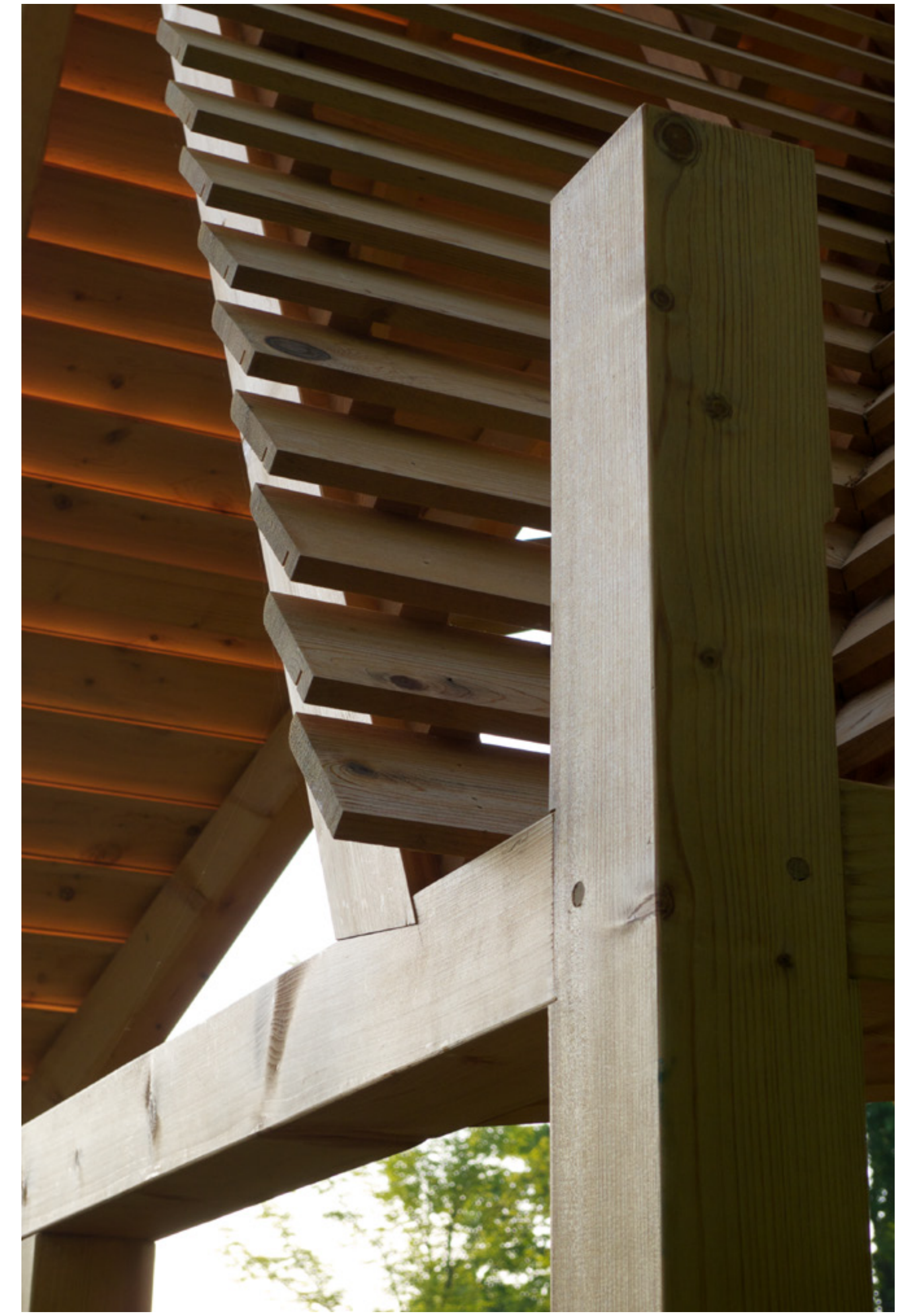


figure 278

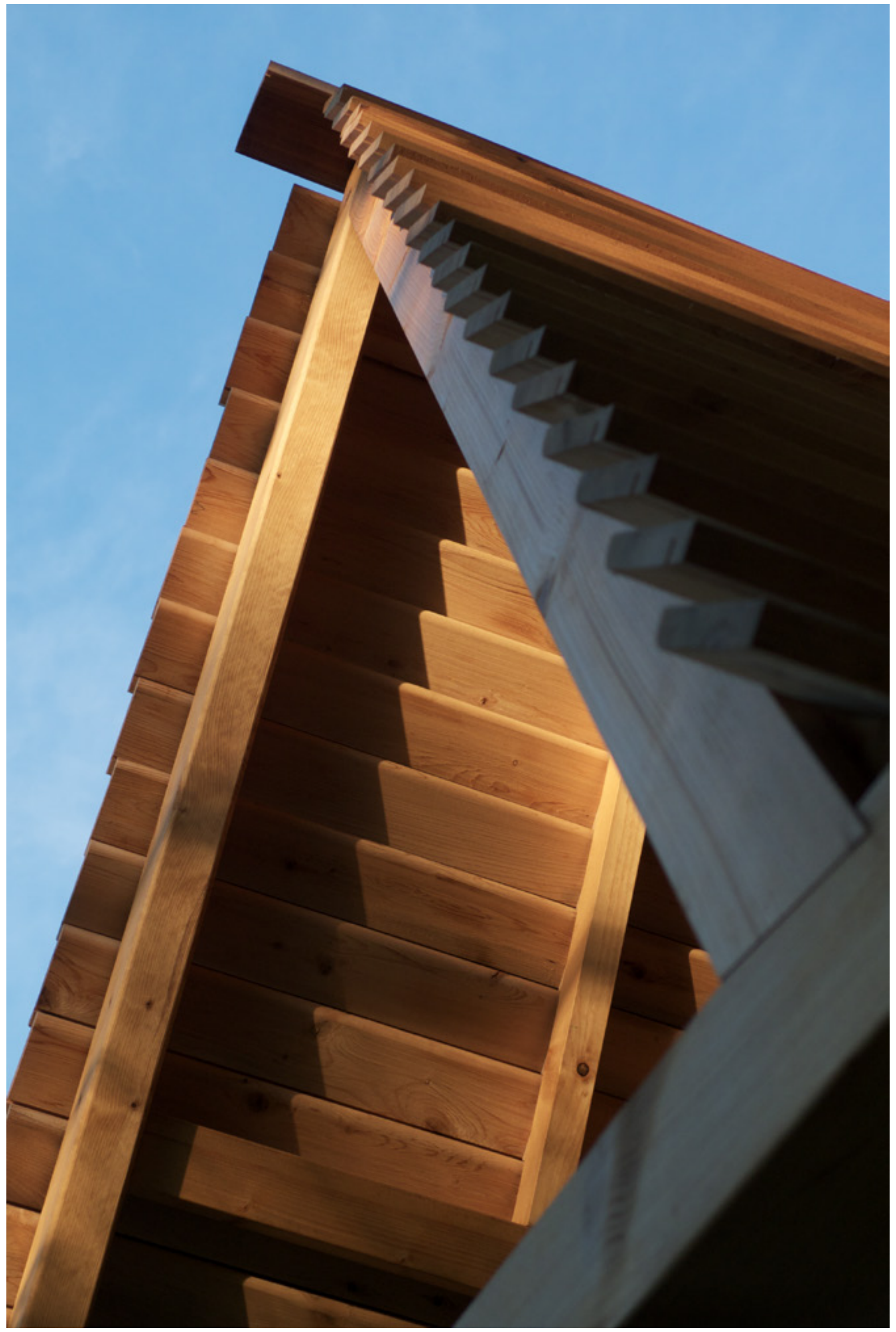


figure 279

figure 280

figure 281

figure 282

figure 283

figure 284

Reflection

There is no secret, no key piece of information which if revealed would instantly confer enlightenment and expertise. If you do not make progress, you cannot blame your teacher. If you have no teacher, do not place your highest priority on finding the "right" one . . . you must develop on your own. [The] key is not an academic or intellectual comprehension. The only way to understand it is to do it.

Jou, Tsung Hwa, on *the way*, in taijichuan *looking, listening, asking, touching*

In Traditional Chinese Medicine (TCM), Looking, Listening, Asking, and Touching make up the "Four Examinations" that together, help the physician reveal a pattern diagnosis for a given patient. Of the four examinations, Touching is normally considered the most important. Pulse taking constitutes a major part of the Touching Examination, because, according to TCM, the pulse reveals a great deal about a patient's condition. The master physician, placing their index, middle, and ring finger along the radial artery below the wrist, palpates the pulse with each finger, at three different pressures: superficial, middle, and deep; this allows for a remarkably nuanced reading of the pulse, which is taken on both wrists. Over a period of centuries, master physicians have identified in the order of twenty eight pulse types, each associated with a specific set of symptoms. Given that most patients exhibit a combination of several pulse types, producing an accurate diagnosis from the pulse alone requires great skill and experience. In many cases, a physician will supplement their reading of the pulse with information gathered during the other three examinations: Looking, Listening, and Asking.

The Four Examinations in TCM underscore a dynamic common in many if not all, traditional craft cultures: the pivotal role of the body in reading, learning from, and interacting with, the surrounding environment. Whether we consider Chinese Medicine, or Woodworking, Taijichuan, or Pottery; the process of learning to think with the whole body is imbedded into the practice of these crafts. In a material craft like woodworking, the act of building is a mechanism through which learning and thinking with the body is cultivated in the apprentice, or student. In the context of an architectural education, the value of a craft guided approach to learning and thinking is two-fold: the student, working closely with materials over an extended period of time, in an act of building, embodies the qualities of the materials they work, within the context of construction, and, as a result of the affective nature of touch, develops a care for those materials and the process of building. For the craftsman, care often manifests itself as a sense of empathy; the craftsman architect is humble, and respectful of the value of material resources, and the value of labour and teamwork.

The complexity of the pulse taking examination in TCM reveals another dimension inherent in craft traditions: the continuum in which these traditions operate and evolve. Ideas, techniques, and technologies are the cumulative effort of generations past, present, and future, recycled, reinterpreted, reimagined. Understood in this context, tradition is a kind of technology, shaped by many hands over many generations to preserve "those fragile constructs we call culture" (Brown, 18). Craft cultures are an embodiment of a particular tradition: they offer a way of perceiving and operating in the world in a given context. TCM teaches us how we might better understand and respond to, the myriad factors contributing to overall health; the craft of woodworking aligns us to the myriad properties and qualities of wood, and suggests how we might harness them in a new construction.

A student, learning a traditional craft, may supplement their own experience and that of their colleagues with the continuum of experience embedded in that craft: allowing a student to test and refine their own understanding; to contribute to that continuum, and to apply their understanding to an even broader continuum, which, in the context of this author's exploration is architecture.

The act of building, guided by the craft continuum, has revealed to me that thought and action inform one another, and that both are in constant flux. In woodworking, as in architecture, every idea owes allegiance to material processes, to environmental processes, and to the lives affecting and affected by these processes. Craft traditions offer students a way of familiarizing themselves with these processses in a specific context. I must stress the "care" in careful, for craft traditions, like woodworking, do not provide answers—but examples: it is up to the student to interpret these examples carefully, and critically, with their whole self, by looking, listening, asking, and touching.

Appendix A - Critique

figure 285

the harvest table

A ten-foot long table to spread out on, to work, and to dine on, is a very accommodating piece of furniture. Being a harvest table, the overall build should be more robust. The top flexes under normal use, and I would not risk sitting on an edge on a regular basis, and not at all on a corner, for fear of collapse. Though pine is soft to the touch, edges and corners could have been made round for greater comfort. I was concerned the rough-sawn edges of the table top would be uncomfortable: where it has worn, it is very soft and pleasant to touch. The finish should have been applied more carefully. Although tung oil has a natural resistance to mildew, there appear to be small patches developing in areas where water has been spilled frequently. Judging by an unpleasant odour, more pronounced in humid weather, the undercoats have not fully cured.

the tree-house

A designation more suitable than tree-house, or playhouse, is gazebo. I worry that, attempting to satisfy designer, adult, and child, the gazebo falls short of providing the ideal space for all. As a place of shelter, the roof does not offer shade enough in the morning and late afternoon, although the surrounding foliage helps in this respect. A light rain may have been less of an issue under the leafy-canopy, inside and around the ornamental roof, inside and around the maple tree on the original site. Because the roof does not provide overhang, nor does it drain water away from the exposed wood joinery, I have no prediction as to the longevity of the structure. I do look forward to monitoring how it weathers.

figure 286

As a place of rest and contemplation, the gazebo performs reasonably well. While the floor is not quite large enough to accommodate lounge furniture, railings at seating height allow one to inhabit the frame comfortably, making a small space feel considerably larger. The integrity of the structure is reassuring, although knee braces, or a more rigid diaphragm under the railings would stiffen the posts more. Several if not all of the connection details could be made more efficient. Wood joinery is nice to behold: it does not reveal all of its secrets at once. The softness of cedar, and pine, and the gentle shape of hand-carved members make the gazebo, for the most part, comfortable and safe to touch and inhabit. Ornament is restrained and integrated with other functions wherever possible: this is a benefit, given that the overall form may draw too much attention to itself—though part of the function of a gazebo *is* to provide ornament.

figure 287

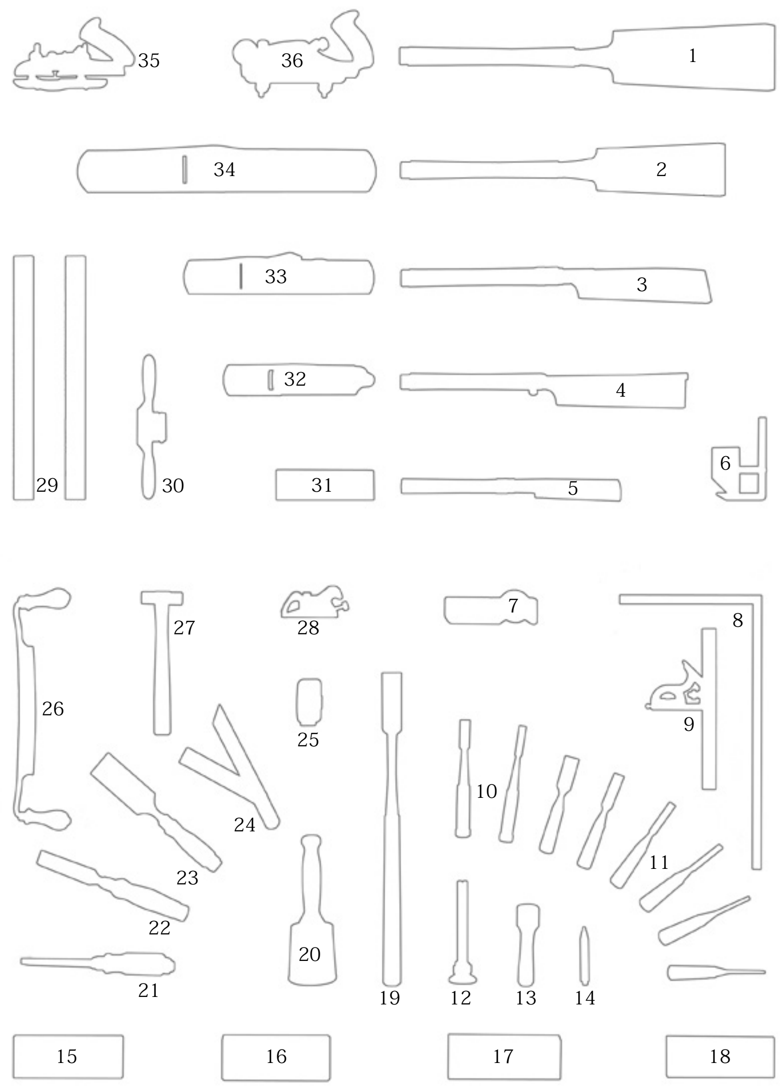
Where formal restraint is questionable, is in a child's space of play. I do believe that the gazebo in its original incarnation—on a slope under a maple tree, with a raised floor providing a crawl-space below—would have accommodated a greater dimension of play, in concert with the surrounding landscape. As it is, the gazebo is somewhat less integrated with its new site.

It would be unfair not to acknowledge the wonder that the overall structure, and individual details, inspire, in children and adults alike. The play of light, the natural beauty of cedar, pine, and oak, and the attention to detail are qualities that the family, and neighbours, have responded well to. The gazebo is an expression of a process of learning and experimentation.

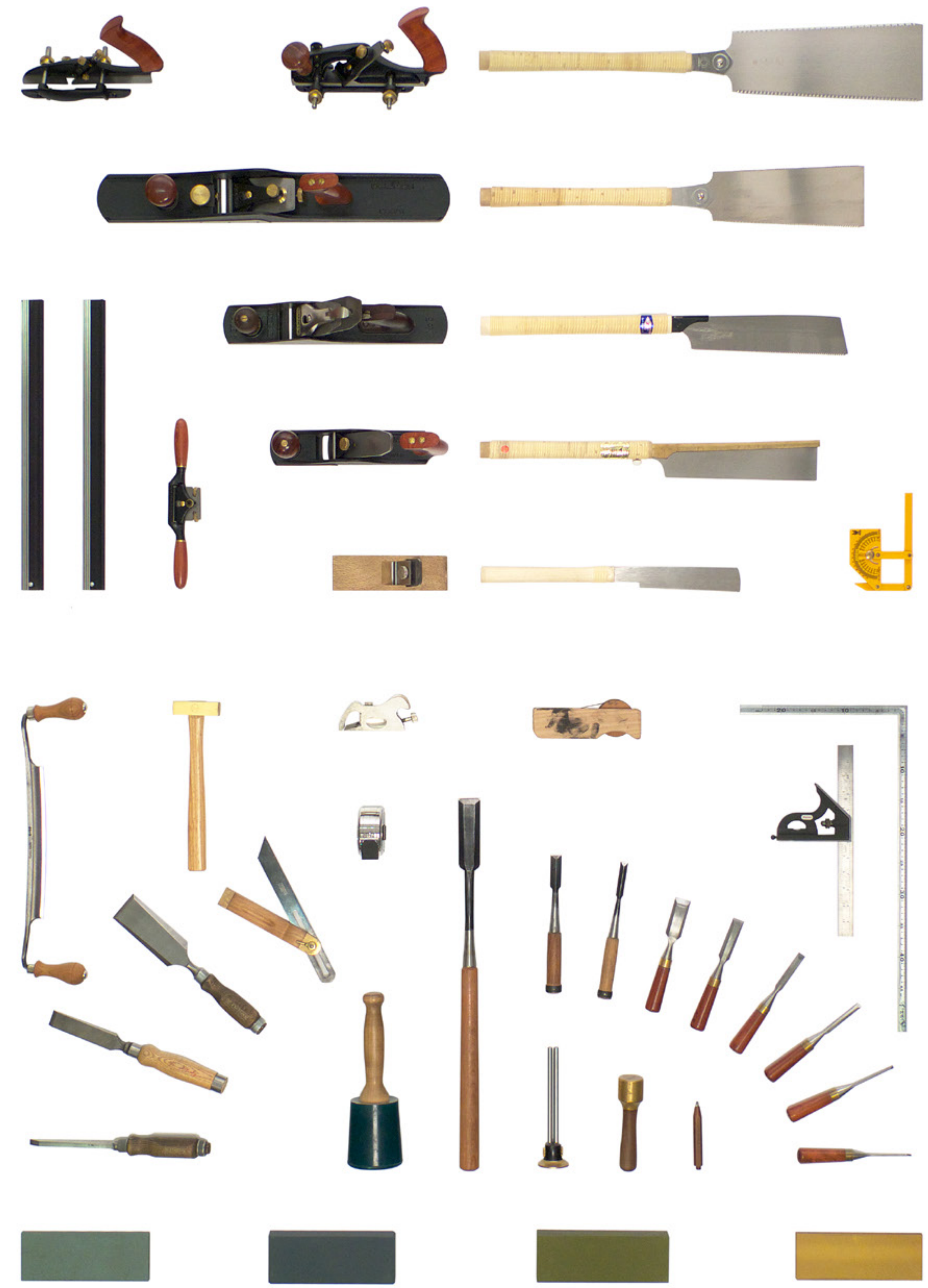
It *is* play.

Appendix B - The Tools Most Used

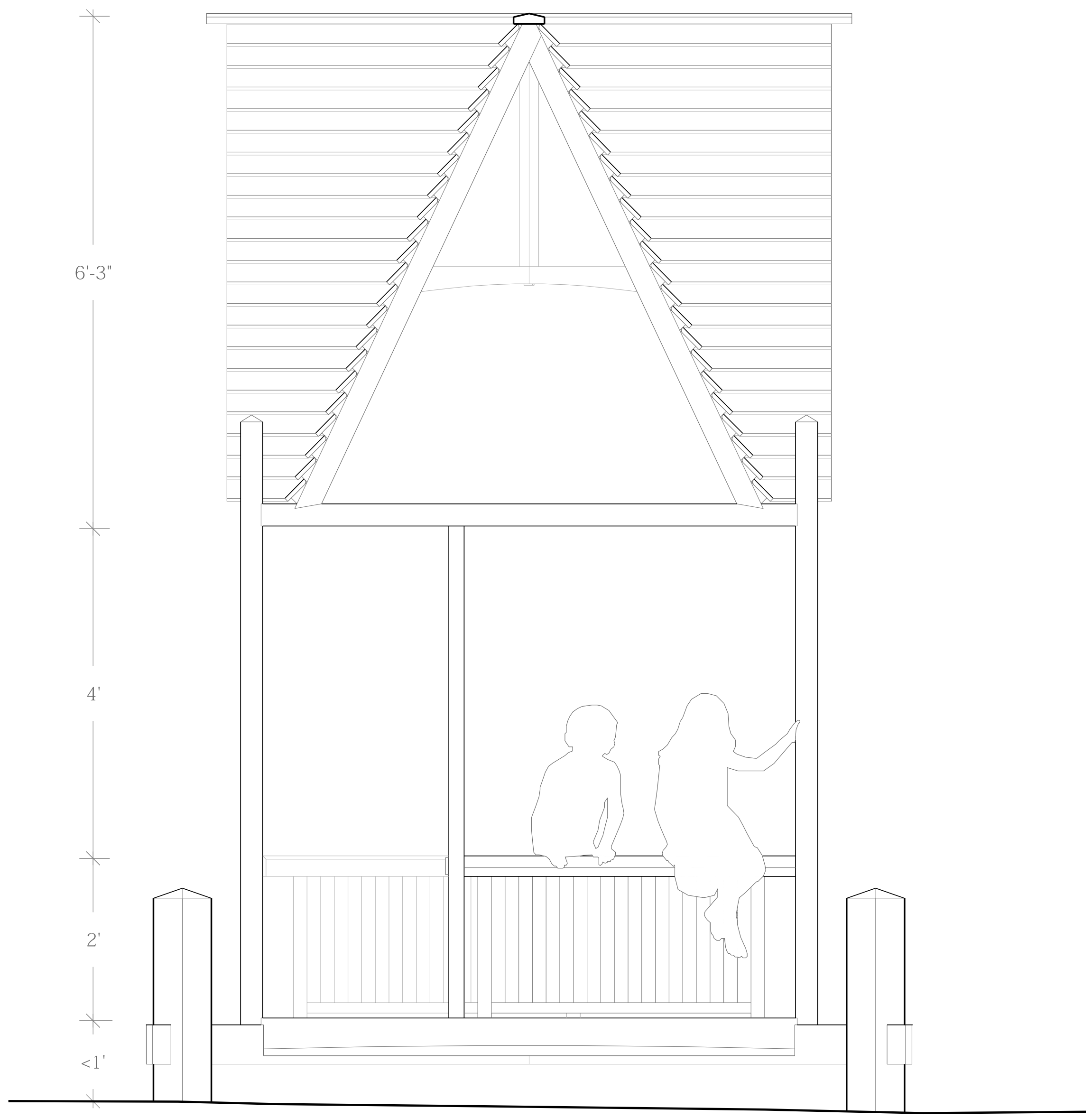
The following diagram is a display of the tools that I used most frequently during the building of the harvest table, and tree-house.



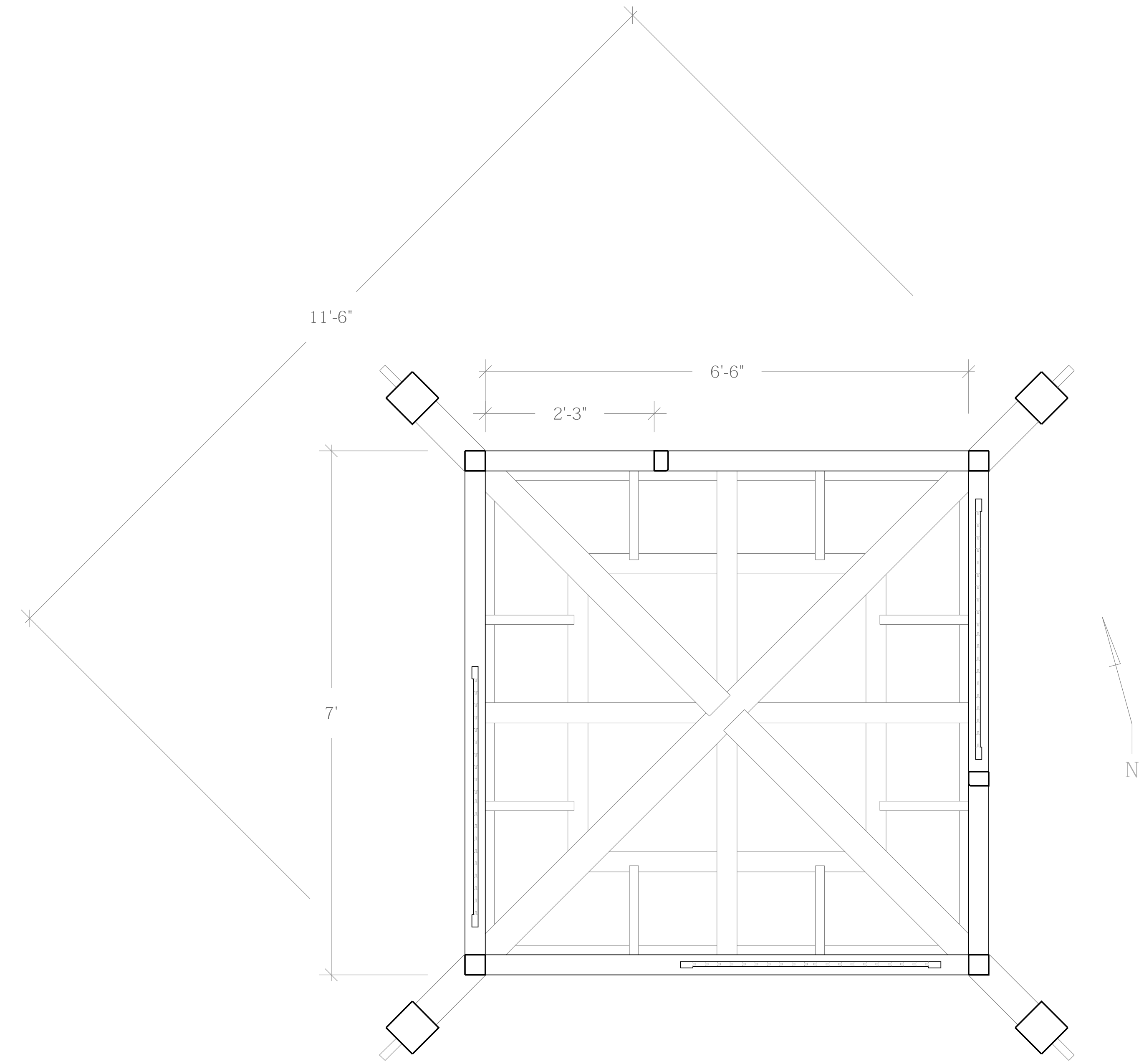
1. 30cm Ryoba saw. **2**. 24cm Ryoba saw. **3**. 25cm Kataba saw. **4**. 23cm Dozuki saw. **5**. Flush-cut Saw. **6**. Adjustable protractor. **7**. Sumitsubo (ink-line). **8**. Carpenter's square. **9**. Combination square. **10**. Two dovetail chisels, 1/2" & 3/4". **11**. Set of six butt-chisels, 1/8"—1". **12**. Marking gauge. **13**. Small brass mallet. **14**. Lead holder. **15**. 240-grit water-stone. **16**. 1000-grit water-stone. **17**. 3000-grit water-stone. **18**. 4000/8000-grit water-stone. **19**. 1-1/4" slick. **20**. Large rubber mallet. **21**. 1/4" mortise chisel. **22**. 1" mortise chisel. **23**. 2" bevel edge chisel. **24**. Sliding Bevel. **25**. Tape Measure. **26**. Draw-knife. **27**. Plane mallet. **28**. Rabbet-plane. **29**. Winding sticks. **30**. Round Spokeshave. **31**. Smooth-plane. **32**. Scrub-plane. **33**. Jack-plane. **34**. Jointer-plane. **35**. Plough-plane. **36**. Skew rabbet-plane.



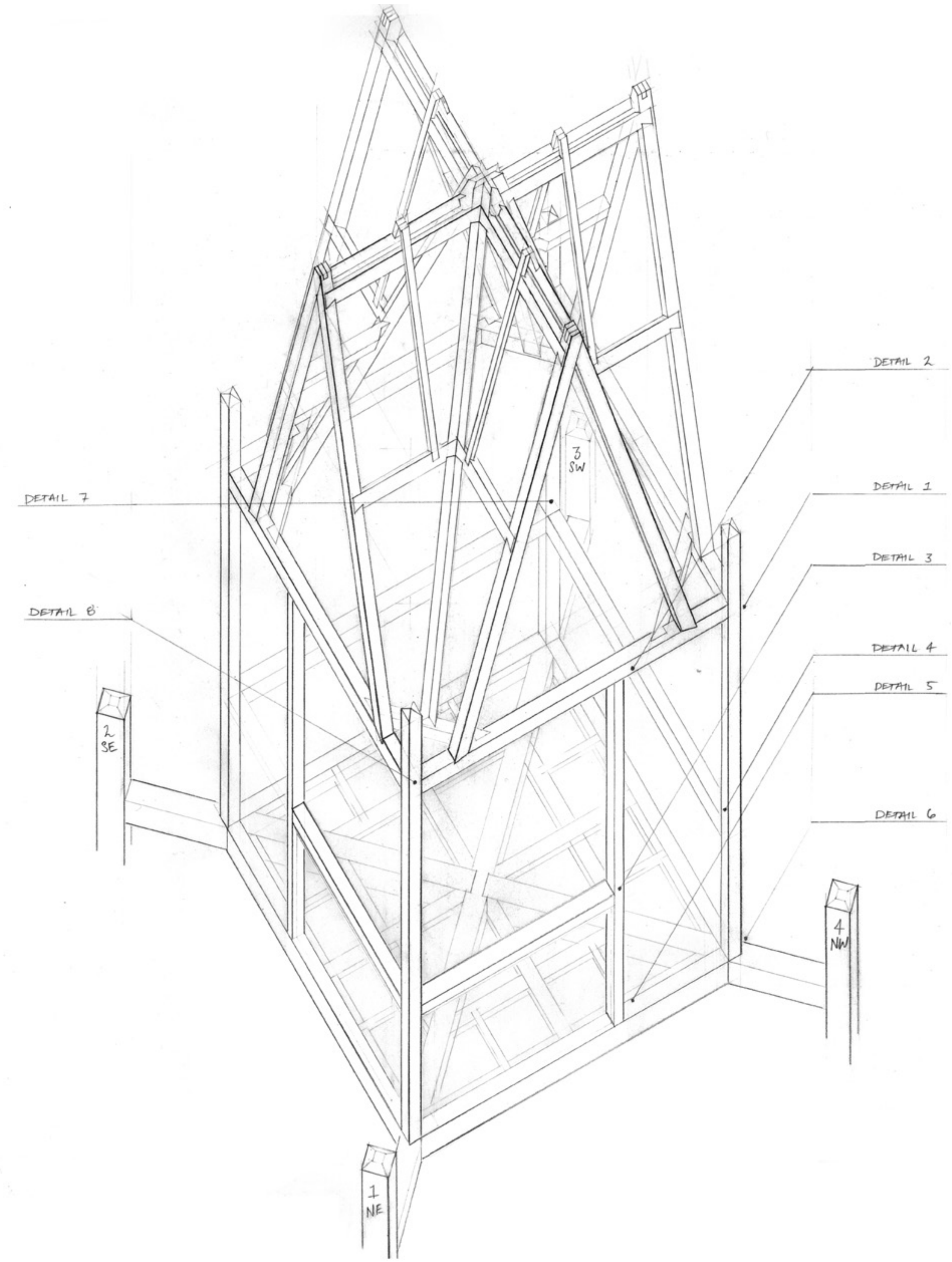
Appendix C - Drawings



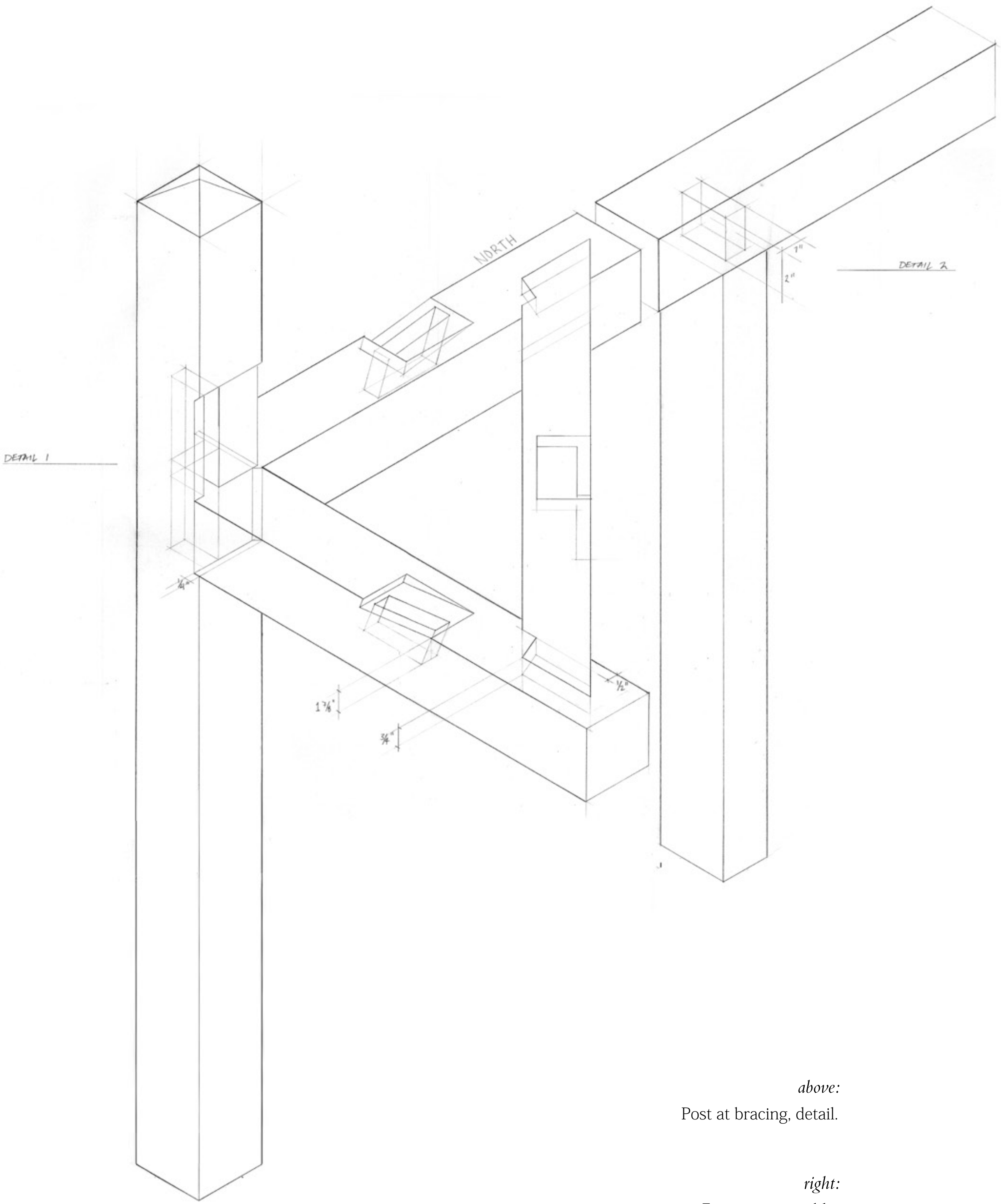
above:
East Elevation.



above:
Structural Floor Plan.

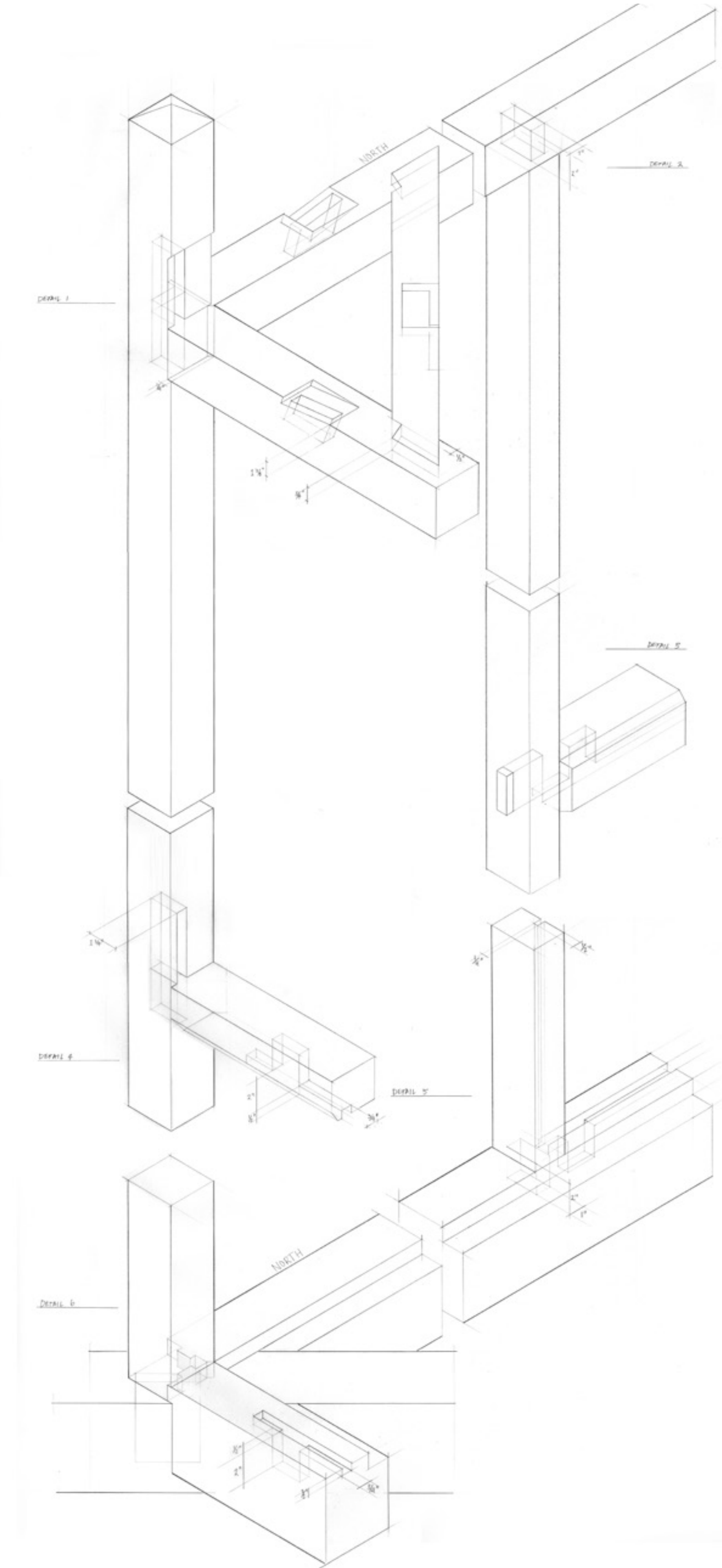


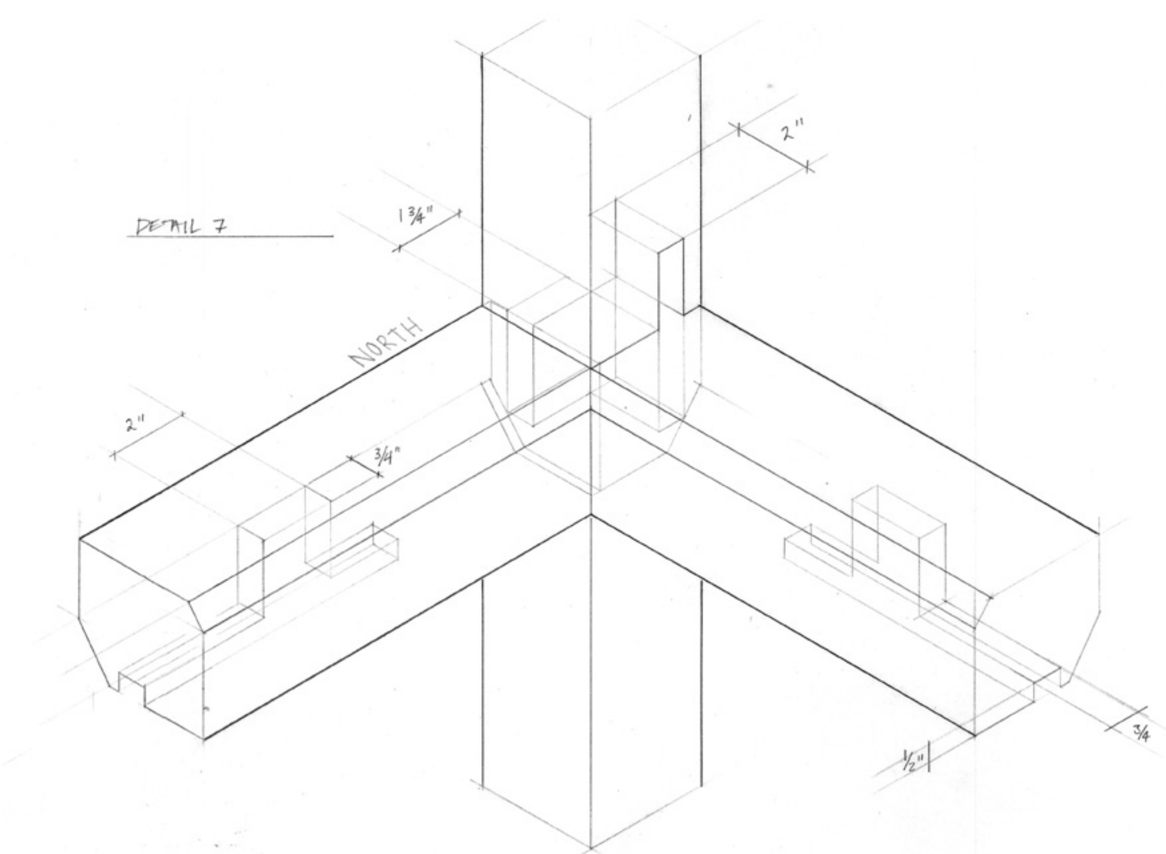
right:
Structural axonometric.



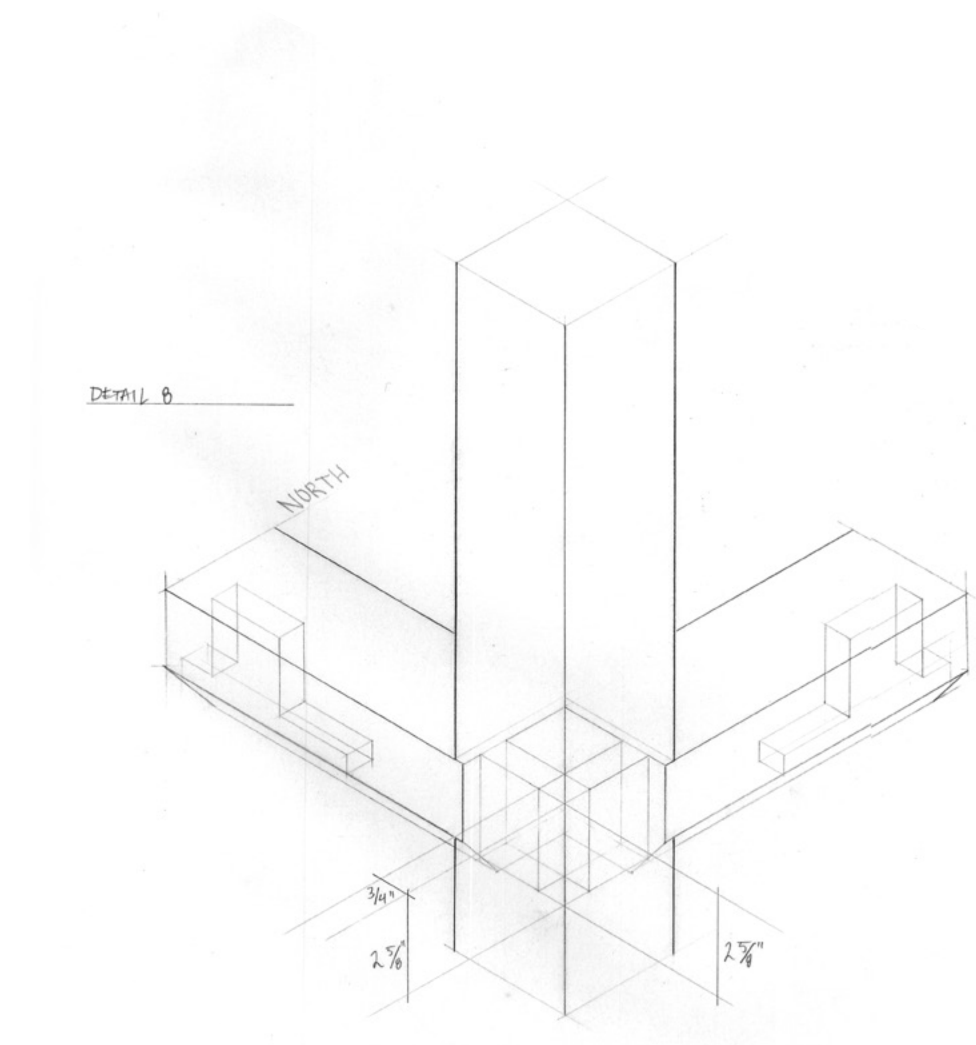
above:
Post at bracing, detail.

right:
Entrance assembly.

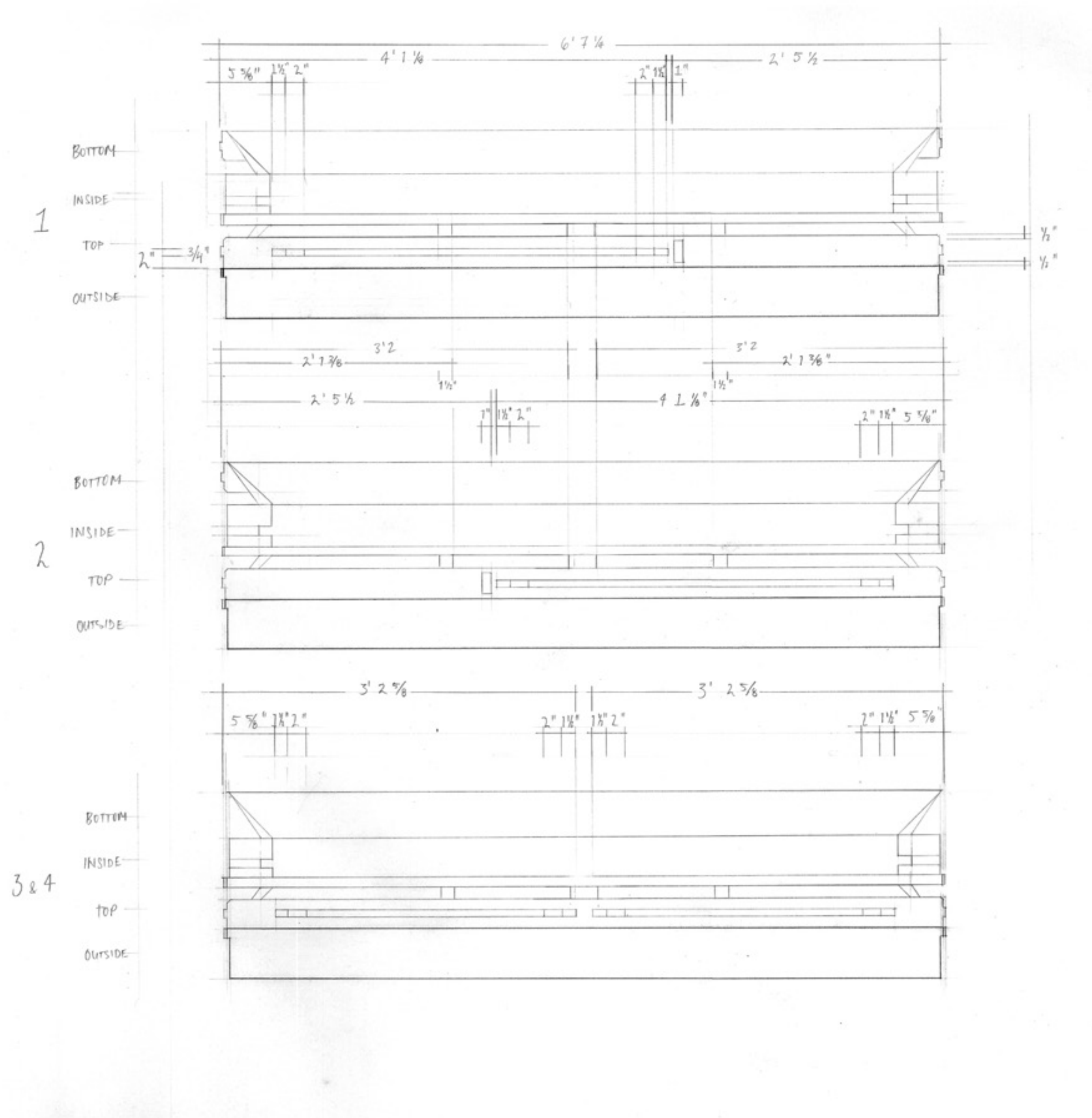




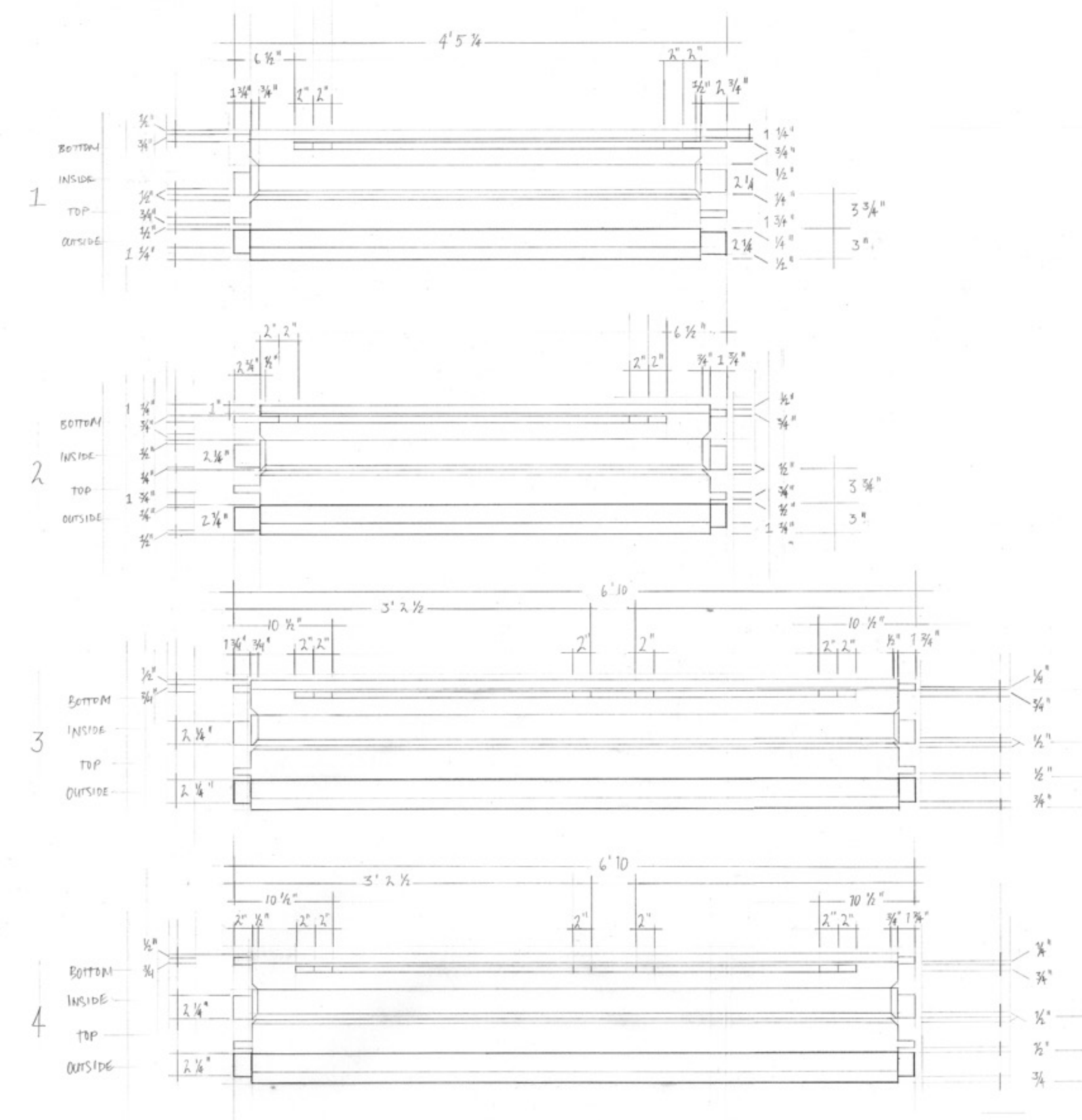
above:
Railing-to-post joint. Inside.



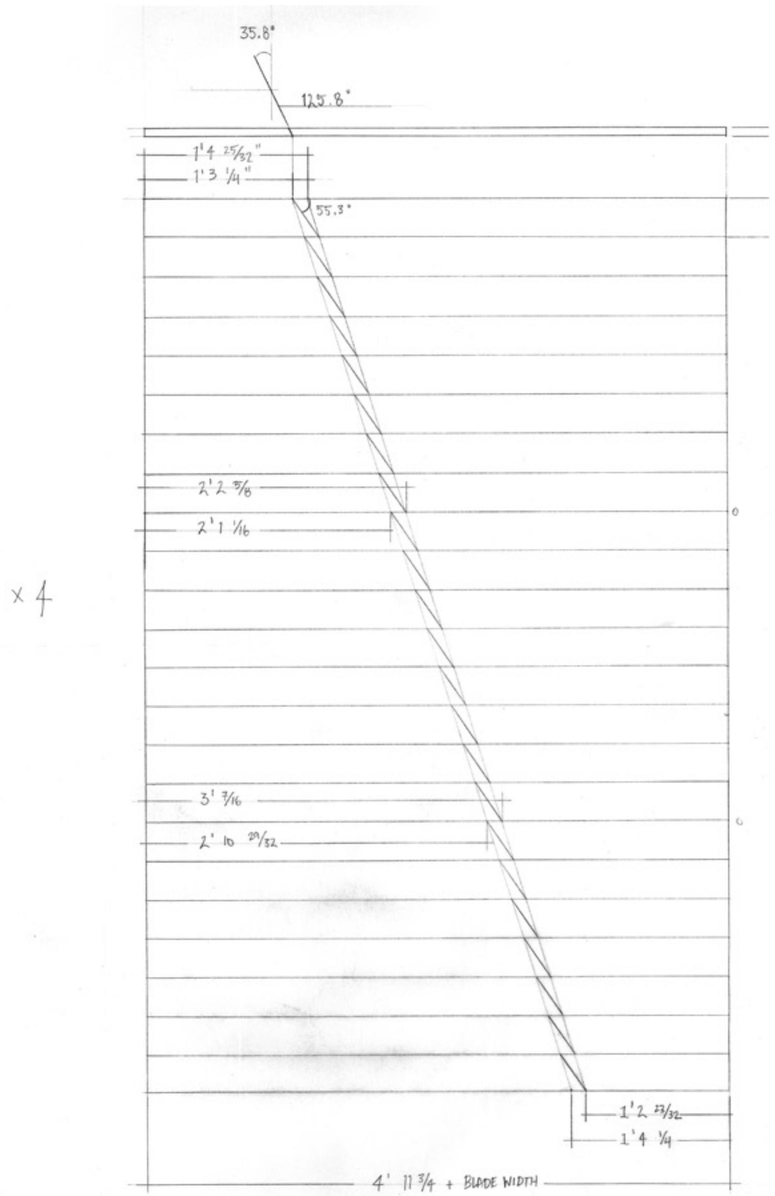
above:
Railing-to-post joint. Outside.



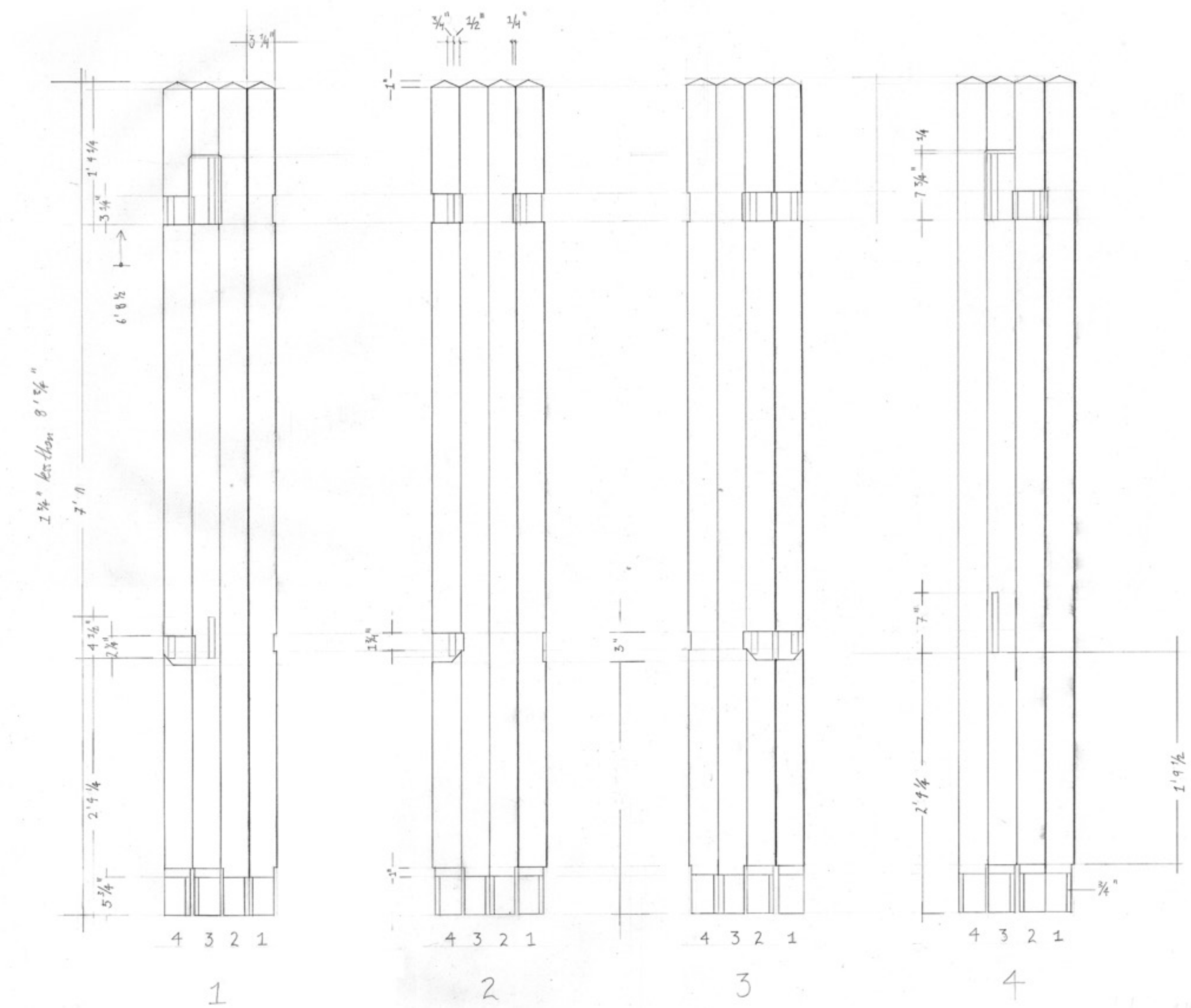
above:
Mud-sill schedule.



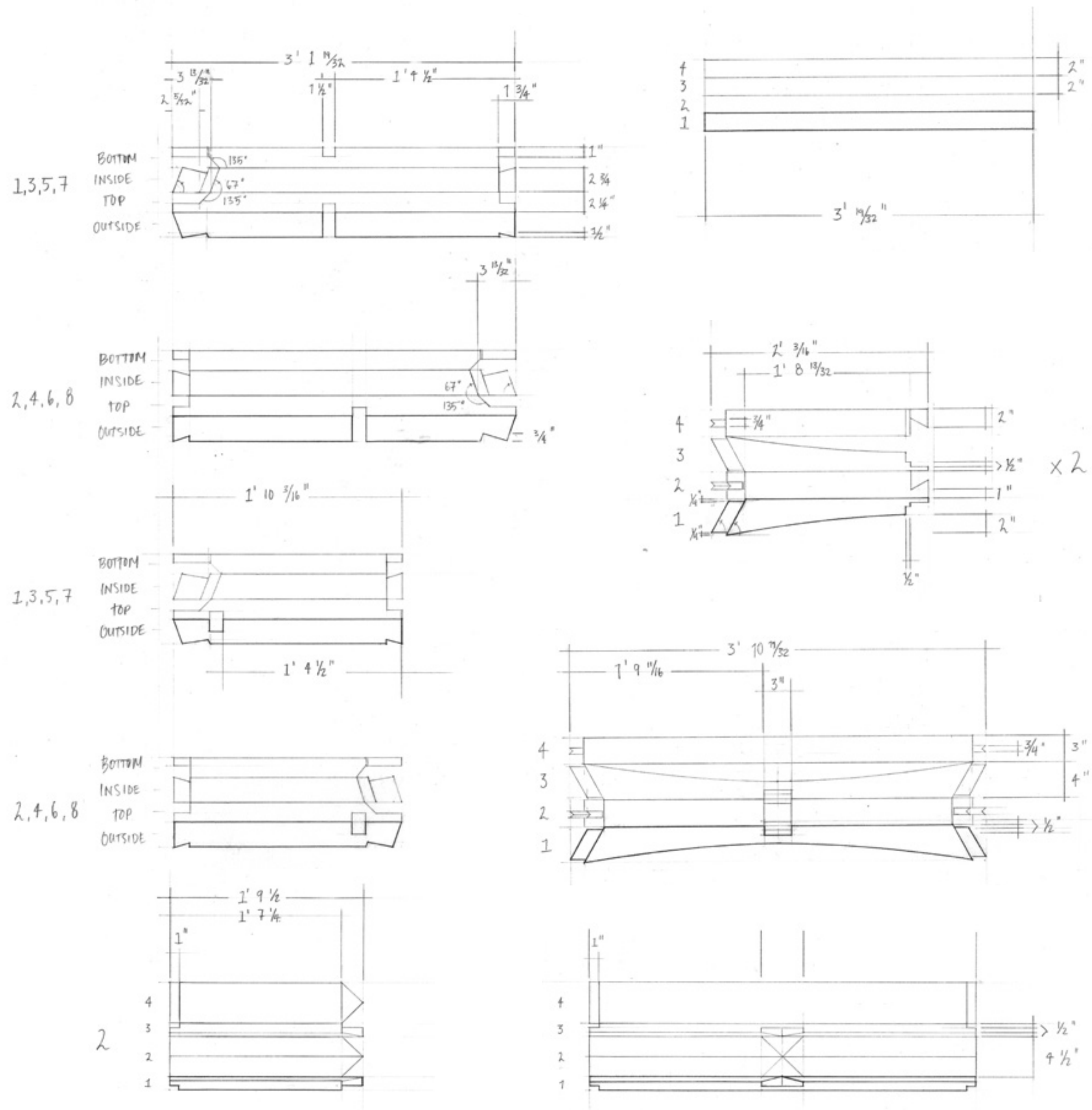
above:
Railing schedule.



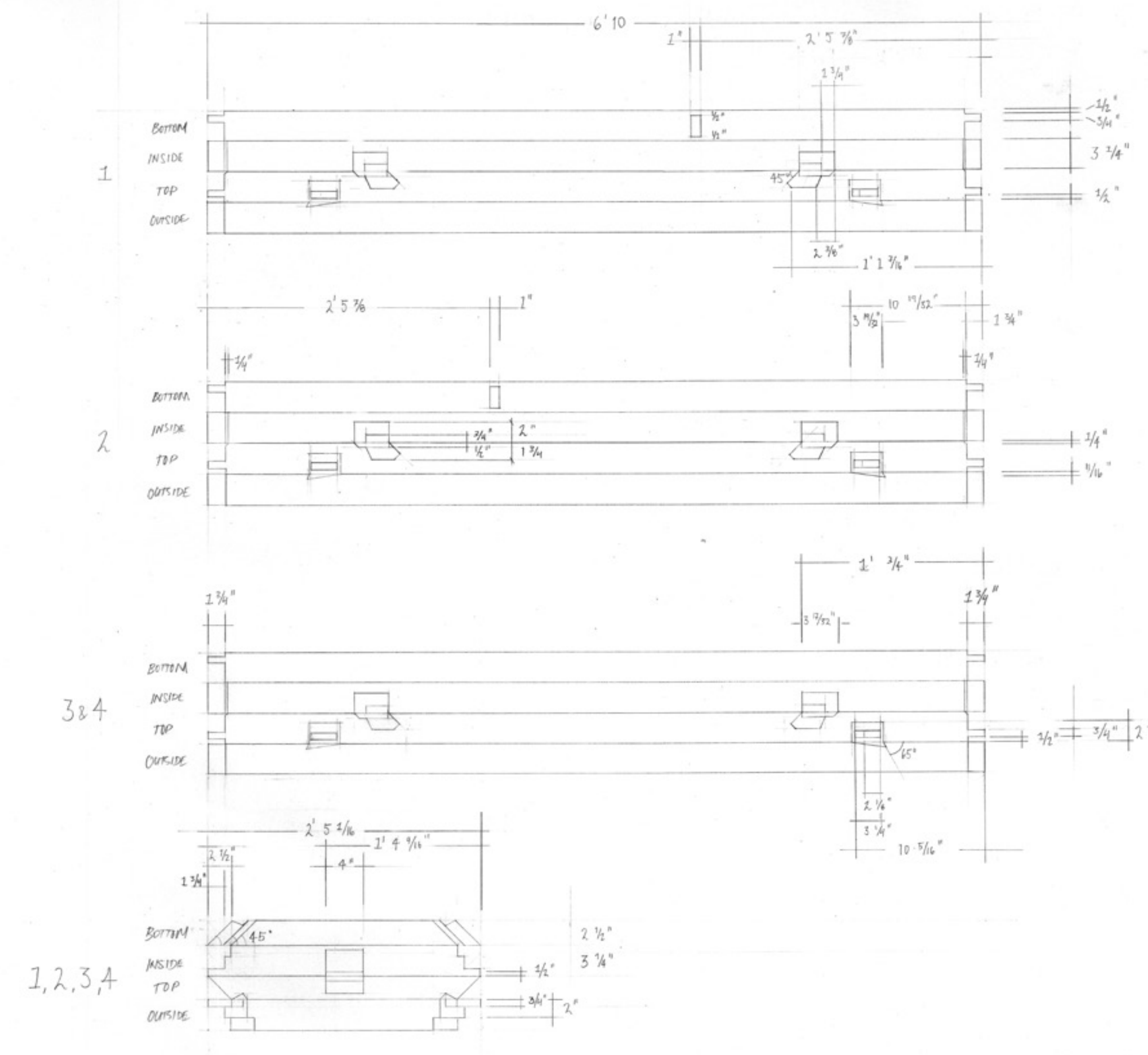
above:
Roof plank schedule.



above:
Post schedule.



above:
Purlin, bridging, collar-beam, king-post, and ridge-cap schedule.



above:
Roof beam, and bracing schedule.

Appendix D - WBS - Tree-House Build

The version included here, is the last of several revisions, each more detailed than the last. Rarely do things go according to plan. Being able to adapt to setbacks is as important as trying to predict tasks with accuracy.

Task	Start	End	Time
1.0 - TREEHOUSE BUILD	13/08/03 9:00 AM	14/03/30 5:00 PM	8mo 3w 2d 6h
1.1 - Phase 1: Prefabrication	13/08/03 9:00 AM	14/02/13 5:00 PM	7mo
MILESTONE - 1.1.1 - Dimensioning Begins	13/08/03 9:00 AM	13/08/03 9:00 AM	
1.1.2 - Dimensioning	13/08/05 9:00 AM	13/09/09 5:00 PM	1mo 1w 1d
1.1.2.1 - Dimensioning Principal Rafters	13/08/05 9:00 AM	13/08/09 5:00 PM	1w
- 1.1.2.1.1 - Planing Principal Rafter, block 1	13/08/05 9:00 AM	13/08/05 5:00 PM	1d
- 1.1.2.1.2 - Planing Principal Rafter, block 2	13/08/06 9:00 AM	13/08/06 5:00 PM	1d
- 1.1.2.1.3 - Planing Principal Rafter, block 3	13/08/07 9:00 AM	13/08/07 5:00 PM	1d
- 1.1.2.1.4 - Planing Principal Rafter, block 4	13/08/08 9:00 AM	13/08/08 5:00 PM	1d
- 1.1.2.1.5 - Thicknessing Principal Rafters, blocks 1-4	13/08/09 9:00 AM	13/08/09 12:00 PM	3h
Only on one side.			
- 1.1.2.1.6 - Ripping Principal Rafter blocks 1-4	13/08/09 1:00 PM	13/08/09 3:00 PM	2h
- 1.1.2.1.7 - Thicknessing Principal Rafters, ripped faces, 1-8	13/08/09 3:00 PM	13/08/09 5:00 PM	2h
1.1.2.2 - Dimensioning Tertiary Posts	13/08/12 9:00 AM	13/08/13 5:00 PM	2d
- 1.1.2.2.1 - Planing Tertiary Post, block 1	13/08/12 9:00 AM	13/08/12 5:00 PM	1d
- 1.1.2.2.2 - Thicknessing Tertiary Post, block 1	13/08/13 9:00 AM	13/08/13 12:00 PM	3h
Only on one side.			
- 1.1.2.2.3 - Ripping Tertiary Post, block 1	13/08/13 1:00 PM	13/08/13 3:00 PM	2h
- 1.1.2.2.4 - Planing Tertiary Posts, ripped faces, 1-2	13/08/13 3:00 PM	13/08/13 5:00 PM	2h
1.1.2.3 - Dimensioning Railings	13/08/14 9:00 AM	13/08/20 5:00 PM	1w
- 1.1.2.3.1 - Planing Railing, block 1	13/08/14 9:00 AM	13/08/14 5:00 PM	1d
- 1.1.2.3.2 - Planing Railing, block 2	13/08/15 9:00 AM	13/08/15 5:00 PM	1d
- 1.1.2.3.3 - Planing Railing, block 3	13/08/16 9:00 AM	13/08/16 5:00 PM	1d
- 1.1.2.3.4 - Planing Railing, block 4	13/08/19 9:00 AM	13/08/19 5:00 PM	1d
- 1.1.2.3.5 - Thicknessing Railings, blocks 1-4	13/08/20 9:00 AM	13/08/20 5:00 PM	1d
1.1.2.4 - Dimensioning Roof Beams	13/08/21 9:00 AM	13/08/23 5:00 PM	3d
- 1.1.2.4.1 - Planing Roof Beam, block 1	13/08/21 9:00 AM	13/08/21 1:30 PM	3h 30m
- 1.1.2.4.2 - Planing Roof Beam, block 2	13/08/21 1:30 PM	13/08/21 5:00 PM	3h 30m
- 1.1.2.4.3 - Planing Roof Beam, block 3	13/08/22 9:00 AM	13/08/22 1:30 PM	3h 30m
- 1.1.2.4.4 - Planing Roof Beam, block 4	13/08/22 1:30 PM	13/08/22 5:00 PM	3h 30m
- 1.1.2.4.5 - Thicknessing Roof Beams, blocks 1-4	13/08/23 9:00 AM	13/08/23 5:00 PM	1d

1.1.2.5 - Dimensioning Tie-Beams	13/08/26 9:00 AM	13/08/28 5:00 PM	3d
- 1.1.2.5.1 - Planing Tie-Beam, block 1	13/08/26 9:00 AM	13/08/26 5:00 PM	1d
- 1.1.2.5.2 - Planing Tie-Beam, block 2	13/08/27 9:00 AM	13/08/27 5:00 PM	1d
- 1.1.2.5.3 - Thicknessing Tie-Beams, blocks 1-2	13/08/28 9:00 AM	13/08/28 5:00 PM	1d
1.1.2.6 - Dimensioning Purlins	13/08/29 9:00 AM	13/09/04 5:00 PM	1w
- 1.1.2.6.1 - Planing Purlin, block 1	13/08/29 9:00 AM	13/08/29 5:00 PM	1d
- 1.1.2.6.2 - Planing Purlin, block 2	13/08/30 9:00 AM	13/08/30 5:00 PM	1d
- 1.1.2.6.3 - Planing Purlin, block 3	13/09/02 9:00 AM	13/09/02 5:00 PM	1d
- 1.1.2.6.4 - Planing Purlin, block 3	13/09/03 9:00 AM	13/09/03 5:00 PM	1d
- 1.1.2.6.5 - Thicknessing Purlins, blocks 1-4	13/09/04 9:00 AM	13/09/04 11:00 AM	2h
- 1.1.2.6.6 - Ripping Purlins, Blocks 1-4	13/09/04 11:00 AM	13/09/04 2:00 PM	2h
- 1.1.2.6.7 - Thicknessing Purlins, Blocks 1-8	13/09/04 2:00 PM	13/09/04 4:00 PM	2h
Only on one side.			
- 1.1.2.6.8 - Cutting Purlin Blocks In Half	13/09/04 4:00 PM	13/09/04 5:00 PM	1h
1.1.2.7 - Dimensioning Bridges	13/09/05 9:00 AM	13/09/09 5:00 PM	3d
- 1.1.2.7.1 - Planing Bridge, block 1	13/09/05 9:00 AM	13/09/05 5:00 PM	1d
- 1.1.2.7.2 - Planing Bridge, block 2	13/09/06 9:00 AM	13/09/06 5:00 PM	1d
- 1.1.2.7.3 - Thicknessing Bridges, blocks 1-2	13/09/09 9:00 AM	13/09/09 11:00 AM	2h
- 1.1.2.7.4 - Ripping Bridges, blocks 1-2	13/09/09 11:00 AM	13/09/09 2:00 PM	2h
- 1.1.2.7.5 - Thicknessing Bridges, blocks 1-4	13/09/09 2:00 PM	13/09/09 5:00 PM	3h
Only on one side.			
MILESTONE - 1.1.3 - Jointing Begins	13/09/09 5:00 PM	13/09/09 5:00 PM	
1.1.4 - Jointing:	13/09/10 9:00 AM	14/02/13 5:00 PM	5mo 2w 4d
1.1.4.1 - Jointing Posts	13/09/10 9:00 AM	13/09/18 5:00 PM	1w 2d
- 1.1.4.1.1 - Jointing Secondary Post, block 1	13/09/10 9:00 AM	13/09/10 5:00 PM	1d
- 1.1.4.1.2 - Jointing Secondary Post, block 2	13/09/11 9:00 AM	13/09/11 5:00 PM	1d
- 1.1.4.1.3 - Jointing Secondary Post, block 3	13/09/12 9:00 AM	13/09/12 5:00 PM	1d
- 1.1.4.1.4 - Jointing Secondary Post, block 4	13/09/13 9:00 AM	13/09/13 5:00 PM	1d
- 1.1.4.1.5 - Jointing Tertiary Posts, blocks 1-2	13/09/16 9:00 AM	13/09/16 5:00 PM	1d
- 1.1.4.1.6 - Jointing Primary Post, blocks 1-2	13/09/17 9:00 AM	13/09/17 5:00 PM	1d
- 1.1.4.1.7 - Jointing Primary Post, blocks 1-4	13/09/18 9:00 AM	13/09/18 5:00 PM	1d

1.1.4.2 - Jointing Roof Beams	13/09/19 9:00 AM	13/09/25 5:00 PM	1w
- 1.1.4.2.1 - Scribing Joints, blocks 1-4	13/09/19 9:00 AM	13/09/19 5:00 PM	1d
- 1.1.4.2.2 - Jointing Roof Beam, block 1	13/09/20 9:00 AM	13/09/20 5:00 PM	1d
- 1.1.4.2.3 - Jointing Roof Beam, block 2	13/09/23 9:00 AM	13/09/23 5:00 PM	1d
- 1.1.4.2.4 - Jointing Roof Beam, block 3	13/09/24 9:00 AM	13/09/24 5:00 PM	1d
1.1.4.2.5 - Jointing Roof Beam, block 4	13/09/25 9:00 AM	13/09/25 5:00 PM	1d
1.1.4.3 - Jointing Braces, Purlins, & Bridges	13/09/26 9:00 AM	13/10/08 5:00 PM	1w 4d
- 1.1.4.3.1 - Jointing Braces, blocks 1-4	13/09/26 9:00 AM	13/10/01 5:00 PM	4d
- 1.1.4.3.2 - Jointing Purlins, blocks 1-4	13/10/02 9:00 AM	13/10/02 5:00 PM	1d
- 1.1.4.4.3 - Jointing Principal Rafters, blocks 5-6	13/10/11 9:00 AM	13/10/11 5:00 PM	1d
- 1.1.4.4.4 - Jointing Principal Rafters, blocks 7-8	13/10/14 9:00 AM	13/10/14 5:00 PM	1d
- 1.1.4.4.5 - Jointing Valley Rafter, block 1	13/10/15 9:00 AM	13/10/17 5:00 PM	3d
- 1.1.4.4.6 - Jointing Valley Rafter, block 2	13/10/18 9:00 AM	13/10/22 5:00 PM	3d
- 1.1.4.4.7 - Jointing Valley Rafter, block 3	13/10/23 9:00 AM	13/10/25 5:00 PM	3d
- 1.1.4.4.8 - Jointing Valley Rafter, block 4	13/10/28 9:00 AM	13/10/30 5:00 PM	3d
1.1.4.5 Jointing Sills and Beams	13/10/31 9:00 AM	13/11/05 5:00 PM	4d
- 1.1.4.5.1 - Jointing Mudsills, blocks 1-2	13/10/31 9:00 AM	13/11/01 5:00 PM	2d
- 1.1.4.5.2 - Jointing Mudsills, blocks 3-4	13/11/04 9:00 AM	13/11/04 5:00 PM	1d
- 1.1.4.5.3 - Jointing Major Beam	13/11/05 9:00 AM	13/11/05 5:00 PM	1d
1.1.4.6 - Jointing Railings and Sidewalls	13/11/06 9:00 AM	13/11/19 5:00 PM	2w
- 1.1.4.6.1 - Jointing Railings, blocks 1-4	13/11/06 9:00 AM	13/11/12 5:00 PM	1w
- 1.1.4.6.2 - Jointing Sidewalls	13/11/13 9:00 AM	13/11/19 5:00 PM	1w
1.1.4.7 - Jointing Decking, & Roofing	14/01/22 9:00 AM	14/02/13 5:00 PM	1mo 3d
1.1.4.7.1 - Jointing Decking	14/01/22 9:00 AM	14/02/04 12:00 PM	2w 3d 3h
- 1.1.4.7.1.1 - Board Count & Finish Dimensions	14/01/22 9:00 AM	14/01/22 12:00 PM	3h
- 1.1.4.7.1.2 - Joint & Thickness Boards	14/01/22 1:00 PM	14/01/22 5:00 PM	4h
- 1.1.4.7.1.3 - Joint & Thickness Boards (Cont.)	14/01/27 9:00 AM	14/01/27 1:30 PM	3h 30m
- 1.1.4.7.1.4 - Mark Boards for Ripping	14/01/27 1:30 PM	14/01/27 5:00 PM	3h 30m
- 1.1.4.7.1.5 - Rip boards to Rough Dimensions	14/01/28 9:00 AM	14/01/29 1:30 PM	1d 3h 30m
- 1.1.4.7.1.6 - Rip Boards to Exact Dimensions	14/01/30 1:30 PM	14/01/31 5:00 PM	1d 3h 30m
- 1.1.4.7.1.7 - Cut Boards to Exact Lengths	14/02/03 9:00 AM	14/02/03 10:00 AM	1h
- 1.1.4.7.1.8 - Rip Grooves on Board Edges	14/02/03 10:00 AM	14/02/03 12:00 PM	2h

- 1.1.4.7.1.9 - Chamfer Board Edges	14/02/03 1:00 PM	14/02/03 5:00 PM	4h
- 1.1.4.7.1.10 - Thickness Plank for Biscuits	14/02/04 9:00 AM	14/02/04 10:00 AM	1h
- 1.1.4.7.1.11 - Cut Biscuits	14/02/04 10:00 AM	14/02/04 12:00 PM	2h
1.1.4.7.2 - Jointing Roofing	14/02/01 9:00 AM	14/02/06 5:00 PM	1w 1d
- 1.1.4.7.2.1 - Board Count & Finish Dimensions	14/02/01 9:00 AM	14/02/01 1:30 PM	3h 30m
- 1.1.4.7.2.2 - Mark Planks for Cutting	14/02/02 9:00 AM	14/02/02 1:30 PM	3h 30m
- 1.1.4.7.2.3 - Cut Roof Planks	14/02/04 1:15 PM	14/02/05 1:30 PM	1d 15m
- 1.1.4.7.2.4 - Mark Planks for Chamfering	14/02/05 1:30 PM	14/02/05 5:00 PM	3h 30m
- 1.1.4.7.2.5 - Chamfer Planks	14/02/06 9:00 AM	14/02/06 5:00 PM	1d
1.1.4.7.3 - Jointing Ridge Caps	14/02/07 9:00 AM	14/02/08 5:00 PM	2d
- 1.1.4.7.3.1 - Board Count & Finish Dimensions	14/02/07 9:00 AM	14/02/07 1:30 PM	3h 30m
- 1.1.4.7.3.2 - Cut Boards to Size	14/02/07 1:30 PM	14/02/07 3:15 PM	1h 45m
- 1.1.4.7.3.3 - Joint & Thickness	14/02/07 3:15 PM	14/02/07 5:00 PM	1h 45m
- 1.1.4.7.3.4 - Cut Lap Joints	14/02/08 9:00 AM	14/02/08 1:30 PM	3h 30m
- 1.1.4.7.3.5 - Cut Gable on Top Face	14/02/08 1:30 PM	14/02/08 5:00 PM	3h 30m
1.1.4.7.4 - Jointing King-Post Assembly	14/02/09 9:00 AM	14/02/12 5:00 PM	4d
- 1.1.4.7.4.1 - Board Count & Finish Dimensions	14/02/09 9:00 AM	14/02/09 1:30 PM	3h 30m
- 1.1.4.7.4.2 - Joint & Thickness Collar-Ties	14/02/09 1:30 PM	14/02/09 5:00 PM	3h 30m
- 1.1.4.7.4.3 - Cut Collar Ties,	14/02/10 9:00 AM	14/02/10 5:00 PM	1d
- 1.1.4.7.4.4 - Joint Collar Ties	14/02/11 9:00 AM	14/02/11 5:00 PM	1d
- 1.1.4.7.4.5 - Modify Collar Tie Joint at Valley Rafters	14/02/12 9:00 AM	14/02/12 5:00 PM	1d
1.1.4.7.5 - Chamfer Roof Structure	14/02/13 9:00 AM	14/02/13 5:00 PM	1d
- 1.1.4.7.5.1 - Chamfer Valley Rafters	14/02/13 9:00 AM	14/02/13 12:00 PM	3h
- 1.1.4.7.5.2 - Chamfer Principal Rafters	14/02/13 1:00 PM	14/02/13 4:00 PM	3h
- 1.1.4.7.5.3 - Break Edges on Purlins & Bridges	14/02/13 4:00 PM	14/02/13 5:00 PM	1h
MILESTONE - 1.1.5 - Miscellaneous	13/11/20 9:00 AM	14/01/06 5:00 PM	1mo 1w 4d
1.1.5.1 - Oiling, Test Fitting, Contingency Buffer, & Miscellaneous.	13/11/20 9:00 AM	14/01/06 5:00 PM	1mo 1w 4d
1.2 - Phase 2: Installation	14/01/07 9:00 AM	14/03/30 5:00 PM	3mo 2w 1d 6h
MILESTONE - 1.2.1 - Footings, Platform, & Walls	14/01/07 9:00 AM	14/02/23 5:00 PM	2mo 1w 6h
1.2.1.1 - List & Diagram of Operations for Install	14/01/07 9:00 AM	14/01/07 5:00 PM	1d
1.2.1.2 - Tool & Material Checklist	14/01/08 9:00 AM	14/01/08 1:30 PM	3h 30m
1.2.1.3 - Cut Keys & Dowels	14/02/21 7:00 PM	14/02/21 10:00 PM	3h

1.2.1.4 - Gather Tools & Materials	14/01/08 1:30 PM	14/01/09 1:30 PM	1d
1.2.1.5 - Coordinate Resources	14/01/09 1:30 PM	14/01/10 1:30 PM	1d
1.2.1.6 - Move Materials to Site	14/01/10 1:30 PM	14/01/15 1:30 PM	1d
Reserve U-Haul truck.			
1.2.1.7 - Clear Site & Working Area	14/01/15 1:30 PM	14/01/16 1:30 PM	1d
Remove snow from tarps. Uncover backfill.			
1.2.1.8 - Miscellaneous Set-up	14/01/16 1:30 PM	14/01/17 1:30 PM	1d
Source dry backfill. Distribute beams, blocks and shims.			
1.2.1.9 - Install Footings	14/01/17 1:30 PM	14/01/18 1:30 PM	1d
Refer to list of operations.			
1.2.1.10 - Install Mudsills and Supporting Platform Structure	14/01/18 1:30 PM	14/01/19 1:30 PM	1d
Refer to list of operations.			
1.2.1.11 - Fasten Platform Corners with Dowels	14/01/19 1:30 PM	14/01/20 1:30 PM	1d
Refer to list of operations.			
1.2.1.12 - Pick Up Gravel Backfill & Plywood	14/01/20 1:30 PM	14/01/20 4:30 PM	3h
1.2.1.13 - Backfill Post Holes	14/01/20 4:30 PM	14/01/21 1:30 PM	4h
1.2.1.14 - Test-Fit Secondary Posts	14/01/23 9:00 AM	14/01/23 5:00 PM	1d
1.2.1.15 - Install Northern Bent	14/01/26 9:00 AM	14/01/26 10:30 AM	1h 30m
Refer to list of operations.			
1.2.1.16 - Install Eastern Bent	14/01/26 10:30 AM	14/01/26 12:00 PM	1h 30m
Refer to list of operations.			
1.2.1.17 - Install Southern Bent	14/02/22 9:00 AM	14/02/22 1:30 PM	3h 30m
Refer to list of operations.			
1.2.1.18 - Install Braces and Keys, Secure with Cable Clamps	14/02/22 1:30 PM	14/02/22 5:00 PM	3h 30m
1.2.1.19 - Install Dowel Pins	14/02/23 9:00 AM	14/02/23 1:30 PM	3h 30m
1.2.1.20 - Cover Joints at Tops of Posts	14/02/23 1:30 PM	14/02/23 5:00 PM	3h 30m
MILESTONE - 1.2.2 - Roofing and Decking	14/02/14 9:00 AM	14/03/30 5:00 PM	1mo 3w 2d 6h
1.2.2.1 - List & Diagram of Operations for Install	14/02/14 9:00 AM	14/02/14 10:00 AM	1h
1.2.2.2 - Tool & Material Checklist	14/02/14 10:00 AM	14/02/14 10:30 AM	30m
1.2.2.3 - Gather Tools & Materials	14/02/14 10:30 AM	14/02/14 11:30 AM	1h

1.2.2.4 - Coordinate Resources	14/02/14 11:30 AM	14/02/14 12:00 PM	30m
Reserve U-Haul.			
1.2.2.5 - Prepare Shop for Oiling	14/02/14 1:00 PM	14/02/14 5:00 PM	4h
1.2.2.6 - Oil Roof Structure	14/02/14 7:00 PM	14/02/14 10:00 PM	3h
1.2.2.7 - Wipe Roof Structure & Consolidate Pieces	14/02/14 10:00 PM	14/02/15 12:00 AM	2h
1.2.2.8 - Oil Roof Planks	14/02/15 9:00 AM	14/02/15 2:00 PM	4h
1.2.2.9 - Wipe Roof Planks & Consolidate Pieces	14/02/15 2:00 PM	14/02/15 4:00 PM	2h
1.2.2.10 - Oil Decking	14/02/15 4:00 PM	14/02/15 10:00 PM	4h
1.2.2.11 - Wipe Decking & Consolidate Pieces	14/02/15 10:00 PM	14/02/16 12:00 AM	2h
1.2.2.12 - Move Materials to Site	14/02/21 9:00 AM	14/02/21 5:00 PM	1d
Transport Roof Structure, Clear and Prepare Site.			
1.2.2.13 - Install Valley Rafters & King Truss	14/02/24 9:00 AM	14/02/24 5:00 PM	1d
Refer to list of operations.			
1.2.2.14 - Install Principal Rafters, Bridges Purlins	14/02/25 9:00 AM	14/02/25 5:00 PM	1d
Shim Bridges and Purlins.			
1.2.2.15 - Install Roof Planks	14/02/26 9:00 AM	14/03/04 5:00 PM	1w
1.2.2.16 - Install Ridge Caps	14/03/05 9:00 AM	14/03/05 5:00 PM	1d
1.2.2.17 - Install Decking	14/03/30 9:00 AM	14/03/30 2:00 PM	4h
1.2.2.18 - Install Dowel Pins	14/03/30 2:00 PM	14/03/30 5:00 PM	3h

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