Japanese Timber Frame Methodology:
Alternative Solutions to Hawaii's Built Environment

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May 2012

Submitted towards the fulfillment of the requirements for the Doctor of Architecture Degree.

School of Architecture
University of Hawai‘i

Doctorate Project Committee
Magi Sarvimaki, Chairperson
Steven Hill
Bob Liljestrand

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We certify that we have read this Doctorate Project and that, in our opinion, it is satisfactory in scope and quality in fulfillment as a Doctorate Project for the degree of Doctor of Architecture in the School of Architecture, University of Hawai'i at Mānoa.

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~ DOCUMENT OUTLINE ~

~ AUTHOR'S NOTE ~

My interest in timber frame design and architecture stems from my passion in woodworking and traditional Japanese architecture and philosophy. This research document was composed to bring into light the innovative design and construction solutions that Japanese carpenter's developed over generations in their history of traditional Japanese architecture. Their sole and primary use of wood as a material for building construction led to the development of a woodworking methodology that pioneered innovations in timber frame architectural design and building construction for centuries. Today, the design features created by the tradition of Japanese architecture has readily been a prominent influence in the realms of architecture and the arts and crafts. However, the extension of its influence seems to be limited to the superficial design features of the Japanese house. Japanese architecture is not merely an aesthetic distinction in architecture and the arts. Japanese architecture is a holistic approach to the built environment that includes a methodology of building design and construction that is rooted in the tradition of the Japanese carpenter and the influence of the values of Zen Buddhism in the carpenter's woodworking philosophy.

Therefore, this research document attempts to introduce Japanese carpentry, as an architectural study, through a different light. Portions of the study do take into consideration the superficial design characteristics that define the Japanese house, but the bulk of the research touches on the tradition of Japanese architecture from the perspective of the Japanese carpenter, who at the time played the dual role of both designer and builder.

This document takes the stance as a how-to study, rather than a theoretical dissertation on traditional Japanese architecture. It includes detailed accounts of the methodology, philosophy, technical skill, and knowledge which were taught to me, under the guidance and expertise of Paul Discoe, in my educational pursuit of the craft of traditional Japanese architectural design, woodworking, and building construction.

I have accomplished this research document in the hopes that I may reflect at the knowledge gained at some point in the future for technical guidance in the craft, to recover the memories of my past, and to share the experiences of my educational journey as a woodworker's apprentice and an architecture student with others that may share the same interest and passion, and with those who seek to better the general practice of architecture, construction, and sustainable design as a whole.

~ ABSTRACT ~

This study **EXAMINES** the historical development of the Japanese tradition of wood-based residential architecture from its prehistoric beginnings up until of the end of the Edo period (1600 – 1868). It starts with a brief look into the history of traditional Japanese architecture, beginning with the construction of early dwelling house-types developed during the early period of Japanese antiquity. This period dates back to pre-Buddhist influence and is followed by the buildings developed post Buddhist era, which includes Buddhist temples and temple complexes, Shinto shrines, and palace complexes. The historic summary culminates with the final development of the *shoin* style residence, which reached its final stage of development during the Edo period, and of which is the main design influence to this research document.

The **OBJECTIVE** is to develop a background understanding of the history of traditional Japanese architecture, particularly its wood joinery component, and how it affected the evolution and development of the design features of the Edo period Japanese house.

The **FOCUS** of the study is to look at the distinct architectural features that characterize the *shoin* style and make this type of residential architecture unique to Japan, such as its modular system of measure and construction, the application of a wood joinery method of construction, its flexible and multi-functional spatial layout, built in furnishings, and the buildings architectural relationship between interior and exterior environments.

The **GOAL** is to primarily develop an understanding of the architectural qualities that are distinct to Japanese residential architecture and to apply some of the things learned to enhance contemporary wood-based building design and residential living in Oahu, in an effort to ensure the preservation and continuation of the knowledge of this form of construction methodology. The goal is to also look at alternative methods of wood-based construction and the use of reclaimed building materials local to Oahu that may be applicable when considering the traditional Japanese building methodology.

~ PURPOSE ~

Wood-based construction places tremendous pressure on our natural forested regions. As human population growth exceeds the growth and rejuvenation of forested regions, care must be placed into the appropriation and application of wood construction resources in contemporary building design. The strategies of applying wood into design must follow a holistic approach, where wood is appropriated, prepared, applied, disposed of, recycled, or reused as efficiently as possible. No other culture of the past has better represented this holistic sustainable design approach in its practice of wood-based architecture than Japan in its history of architecture.

The purpose of this work is to study the distinguishing qualities that characterize traditional Japanese architecture, primarily the design features and construction methodology of residential architecture of the Edo period, in an attempt to discover alternative and appropriate solutions to problems affecting current trends in timber frame design and construction The distinguishing design features of Edo period residential architecture are characterized by: (1) its use of wood as a primary building material, (2) the implementation of an ordered modular system, (3) flexibility of spatial arrangements and functionality, (4) the design integration and connection between the built and natural environment, (5) the application of a wood joinery construction methodology, and (6) a holistic sustainable design approach.

Contemporary wood-based building design and construction lacks a holistic sustainable design approach. Much of today's timber frame methods of design and construction are wasteful, lacking any thought, care, and attention to how wood is acquired, designed with, used in construction, and disposed of. In order to create new appropriate building structures made from wood we must consider alternative methods of construction than just those that are currently available. A look into traditional Japanese residential architecture, and its method of construction and philosophy, may in fact lead to a reawakening of a holistic sustainable design approach and lead to appropriate wood based design and building practices for contemporary wood-based architecture.

~ INTRODUCTION ~

For centuries, wood has been used as a primary building material across cultures. As a naturally occurring renewable resource, wood provides a sustainable material for building construction that is easily procured, processed, and worked with. The inherent strength and aesthetic beauty of wood allows for its use in a wide range of design and building applications, such as structural design, interior and exterior finish, and furnishing. If wood is properly maintained, the life span of any wood-based building can withstand decay longer than it is usually imagined.

Traditionally, the lumber acquired for construction was gathered from forested regions that once provided an abundant resource of old growth wood. Old growth wood is wood that grows naturally in forests, without any human intervention. In these forests, trees grow slowly because of natural competition for sunlight with surrounding trees. The slow growth of trees leads to denser and more tightly packed rings and pores. Tree rings are the cause of grain pattern. The slower a tree's annual growth is the tighter the ring patterns, which give lumber a denser grain pattern, quality, and structural strength. Also, in natural forests the decomposition of natural organic matter helps to sustain a healthy soil environment for trees to pull nutrients from.

However, current unsustainable practices of wood based construction have for a long time exploited and depleted our wood resources by destroying forested habitats. This exploitation has led to the current belief that wood based design is unsustainable and therefore environmentally unfriendly. Although this belief holds some merit, wood-based construction can still play an important role in contemporary sustainable building design. As is the case with many of the contemporary materials used for building, sustainable awareness and practices have shifted in wood design. New forest management initiatives and harvesting practices, and a look into alternative wood resources, such as engineered wood and reclaimed wood, have slowly brought wood back into the building scene.

As our resources for old growth lumber have diminished, many individuals have sought out the use of second growth lumber for design and construction. Second growth trees are trees that have been replanted into zones where these trees would not have normally grown in nature, such as urban zones, tree nurseries, or in forests after timbering, fires, etc… Here, because of the lack of sunlight competition, trees grow rapidly, resulting in the weaker structural composition of tree trunks. Here, the cellular pores of second growth trees are more open than that of old growth trees. Second growth trees dry quicker because the loose pores lose moisture more rapidly. When compared to old growth trees, second growth trees are more inferior because they are prone to rotting and are structurally weaker and soft. However, they do still provide a structurally sound and aesthetically pleasing material for a variety of contemporary construction applications.

As timber frame construction is concerned, no culture has achieved more sophistication and developed such a complete design and construction methodology than the Japanese. A look into the history of traditional Japanese residential design may help us find solutions to the problems affecting wood based architecture today. The Japanese tradition of woodworking and wood based design spans hundreds of years. What is most striking about its past is that, unlike many other cultures which relied on wood and other materials for construction, the Japanese solely relied on wood for the construction of their buildings, never looking beyond it for any other building material resource. Their highly exclusive wood-based building history has over time developed very specialized traditional systems in wood-based construction and technical skill that cannot be paralleled by any other culture. A study of traditional Japanese architecture is one and the same as a study into the history of wood-based building design.

Thus, this research document will take a close look at the history, tradition, methodology, and philosophy of the Japanese builder, throughout their history of traditional Japanese architecture, as a means to potentially enhance and find alternative building solutions to appropriate local sustainable architecture for Hawaii.

MAIN SECTION OULTINES

PART 1 – A CONCISE HISTORY OF TRADITIONAL JAPANESE ARCHITECTURE

This section of the research document provides a concise history of traditional Japanese timber frame architecture. It begins with a brief look into the early primitive shelters found during Japan's Pre-historic period. During the Yayoi and Jomon period, these rudimentary shelters evolved into more advanced, but still simple, building dwelling typologies. It was not until the Asuka period that traditional Japanese architecture experienced a major progressive shift in building design and construction. The onset of this progressive change was made possible by the introduction of Buddhism into Japan, at around 552 A.D., from mainland China, via Korean influence. This "Buddhist Phase," as it is referred to by historians, marks the inauguration of Japanese "architecture." During this extensive period, structural systems introduced by migrant Korean carpenters revolutionized timber frame construction in Japan. Overtime, generations of Japanese carpenters refined these borrowed building systems and assimilated them into their culture and tradition, creating a building methodology of their own. The creation of a wholly Japanese timber frame building methodology gave rise to the various Japanese timber frame building typologies found throughout the duration of the history of traditional Japanese timber frame architecture up until the end of the Edo Period. The beginning of the Meiji Restoration, which follows the Edo Period, marked the end of the hallmark of traditional Japanese timber frame architecture, as Japan entered a period of strong outside western influence that gave rise to a more "International" practice of architectural design and construction.

PART 2 – CHARACTERISTICS OF THE JAPANESE HOUSE

This section of the research document looks at the design and construction characteristics of traditional Japanese residential architecture which make Japanese timber frame construction unique as a distinct type of architecture. It includes information about the Japanese primary use of wood as a material for construction, the influence of the carpenter as both architect and builder, and their methodology of measure and construction. The section also looks at distinct design features of the Japanese house such as its post and lintel structural framework, the use of Japanese joinery, the *engawa*, and wall systems that are functionally flexible.

PART 3 – PRELIMINARY STUDY OF BASIC JAPANESE WOOD JOINERY MAKING

This section of the document allowed for a first glance look and hands-on practice in the fabrication process of Japanese wood Joinery. Here, the traditional methodologies applied by the Japanese in the fabrication of such joinery types were also learned. Under the guidance and help of Steven Hill, at the University of Hawaii at Manoa woodshop, basic Japanese techniques of woodworking were explored and applied to enhance the background knowledge of woodworking for the benefit of the research topic.

PART 4 – JAPANESE CARPENTRY: METHODOLOGY OF WOODWORKING, JOINERY LAYOUT AND CONSTRUCTION

Part 4 of the research document provides an in-depth look into the construction methodology of traditional Japanese timber frame construction as it was developed and applied by Japanese carpenters. This portion of the research was performed, by this author, in order to gain hands-on experience and understanding of the pre-industrial design and building methodology of the Japanese carpenter.   The section offers insight and a firsthand account into more technical aspects of Japanese timber frame construction. It focuses on the learning of Japanese pre-industrial tool use and maintenance, woodworking technical skills, joinery layout and construction methodology, and the philosophy of the Japanese carpenter. The woodworking knowledge gained in the experience was learned over a period of approximately 7 months, under the guidance and mentorship of Paul Discoe, during my Professional Studio semester at Joinery Structures, a design-build firm that specializes on the design and construction of traditional Japanese building structures in the United States and around the world.

PART 6 – DESIGN FROJECT

This section focuses on the design of a Japanese timber frame pavilion for the North Shore of Oahu. The design project **examines** the potential of traditional Japanese timber frame design and construction methodology in facilitating appropriate sustainable wood-based building design in the tropical climate of Hawaii.   The **objective** is to integrate traditional Japanese methods of design and construction with current design tools and construction methods to facilitate timber frame design and construction in Hawaii. The **goal** is to develop a wood-based building typology and building methodology in Hawaii that is site appropriate and that offers qualitative solutions to sustainable wood-based design in Hawaii.

METHODOLOGY

INTERPRETIVE – HISTORICAL RESEARCH

The nature of the research required a close look at the historical evolution of the traditional Japanese house, and of the study of traditional Japanese wood joinery techniques and methodology. Given that an extended leave of absence to visit Japan to work hands-on with Japanese carpenters was not an option, a good portion of the knowledge base concerning the tradition of Japanese wood joinery, and the historical evolution of the Japanese house, was gathered from an interpretive – historical research methodology based on the literature review of books, journals, articles, and other published literary resources related to the thesis topic. The knowledge gained also allowed for a preliminary hands-on study and experimentation of Japanese joinery fabrication. Furthermore, interviews and work with local carpenters with a well-rounded knowledge base of traditional Japanese joinery methodology also helped to provide the research document with essential background information related to the topic of study.

The interpretive – historical methodology also facilitated precedent studies to be amassed and to be used as evidence in support of the beneficial applications of traditional Japanese timber frame construction in Oahu.

SIMULATION AND MODELING RESEARCH METHODOLOGY

For the study there was also a need to learn the extensive typology of traditional Japanese joinery systems, the specific application of each joinery type, and the methods of construction used in Japanese carpentry and building construction. Research and hands-on work with Paul Discoe, a trained carpenter and architect, in the Japanese tradition of Temple design and construction, allowed for a close and personal one-on-one study of the reproduction of such extensive joinery typologies, and a better understanding of how each joinery system is produced and applied in contemporary design.

The reproduction of joinery systems was not limited to the traditional, pre-industrial methodology of the Japanese craft of timber frame design and construction. The use of contemporary architectural computer design software, such as AutoCAD, Rhinoceros 3D, and Revit Architecture also helped in the research and learning process by facilitating graphical cataloguing, understanding, categorization, and the analysis of specific joinery types.

PART 1 – A CONSICE HISTORY OF TRADITIONAL JAPANESE ARCHITECTURE

PREHISTORY

Since prehistory the Japanese have implemented wood in the construction of their most simple and primitive shelters. According to Nish and Hozumi, in the book *What is Japanese Architecture?*, "the distant ancestors of the modern Japanese appear to have sought protection from the wind and rain in natural shelters such as rocky overhangs or caves, or in simple huts built of wood from nearby trees."[1] These shelters were built from local natural materials gathered from nearby resources and around the site, and were in use during the Jomon period, circa 9,000 to 10,000 years ago, and continued on until the beginning of the Yayoi period, circa 300 BCE to 300 CE.

During the Jomon period these rudimentary shelters began to evolve into pit dwellings (*tateana juukyo*). These early house-types were "built by digging a circular pit (or a rectangular one with rounded edges) fifty or sixty centimeters deep and five to seven meters in diameter, then covered with a steep thatched roof,"[2] made from wood lashed together with simple rope ties and covered with straw.

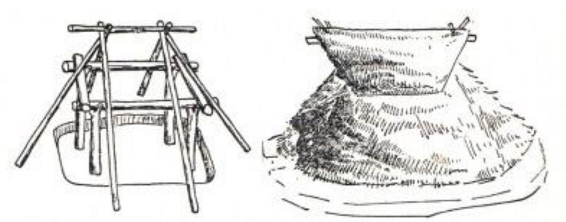

Figure 1: Jomon period pit-dwelling
Source: Nishi and Hozumi, 1996

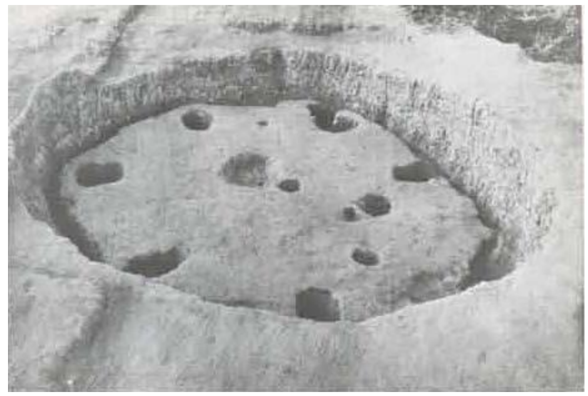

Figure 2: Pit dwelling footprint
Source: Nihon kenchikushi Zushiu, 1980

In the Yayoi period a new type of architecture was developed. Although pit dwellings continued to exist through the Yayoi period, some pit dwelling houses were no longer just dug into the earth. Rather, "earthen dykes began to be built around the pit."[3]

Figure 3: Pit dwelling (earthen dyke)
Source: Nihon kenchikushi Zushiu, 1980

The further development of iron tools, and an agricultural evolution in wet-rice cultivation, also brought about new sophistication to these early house-types. Along with pit dwellings, elevated

[1] Nishi and Hozumi 1996, 54
[2] Nishi and Hozumi 1996, 54
[3] Sarvimaki 2010, 2

buildings on posts, or pile-dwellings (*taka-yuki*), began to make an appearance in Japanese architectural history as granaries or storage houses. These elevated buildings were most likely the product of finding working solutions to keeping pests from entering the store houses.[4] Also, wet rice cultivation brought about a major shift in the settlement patterns of Japanese farmers. Wet river valleys offered fertile soil and an abundant water source for the cultivation of rice. With the Japanese settlement shifting into river valley zones, building structures surrounded by earthen dykes or elevated on posts offered added protection to wooden structures from the flooding waters that often occurred during the regular yearly monsoon season in Japan.

Figure 4: Raised granary
Source: Nihon kenchikushi Zushiu, 1980

The development of structures built on elevated posts gave way to a tradition in building design and form in Japan from which the Japanese never departed from. This distinguishing feature of the Japanese house can be seen in the form of Shinto shrines which to date are still existent, and continue to influence Japanese tradition, culture, and architecture. The Ise Shrine, located in the city of Ise in the Mie prefecture, Japan, is one such example of early Shinto shrine architecture.

[4] Nishi and Hozumi 1996, 54

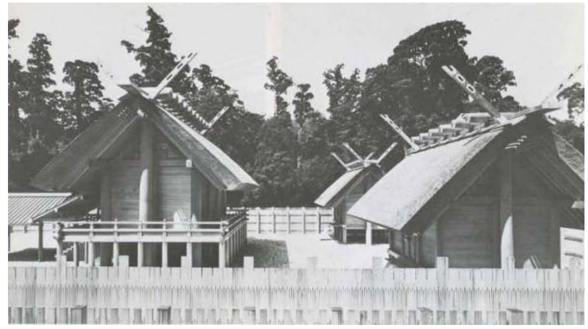

Figure 5: Shinto shrine
Source: Nihon kenchikushi Zushiu, 1980

Although Shinto shrines were existent before 552 A.D. (552 A.D. marking the start of the Asuka period), it is important to note that Shinto shrines did not fully develop in form and function as we know it today until after the introduction of Buddhism into Japan. Prior to the introduction of Buddhism, "there was no distinction in the style of buildings for shrines, palaces and commoners' dwelling-houses."[5]

THE INTRODUCTION OF BUDDHISM

The introduction of Buddhism into Japan brought about major evolutionary development in traditional Japanese architecture. Buddhism entered Japan from China, via the Korean peninsula during the 6th Century A.D, at around 552 A.D, from Kudara, a part of Korea in those days.[6] It was Buddhism that brought a new type of Asian architecture to Japan with the crafts of painting and sculpture, metal work and ceramics.[7] This introduction indisputably inaugurated the tradition of Japanese architecture, sparking the construction of massive timber framed Buddhist temple structures and temple complexes for centuries to follow. These

[5] Kishida 1936, 28
[6] Kishida 1936, 48
[7] Sadler 1963, 37

Buddhist temple complexes were to later directly influence the construction and design of the traditional Japanese house.

The first Buddhist temples were built in Japan by migrant Korean carpenters during the Asuka period (552 – 710 A.D.). This period witnessed increased focus in Buddhist temple architecture influenced from Korea.

Figure 6: Horyuji, Nara, Japan
Source: Nihon kenchikushi Zushiu, 1980

During the Nara period (645 – 783 A.D), Buddhist temple architecture was still prevalent and the main focus in architecture. Nonetheless, the construction of imperial palaces also became dominant. In this period, Japan was heavily influenced by China, especially in the realm of the arts and crafts. With strong influence from China, Japanese architecture was directly affected, and the "arrangements of temple building complexes changed from the Korean style to that of the Chinese style."[8] Chinese influence in Japan continued through the beginning of the Heian period (784 – 1185 A.D.).

Buddhist temple construction was still prevalent in the Heian period. However, depleting wood resources caused a major shift in the size of lumber used for construction. During this time "timber was cut smaller and smaller, and more attention was given to technical skill, grace, and refinement."[9]

Figure 7: Byodo-in, Japan
Source: Nihon kenchikushi Zushiu, 1980

This shift in construction methodology, along with social change, gave way to a new form of traditional Japanese residential architecture, that of the *shinden zukuri* style. The *shinden zukuri* style of residential architecture was also influenced by the spread of Zen Buddhism and Zen Buddhist temples of the Kamakura and Muromachi period, which exhibited a new wave of Chinese influence from the southern Sung dynasty – for example, the *daibutsuyo* style of Todaiji Temple as shown below.

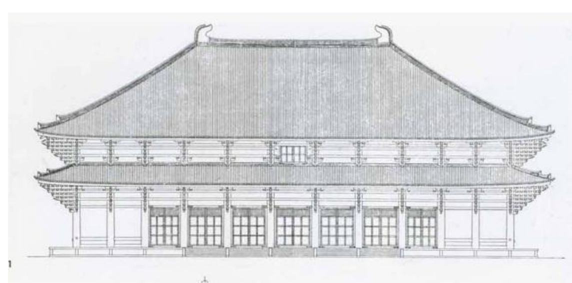

Figure 8: Todaiji Temple, Nara, Japan.
Source: Nihon kenchikushi Zushiu, 1980

[8] Kishida 1936, 29

[9] Kishida 1936, 30

Also, the features that characterize the *shoin zukuri* residential type of architecture; which will be later mentioned in this study, can be first found in the abbot's quarters of such Zen temples.

Figure 9: Jizodo of Shokufugi; built in 1407
Source: Nihon kenchikushi Zushiu, 1980

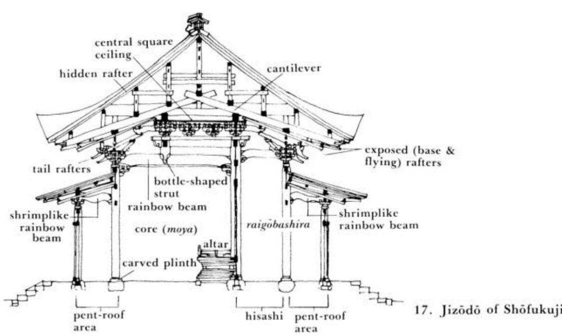

Figure 10: Jizodo of Shokufugi; built in 1407
Source: Nishi and Hozumi, 1996

SHINDEN ZUKURI STYLE

Shinden literally means "hall for sleeping," and this style of architecture became the residential-dwelling house-type for the aristocracy during the Heian period. They were profoundly influenced by Korean and Chinese Buddhist building temple complexes, palaces, and the residential architecture of the Nara and Heian period.

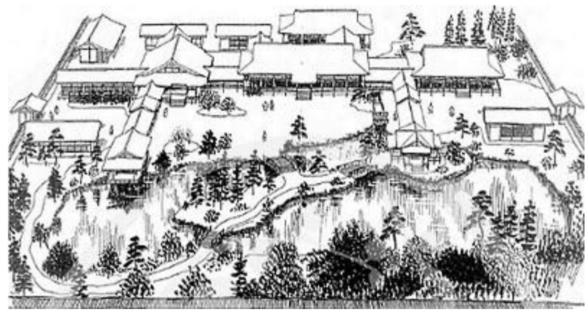

Figure 11: Drawing of a shinden zukuri style complex
Source: Nishi and Hozumi, 1996

These mansions consisted of "a central hall facing a pond and bounded by hallways (*watadono*) leading to subsidiary structures (*tainoya*: literally meaning opposed halls)."[10] "Though every known *shinden* style complex has its own unique aspects, most faced south over a courtyard garden where ceremonies and entertainments were performed. South of the courtyard a pond was dug with a central island reached by bridges. At the pond's periphery might be a hill, made from earth excavated to create the pond, with trees planted on it."[11]

Figure 12: The Golden Pavillion. Original built in 1397; rebuilt in 1955 (Athough the building itself does not display features of the shinden-zukuri style, its landscape design does)
Source: Nihon kenchikushi Zushiu, 1980

The initial layout of *shinden zukuri* was strongly symmetrical. The layout extended from a

[10] Nishi and Hozumi 1996, 53
[11] Nishi and Hozumi 1996, 64

central axis, common to that of palace complexes found in China (i.e., the central column distance, Chinese *jian*, Japanese *ken*, was longer and wider than on both sides). It was not until later that the layout of *shinden zukuri* residences evolved into a more asymmetrical pattern. In *shinden zukuri* residences curtains were mainly used for space partitions. The implementation of sliding doors was not yet set as a common feature in residential design at that time. The use of portable straw mats, called *okitami*, round columns, and non-sliding space dividers was also characteristic of *shinden zukuri* residences.

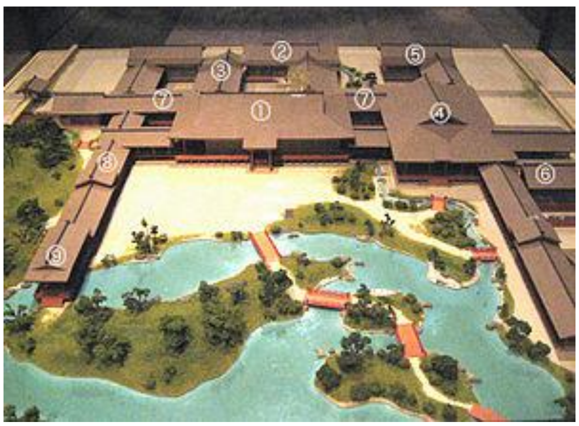

Figure 13: Model of Higashi Sanjo-dono. A typical shinden zukuri architectural complex
Source: *Wikipedia.com*. http://en.wikipedia.org/wiki/Shinden-zukuri (accessed April 21, 2011).

The Kamakura period (1868 – 1392), witnessed the rise of the samurai military class in Japan, and with the rise of the Shogunate in Kamakura power shifted from the noblemen and the aristocratic class into the hands of the samurai feudal system. During this period, and into the periods that followed, the Muromachi (1393-1572) and Momoyama (1573-1614) period, innovation in the construction of Buddhist temple architecture began to weaken and the construction of *shinden zukuri* style residences of the samurai class became the primary focus in architecture up until the Edo period (1600 – 1867). These *shinden zukuri* residences gradually started to develop into the *shoin zukuri* style during the Muromachi period, "but did not reach its final stage of development until sometime in the Edo Period. Early *shoin*-style features were found particularly frequently in the *kaisho* hall of *shinden* complexes and the abbot's quarters (*hoojoo*) of Zen monasteries."[12]

SHOIN ZUKURI STYLE

It was during the Edo period that the Japanese witnessed the hallmark of Japanese residential design. The Edo period is named after the city of Edo, which was the capital of the Tokugawa shogun, Japan's military rulers. The period is also called the Tokugawa Period. During this period, between 1600 and 1868, Japan's doors were closed to the rest of the world. No contact was allowed between Japan and any other nation beyond Japanese borders. It is within this isolation that the Japanese refined their tradition of the arts and crafts, and it was a time where progressive social development changed the way Japanese people lived. Here, a more educated and populous middle class rose. In his book, *Rediscovering Japanese Space*, Kisho Kurokawa cites that in "Ronald Dore's notes in his Education in Tokugawa Japan, that by the end of the Edo period (1868), forty three percent of boys and ten percent of girls between the ages of six and thirteen attended school – higher percentages than in England at the time. Edo was the largest city in the world, with a population of well over one million."[13] With the rise of the middle class and the populous,

[12] Nishi and Hozumi 1996, 74
[13] Kurokawa 1988, 48

the residences of the time also changed and developed into a more modern and standardized Japanese style. It was within this period that the Japanese residential house reached its final stylistic stage of development with the *shoin zukuri* residential style.

The word *shoin* literally means "writing hall" and it "developed from the *shinden* style, and was to provide to be a decisive stimulant for the evolution of the Japanese house."[14] One of the earliest extant examples of this style of architecture is the Manshu-in Temple in Kyoto.

Figure 14: Manshu-in Temple/Figure 15: Manshu-in Interior in the Shoin Style
Source: Fig 14.: *Edgardrubin.com*. http://edgardurbin.com/Japan2006/TemplesShrinesFrame.htm (accessed April 26th, 2011)

Source: Fig. 15: *Panoramino.com*. http://www.panoramio.com/photo/9034689 (accessed April 26th, 2011)

In general, the most formal room in a *shoin zukuri* residential structure typically contains two or more of the following architectural features: "a decorative alcove (*tokonoma*), staggered shelves (*chigaidana*), built-in desk (*tsukeshoin*), and decorative doors (*choodaigamae*). The shoin style is also characterized by tatami mats over the entire floor, square posts (though with slightly beveled corners), ceilings (often coved or coved and coffered), *fusuma* (plain or painted sliding screens) between interior spaces, and *shoji* (white translucent paper screens reinforced with a wooden lattice; on the exterior, protected by heavy sliding panels (*amado*) moved in front of them at night or in inclement weather"[15] and slid into built-in boxes of the outer wall when not in use.

Figure 16: Shoin Style Residence
Source: Nihon kenchikushi Zushiu, 1980

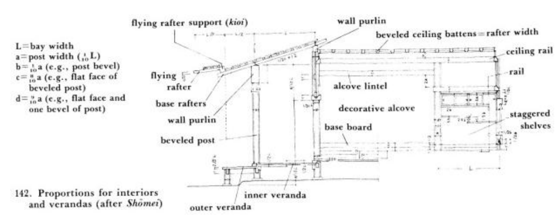

Figure 17: Interior Design Features of a Shoin Residence
Source: Kazuo and Hozumi, 1996

[14] Engel 1964, 405

[15] Nishi and Hozumi 1996, 74

There also exists the *sukiya* style of *shoin zukuri* residences. These residences come in many shapes and sizes and display elements characteristic of Japanese tea houses in its internal composition, such as a highly refined manner of construction with delicate proportions, rustic overtones, the ample use of natural unadorned materials, and a rustic quality, all together giving a sense of quiet elegance. Within this design style the integration between interior and exterior space is highly desired. Much like the Japanese tea houses, the *sukiya* style employs architectural elements that attempt to connect human senses with the space, built objects, and natural environment surrounding it.

Figure 18: *Katsura Imperial Villa Exterio; built in 1616*
Source: *Virtualtourist.com.*
http://www.virtualtourist.com/travel/Asia/Japan/Kyoto_fu/Kyoto-973793/Things_To_Do-Kyoto-Katsura_Imperial_Villa-BR-1.html (accessed May 5th 2011)

Figure 19: Katsura Imperial Villa Interior

Source: *Panoramio.com*.
http://www.panoramio.com/photo/897525 (accessed May 5th 2011)

OTHER TRADITIONAL JAPANESE RESIDENCES

MINKA

The word *minka* literally means "houses of the people." The diversity of *minka* houses are as broad as the residents these structures housed, from rich merchants and village headmen to the people living at the lowest levels of the social classes. The characteristics of these structures varied from region to region, influenced by climate, context, and the requirements of household members. They also changed, grew and expanded according to need and function. Though the term is typically associated to farm houses of pre-modern Japan, *minka* refers "to all houses not belonging to the members of the very highest social strata in pre-modern Japan."[16] The most important thing to note here is that the *minka* house developed from the pit-dwelling houses of the Yayoi period, and they continued on separately in the history of traditional Japanese residential architecture, but coexisted along with the development of the *shinden* and *shoin* style residences. "The Japanese farmhouse, or minka house, influenced the evolution of the Japanese house, both directly and indirectly,"[17] continuing some of the traditions of the pit and pile-dwellings, such as a thatched roof, elevated floors, and frame structures. During the Edo period *minka* houses belonging to the higher class, such as village

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[16] Nishi and Hozumi 1996, 82
[17] Engel 1964, 400

headmen and high ranking samurai, even exhibited influence from *shoin* style residences, for example, tatami mats and formal reception rooms with *tokonoma (decorative alcove)*, and *chigaidana (staggered shelves)*, and *tsukeshoin* (built-in desk).

Figure 20: Minka House
Source: Nihon kenchikushi Zushiu, 1980

Figure 21: Minka House
Source: Nihon kenchikushi Zushiu, 1980

MACHI-YA

Machi-ya is the Japanese version of a city house, or townhouse that developed in the increasingly dense Edo period cities. There exists variation in the architectural expression of the *machi-ya* from region to region. However, some common spatial characteristics and architectural elements remain constant throughout, such as the "building being sited on a level plot of land that gave way to a very narrow and deep floor plan layout, a *genkan* (transitional space between the inside and the outdoor walled in corridor), the inclusion of a walled-in garden, sliding *shoji* screens, raised *tatami* floor mats, delicate proportions, rectilinear architecture, and a *tokonoma* (raised alcove)."[18] *Machi-ya* can also be characterized as a city merchant house. Often times these structures functioned as both home and workplace, including a merchant shop at the front-most portion of the complex bordering the street side of the structure, and residential spaces at the back, which included a kitchen, rooms for living, bathroom, and a dirt floor corridor (*doma*) leading from the street to the backyard. These residences developed as a result of urban growth, the increase of population density of pre-modern Japanese cities, as well as the rise of the middle class and merchant class.

Figure 22: Machi-ya
Source: Nihon kenchikushi Zushiu, 1980

[18] Discoe 2008, 33

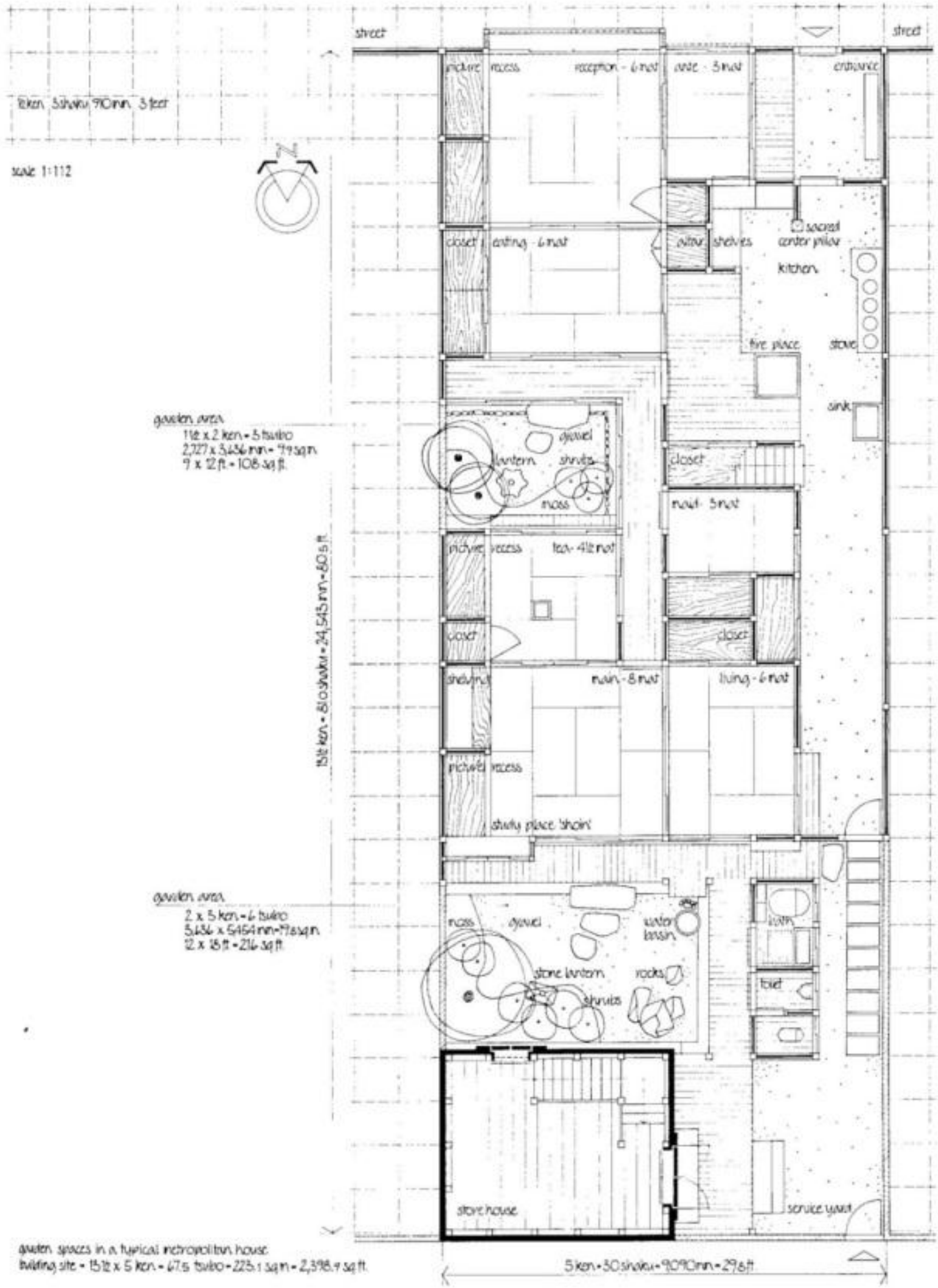


Figure 23: Floor plan layout of a typical Machi-ya residence
Source: Engel, 1989

GRAPHIC CHRONOLOGICAL TIMELINE (Attached separately as an 11 x 17)

PART 2 – CHARACTERISTICS OF TRADITIONAL JAPANESE RESIDENTIAL ARCHITECTURE

WOOD-BASED DESIGN

Throughout the history of traditional Japanese architecture, wood has been used as the primary material in building construction. In fact, the use of wood in traditional Japanese architecture was so readily applied that it has become one of the most striking and distinct characteristics of traditional Japanese architecture. Almost all buildings in Japan up until the Meiji Restoration in 1868 were timber structures. One cannot speak of traditional Japanese architecture without noting the influence of wood in its historical development and evolution.

The choice of material did not stem from one single source of influence. Instead, it was the result of the influence of a multitude of external factors, such as the natural context from which the wood tradition arose from, and the influence of cultural values and religious belief systems, and socio-political conditioning. S. Azby Brown, in his book *The Genius of Japanese Carpentry: The Secrets of a Craft*, partly attributes Japan's exclusive use of wood in building construction to Japan's natural ecological endowment of abundant forested regions, the influence of a Shinto value system, political influence, and the archipelago's proneness to seismic activity.

Approximately 70 percent of Japan's landmass is covered with lush forests. Given this fact, it is of no wonder why the Japanese relied so heavily on timber for construction. These forested regions, for a long time, provided Japanese builders with the highest grade lumber for design and construction.

Brown also postulates that the influence of a Shinto belief system "may have been an element of consideration of the supernatural that influenced these choices. Part of the shadowy value system symbolized by Shinto beliefs stressed love and respect for wood as a living organism."[19] The Shinto belief system is the oldest religion found in Japan. Even after the introduction of Buddhism, Shintoism continued to play a major role in the value system of Japanese culture. In fact, Buddhism and Shintoism co-existed and still co-exist today in Japan without conflict. Shintoism stresses a love and reverence for nature. This sense of nature was in fact of major importance in the daily lives of the Japanese. Whether or not it is still so strongly prevalent today is up for debate. Nevertheless, this value system had a major impact in the development of traditional Japanese architecture.

Zen Buddhism also had an effect in the Japanese preference for wood-based design. Much like Shintoism, Zen Buddhist practice also strongly stresses a love for nature. Within Zen practice there exists five key natural elements that are entrenched in Zen Buddhist life and teaching. Along with the elements of water, air, earth, and fire, in Zen Buddhism wood is also one of the elements that make up the natural building blocks essential to a physical, mental, and supernatural balance, as is described in the book *Zen Buddhism: The building Process as Practice*, by Paul Discoe. In Zen Buddhism, humans

[19] Brown 1995, 21

and nature are intrinsically connected and are a part of one another's existence that is enveloped in a continuum of life and all things existing.

The archipelago of Japan has been, and still is suffering from the misfortune of being sited in a highly seismic active zone. The choice of wood as a primary source of building material may be attributed to this condition. Prior to the discovery of steel, traditionally buildings were constructed primarily of wood, as it is readily seen in Japan, and sometimes of stone masonry and brick, as was mostly used by the Japanese's Western counterparts. Wood, when compared to stone and brick, offers greater elasticity, and therefore greater structural resistance against seismic activity. This is one of the reasons why wood was favored by Japanese builders.

As Buddhist influence quickly became universally accepted in Japan by the political regime and its people, the construction of Buddhist temples and temple complexes became the major focus in architectural development. The construction of Buddhist wooden temple complexes was so strong in Japan that major technical advancement in the craft of carpentry took shape. Wood-based design and the wood joinery method of construction was so advanced and strongly revered for its aesthetic quality in Japan that is was quickly canonized as symbolic of the political regime of the time.[20] During the Edo period the wooden methodology of measure and construction developed by Japanese carpenters became the standardized modular system of construction that was enforced by the Japanese government.

[20] Brown 1995, 21

THE JAPANESE CARPENTER: ARCHITECT AND BUILDER

Throughout the history of traditional Japanese architecture the design and construction of all religious complexes and residential buildings fell solely to the hands of the Master Carpenter and his assistants. The carpenters of the time demonstrated mastership as doubly builder and designer, construction worker and architect.

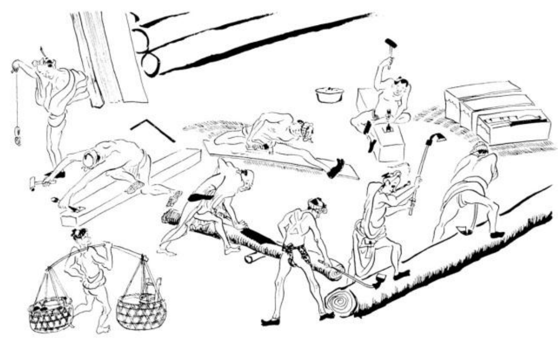


Figure 24: Carpenters (*Kuwakata keisai's Pictures of Tradesmen*)
Source: Kazuo and Hozumi, 1996

The carpentry tradition was also directly influenced by the introduction of Buddhism. Japanese carpentry philosophy is rooted in Buddhist and Shinto philosophy. As mentioned before, Shinto belief and value, as well as Zen Buddhism, emphasize respect and reverence for all natural elements. Entrenched in the philosophy of the Japanese carpenter is the idea that:

> "A tree, like other natural phenomena, is believed to possess a spirit, and a carpenter, when he cuts down a tree, incurs a moral debt. One of the themes that run throughout Japanese culture is the belief that nature exacts from man a

price for co-existence. A carpenter must put a tree to uses that assure its continued existence, preferably as a thing of beauty to be treasured for centuries. There is a prayer that Nishioka (a Japanese Master carpenter responsible for the renovation and reconstruction of Yakushiji temple) recites before laying a saw to a standing tree. It goes in part: I vow to commit no act that will extinguish the life of this tree. Only by maintaining this pledge does the carpenter repay his debt to nature."[21]

Zen Buddhist teaching stresses a strong focus on repetitive practice. Only through rigorous, conscious, and attentive repetition can a person master the art of his craft and balance physical and mental health. The Japanese carpenter's tools of the trade were of a pre-industrial era. Wood-based construction and design was carefully done with hand tools. The skills involved in mastering these pre-industrial tools required a lifetime of study and commitment by the carpentry apprentice. In fact, and to date, a carpentry apprentice in Japan is not even considered a carpenter until 15 plus years of carpentry experience, working long daily work hours that extend beyond the customary 40 hour work week of modern Western traditions.

The skills and techniques involved in the construction of wood structures varied from region to region, schools to school, and from religious sect to sect. Even within the same group of carpenters the detailing techniques of wood working varied from the teachings of one Master Carpenter to another. For a long time, this knowledge, held by the Master Carpenter, would be passed down from one generation to the next. The craft of the trade was often considered to be a secret within a lineage, and so, the knowledge base of woodworking would be passed down orally and without any written record. The transmission of knowledge followed the family lineage from father to son for many generations. If no son was present, an apprentice outside of the family would be taught and this apprentice would be officially adopted into the family as a son.

It was not until the middle of the Edo period that carpenters began to record the secrets of their craft and made them open to the public at large. This is made clear in Kurokawa's book, *Rediscovering Japanese Space*, as he states that "the publication of such manuals as the Master's revelations (*Shomyo*) of the Heinouchi lineage or the Kenninji School Transmission (*Kenninjiha Kadensho*) of the Kora lineage of carpenters gave access to the carpentry trade, eventually leading to the conformity of methods and standardization of measures that can be seen in the New edition Pattern Book (Shimpen Hinagata)."[22]

MEASURE

One of the biggest misconceptions concerning the measure of the traditional Japanese house is that it follows a modular system of measure based on the dimensions of a *tatami* mat. As stated by Heino Engel in his book, *Measure and Construction of the Japanese House*, "it is important to note that the tatami has never, not even fictitiously,

[21] Brown, 1995, 21-22

[22] Kurokawa 1988, 49

functioned as a module of any kind in the Japanese house, as it is frequently assumed."[23]

The word *tatami* originated from the word *tatamu*, which literally means "to fold." It first took form as a folding mat cover that could easily be folded, transported, and used whenever needed. The dimensions of the tatami mat varied greatly throughout its evolution, but in general it was big enough that, when unfolded, provided a space comfortable enough for two Japanese adults to sit side by side, or for one adult to sleep. It was not until around the Muromachi period that the *tatami* became a fixed floor mat in the traditional Japanese residence. Even so, it was not fully implemented in residential design until the Edo period. "The spread of the shoin style markedly helped its propagation, but economic circumstance prevented general use among the people before the 18th century."[24]

The correct measuring system of the traditional Japanese house is based on the *ken* module. The *ken* was developed by Japanese carpenters during the Middle Age in Japan, and since its finding it was nationally adopted as the universal system of measure for the construction of all traditional Japanese residences. Engel mentions in his book, *Measure and Construction of the Japanese House*, that the history of the Japanese residence is the history of the *ken*.[25]

Although the measurement of the *ken* varied throughout its development (between *ken kyo-ma* and *ken inaka-ma), ken inaka-ma* is measured equivalently to 6 *shaku*, while the *ken kyo-ma* is a variable, approximately 6.5 *shaku*. The *shaku* is the equivalent to the English foot, measuring to approximately twelve inches. The *shaku* measure stemmed from the foot measure of a man from heel to toe. This system of measure, based on a human physical modularity, is not entirely unique to Japan and can be found in the American system of measure, as well as many other traditional measuring systems. From the graph below, the similarities of the *ken, shaku*, and foot are clearly expressed and follow closely to the decimal system. "Though in Japan the metric system has been in use since 1891, the ordinary residence is still controlled by the traditional Japanese measure system"[26] of the *ken*.

[23] Engel 1985, 34
[24] Engel 1985, 36
[25] Engel 1985, 24
[26] Engel 1985, 22

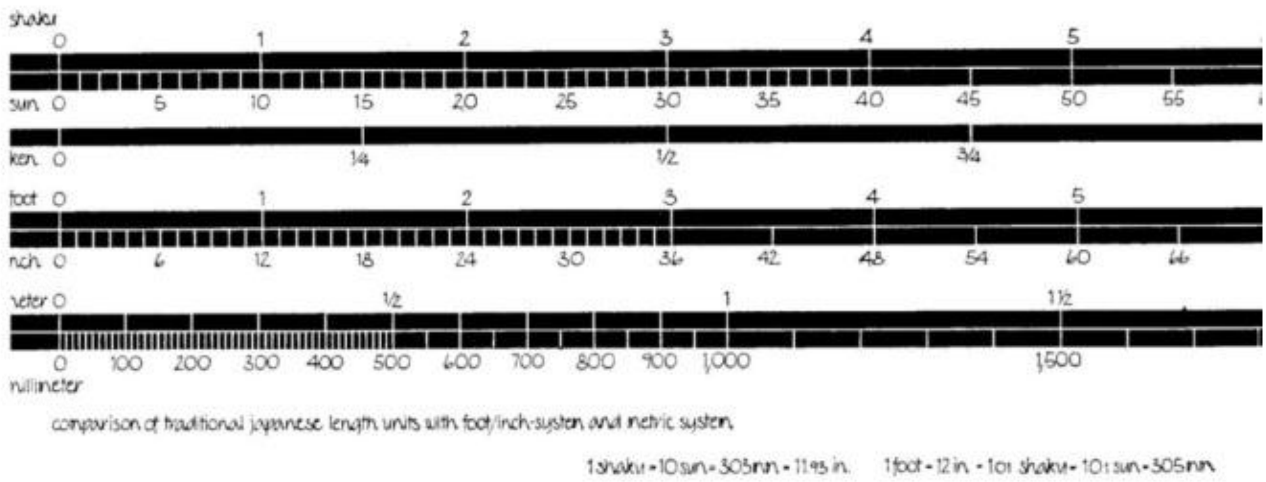


Figure 25: A comparison of systems of measure (shaku, sun, ken, foot, meter, millimeter)
Source: Engel, 1989

With the discovery of the *ken*, the Japanese carpenter revolutionized the measure and construction of traditional Japanese residential architecture. With regard to the *inaka-ma* system, Engel describes this evolvement as follows:

> "When the ken was consciously applied for the first time, Japanese architecture struck one of its most distinct features, order. What contemporary architecture hitherto has striven for so unsuccessfully emerged in Japan logically: a unit universally applied in living as in building, a standard distance for construction and economy, a module for aesthetic order, a six-fractioned measurement in decimal system, a length related to human proportions, even a link between city and domestic planning."[27]

The *ken* module is based on a measuring system that determines the interval between columns in traditional Japanese residential architecture; the other reading of the same character is "*ma*," the well-known space-time concept of Japanese architecture.

Kyo-ma was the first module of measure to be developed and was initially applied for the measure of Japanese residences found in urban zones. *Inaka-ma* developed later and outside of city and town settings, being only applied to countryside Japanese residences at first. "Only the ken of the inaka-ma method of 6 shaku, or 6 feet, relates to center-to-center distance between columns. The primary reasons for this development were the ken intimacy with daily life, its close relationship to human measurements, and its practicality in use."[28]

The *Ken kyo-ma* follows a different design layout method than *Ken inaka-ma*. In *Kyo-ma* the column-to-column distance module is not fixed and varies according to tatami mat placement and size. However, in *inaka-ma* the column-to-column distance is fixed to a standardized module, and it is the mat size that varies in the design. In this respect both *kyo-ma* and *inaka-ma* vary greatly in their

[27] Engel 1985, 24

[28] Engel 1985, 22

ability to accommodate the idea of standardization of construction. *Kyo-ma* allows for a set standardization of tatami mat sizes, but not building construction. On the other hand, *inaka-ma* allows for a set standardization for building construction, and not mat size. The two images bellow provides a graphical explanation between the differing measuring modules of *Kyo-ma* versus *Inaka-ma*.

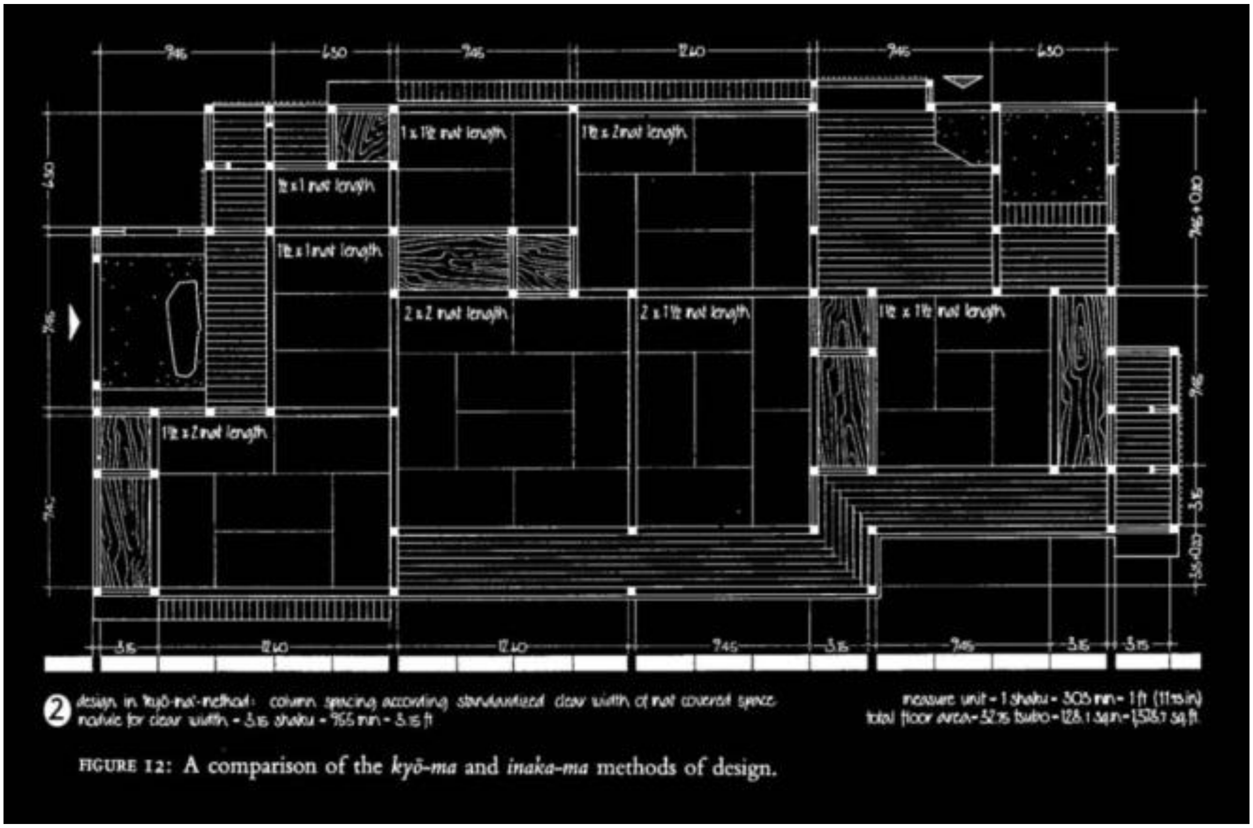


Figure 26: Residential layout based on the ken kyo-ma modular system of measure
Source: Engel, 1989

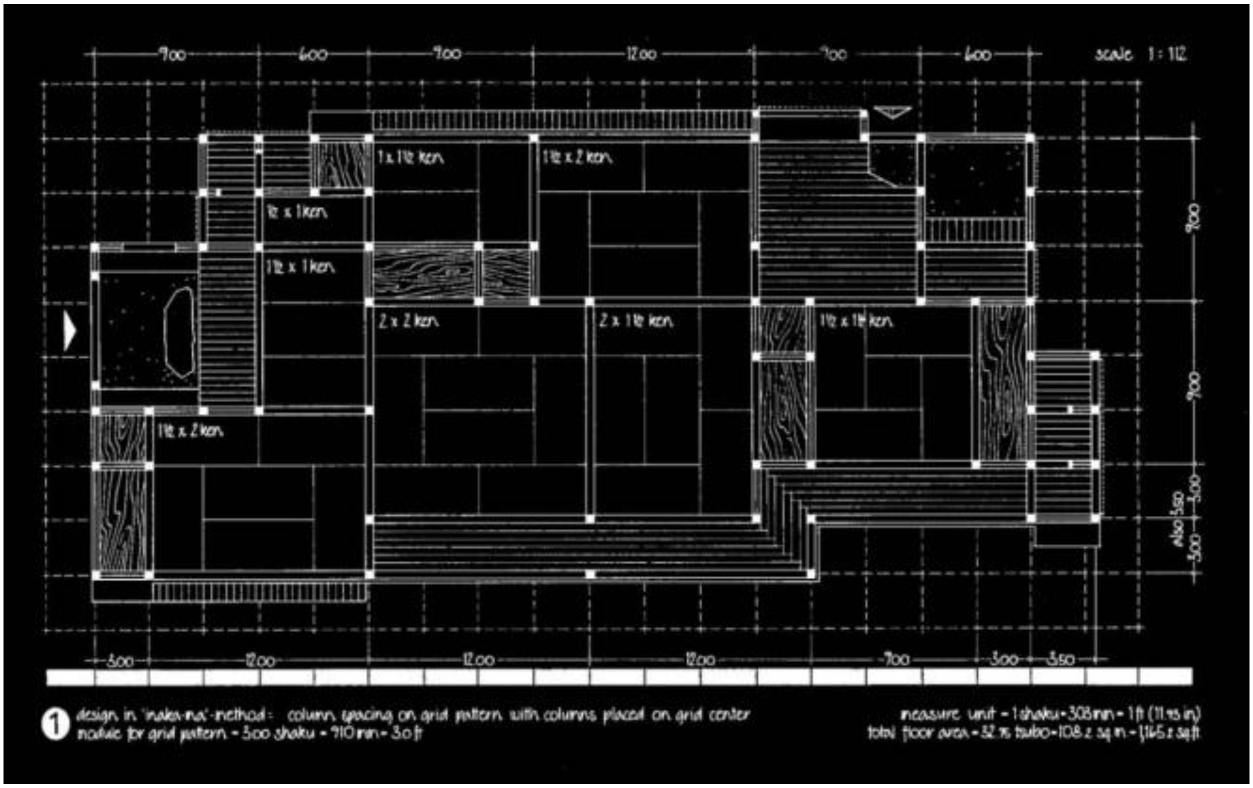


Figure 27: Residential layout based on the ken inaka-ma modular system on measure
Source: Engel, 1989

CONSTRUCTION

Traditional Japanese building construction is based on a post and lintel structural system where columns provide the main supporting members of the structure. Unlike the use of stone and brick, which rely on load bearing walls to support the building's structural integrity, in timber frame construction wood columns and beams act as the primary structural members of the building. This allowed longer free spans between columns by extending beams and rafters from one column to the other. The Japanese system of construction also lacks diagonal bracing. As for the foundations, Engel describes the efficiency of the system as follows:

> "Because the structure is a simple post and beam framework without any braces or struts, the wall panels in between those structural members support only themselves and do not require foundations. Only at places of actual structural supports, i.e., at the columns, is the groundsill provided with a simple foundation of natural or hewn stone that raises the whole wooden framework above the damp ground."[29]

[29] Engel 1985, 72

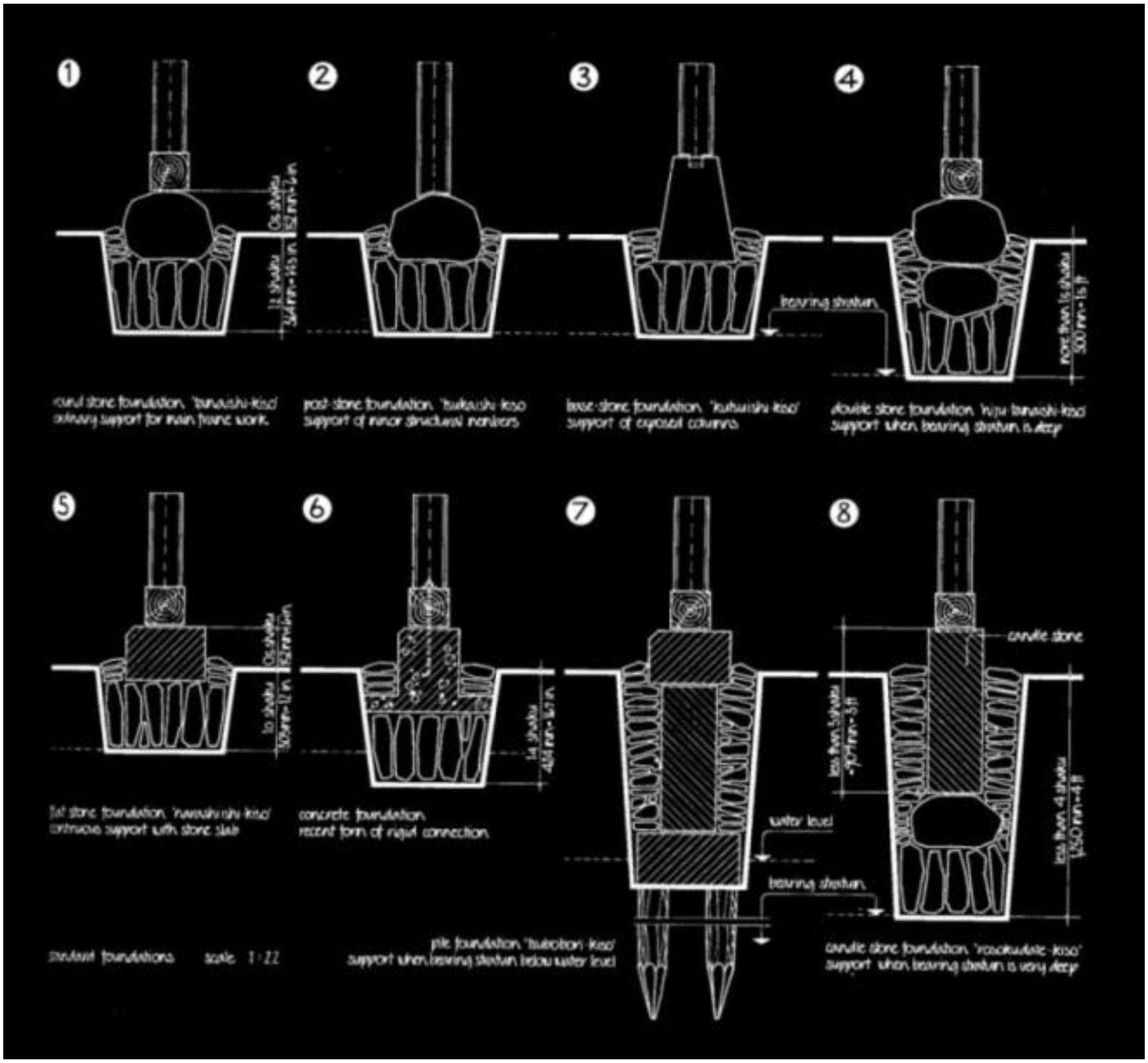


Figure 28: Types of foundations
Source: Engel, 1989

The end result was the distinct Japanese building design aesthetics of large open spaces of window and door treatment, and lighter exterior and interior walls and partitions. This design allowed for a strong connection between indoor and outdoor spaces, so readily sought out in traditional Japanese architecture.

The connection between the interior space of the Japanese house and the exterior environment is best explained by Kurokawa, in his book *Rediscovering Japanese Space,* in the section titled "A Culture of Grays." Here, Kurokawa compares Western culture to Japanese culture. He explains that "Western societies have two dimensional cultures, while Japanese society has a three- or multi-dimensional culture."[30] Western cultures often distinguish language and meaning between polar dichotomies, such as black and white and inside and out. The Japanese, on the other hand, is "a culture of grays" where the polar dichotomy between black and white and inside and out, is open ended, meaning that they do not exist apart from one another, but rather, coexist as one. This idea can be further expanded and made clear when one looks at the multi-meaning and expression of Japanese characters in their language, and also the architectural feature of the "*engawa,*" or veranda, and its multi-function in spatial representation.

Engawa is "a wraparound veranda or corridor characteristic of Japanese architecture."[31] The word *engawa* contains the prefix "*en*" which in Japanese means "bond," "relationship," or "affinity" [32] depending on the context it is used in. When looking at the architectural function of the *engawa* one can see that *engawa* serves a multi-dimensional function in architecture and in the meaning of the word itself. Architecturally it serves as a corridor connecting interior spaces, an outdoor veranda that extends into the natural environment, and a connecting space where inside and out merge as one. In his writing Kurokawa explains that:

> "The *engawa* is multipurpose, serving simultaneously as an external corridor connecting all the rooms of the house, a sheltering structure against rain, wind, and summer heat, an area for greeting or entertaining guests, and as a passageway to the garden, among many other miscellaneous functions."[33]

He expands on the meaning and multi-function of the engawa stating that "perhaps the most important role of the engawa is as an intervening space between the inside and the outside – a sort of third world between interior and exterior,"[34] what Kurokawa refers to as the "gray space," which is directly connected to the idea of Japanese culture being "a culture of grays." It is this merging of architecture and nature, of interior space and exterior space that is one of the most pronounced and distinguishing qualities of Japanese architecture.

Figure 29: "*Engawa*," or veranda
Source: Kurokawa, 1988

This idea of relationship, connectedness, and bond can also be seen in the prefix of the word *Inaka-ma* and *kyo-ma*, where the meaning of the word "*ma*"

[30] Kurokawa 1988, 53
[31] Brackett 2005, 25
[32] Kurokawa 1988, 53
[33] Kurokawa 1988, 53
[34] Kurokawa 1988, 54

is multi-dimensional, meaning space, gap, or interval all in one.

The connection or bond, and the multi-functional quality of Japanese architecture between interior and exterior, and between interior spaces, is further manifested in the architectural detail and use of translucent (*shoji* screens) space partitions and opaque (*fusuma*) space partitions.

Figure 30: Shoji screen/Figure 31: Fusuma
Source: Fig.: 30: *Sitebits.com.* Noelia. "More patterns of Japan." 2006. http://www.sitebits.com/2006/more_patters_of_japan.html
Source: Fig. 31: *Picasaweb.google.com.* http://picasaweb.google.com/113767328858355906027/Japan#
(accessed April 26th 2011)

Windows were also applied to Japanese residences. However in the architectural features of the Japanese house a window is merely a window, while a *shoji* and *fusuma* wall partitions have the multi-function as a window, a door, and a wall partition. This architectural feature was suited for the hot and humid climate of Japan since interior and exterior wall partitions could be easily removed to adjust the internal climate of the house, spatial functions, and the connection between spaces.

STRUCTURAL FRAMEWORK

The traditional Japanese method of building construction is primarily based on a wood joinery structural framework. This method of construction was already in use prior to the introduction of Buddhism, as simple wood joinery systems are evident in the construction of early pit- and pile-dwelling structures. However, the introduction of Buddhism into Japan sparked a remarkably rapid development in the detailing systems applied to wood joinery building structures, giving rise to a sophisticated method of building construction and building design for its time.

Japanese wood joinery is based on a bracketing system of construction where each structural member is joined together without the application of any other non-wood based fasteners and braces. In traditional Japanese architecture, the intricate bracketing components were carefully carved from wood, using preindustrial woodworking hand tools, and fitted together and held in place solely by the force of gravity and the by the strength in the connections of the joints themselves.

This form of construction was developed out of the carpentry tradition. When the first Buddhist temples began to be built in Japan, not only did it inaugurate an architectural tradition in Japan, but it also spawned the craft of Japanese carpentry.

WOOD JOINERY

The construction of any wood joint is not an easy task. Especially when you consider the fact that most buildings of the time were constructed using pre-industrial woodworking hand tools. Making wood joints requires a level of skill that can only be properly and efficiently applied through years of exposure, practice, and experience. Although one may go about creating a joinery piece in a number of different ways, some basic foundations to joinery making cannot be overlooked, such as proper layout, the importance of the center line, the direction of wood grain, and the sought out end result of a tightly fitting joint.

Within the catalogue of traditional Japanese wood joinery there exists a standard set of joints for different applications in structural design, but within each standard set, variations in the detail of each basic joint also exists. The methods of construction and joint styles applied to a particular structural function vary in Japan from region to region and from school to school, as stated by Sato and Nakahara as follows:

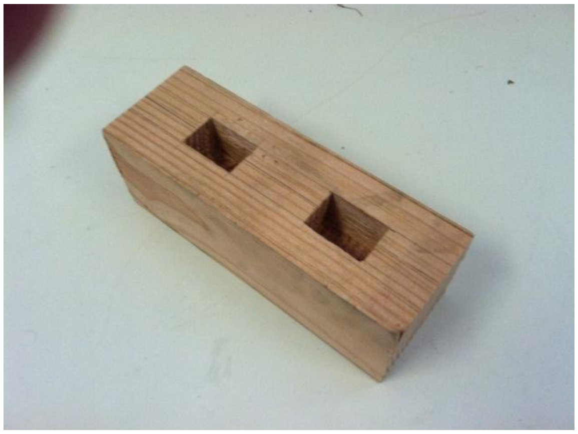
> *"Different methods are stressed even within the same school by such master carpenters as hiruuchi, Kira, Kiuchi, and Tsuru. Then there are alterations in detailing methods brought about by changes in style of periods such as Asuka (ca 700 A.D.-800 A.D.), Momoyama (ca 1550 A.D.-1600A.D.), and Edo (ca. 1600 A.D.-1860 A.D.) periods. There are further differences in technique styles such as the Karaya (Chinese style), Tenjikuyo (Indian style), Wayo (Japanese style), shoin zukuri (study room style), Sukiya zukuri (free style), and the cha-shitsu (tea room style)."*[35]

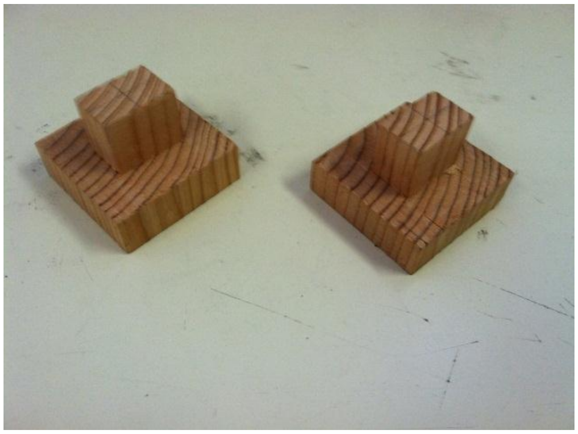
[35] Sato and Makahara 1995, Preface

PART 3 – PRELIMINARY STUDY OF BASIC JAPANESE WOOD JOINERY MAKING

This section describes some of the basic sets of joinery types used by the Japanese in the construction of timber frame structures. The hands-on production of the joints recorded below allowed for a closer investigation into the process involved in the fabrication of Japanese wood joinery, and the initial development of the technical skill sets which the craft demands.

BASIC MORTISE AND TENON

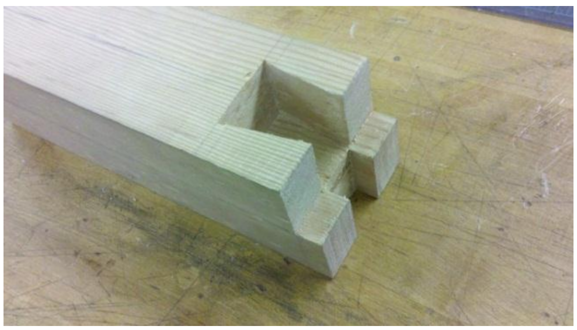


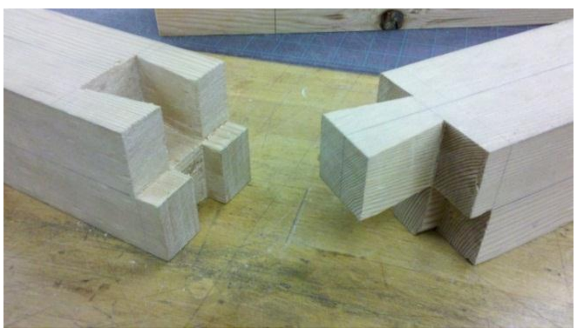


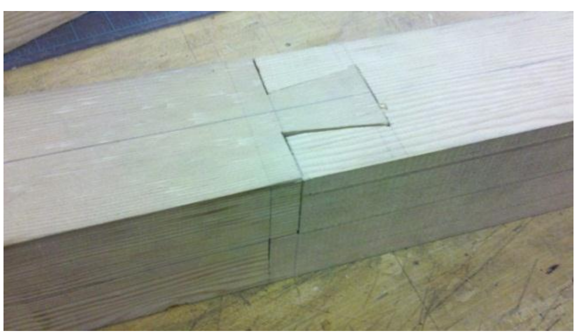
The joinery study began with the most readily used and simplest of joint connections, the mortise and tenon joint. While simple, the tenon and mortise is the foundation, the basic principle, from which many other joints are founded on. It is not only found in the Japanese tradition of wood joinery, but also throughout various Western joinery traditions.

The process of fabricating any joint begins with the layout, the transcription of measure and marking. Following the Japanese tradition, this joint, as with all other joints that follow, began with the layout of the center line. From there the tenon, which is the male piece, was cut with a Ryoba saw, while the mortise was chiseled away. Chiseling, as it was found in the process, requires the knowledge and skill set of basic wood working techniques, without which is very arduous and time consuming. It is better to chip away from the center of the mortise and then out, rather than the other way around. This is done by slowly chiseling pieces from the center out, into a "V" pattern until the desired depth of the mortise is reached. Once that is attained, refinement of the edges can be carefully accomplished. The tenon in this case was easily cut, since all cuts were made at a ninety degree angle from all sides and did not require additional chiseling to finish the piece, which is the frequent case with the majority of all other joints. This particular piece was made from reclaimed Douglas fir wood.

KOSHIKAKE ARI TSUGI (lapped dovetail joint) – *tsugite end joint: used to join and extend pieces in its axial direction.*

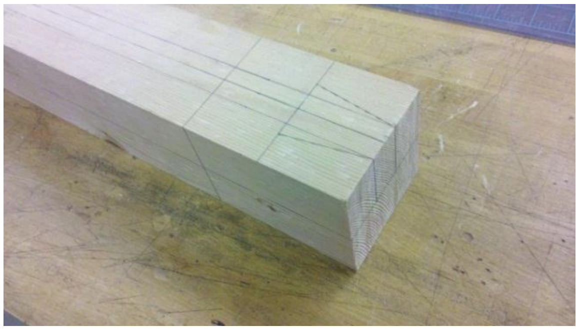


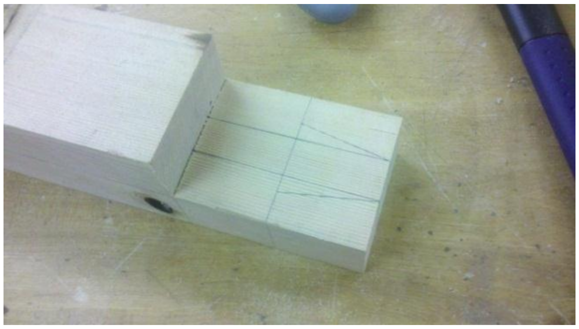


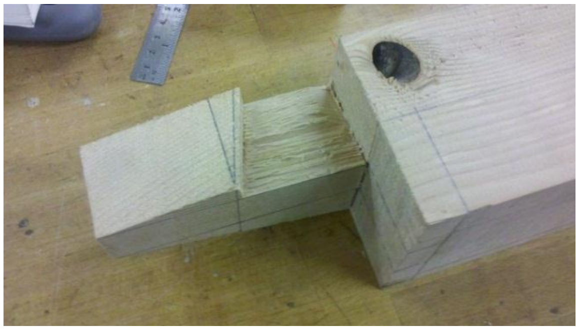


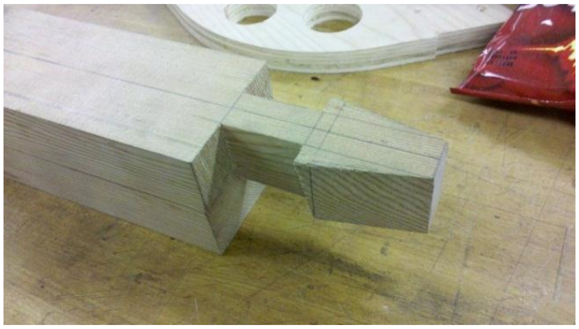
The joint was also cut from reclaimed Douglas fir wood. This joinery piece is used to connect end to end wooden members in their axial direction. In the Japanese tradition, this Joint is the basic connection used to join the spanning construction of mudsills. The female piece of the joint may also be laid out and cut at the side of a long spanning horizontal member in order to connect floor beams to the mudsill. Here, precision in the angle of the cut is of utmost importance. During the fabrication process, whether it is the female or male piece, one must keep in mind the multiple surfaces that need to work with. The slightest error in the angle of the cut can throw off the snug fitting and proper alignment of the two connecting pieces, which is the key to a proper working joint. Error in the process means more time spent in adjusting each piece so that an appropriate fit is achieved. When working with smaller wood members, such as in the case of this joint, fitting can be easily achieved through trial and error. However, when considering larger timber frame joints, a person cannot easily attempt to connect the pieces every so often to see if the pieces fit. Realistically, most timber frame members of a building structure are too large and heavy to be lifted and fitted regularly to spot errors. Careful and correct cutting is the key to speed and efficiency in wood joinery construction, a technical skill that is instilled and revered in the philosophy tradition of the Japanese carpenter.

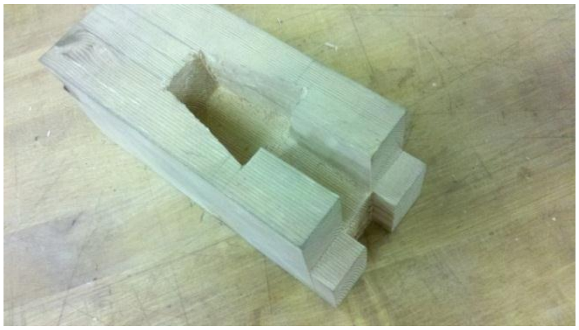
KOSHIKAKE KAMA TSUGI (lapped gooseneck joint) – *tsugite end joint: used to join and extend pieces in its axial direction.*

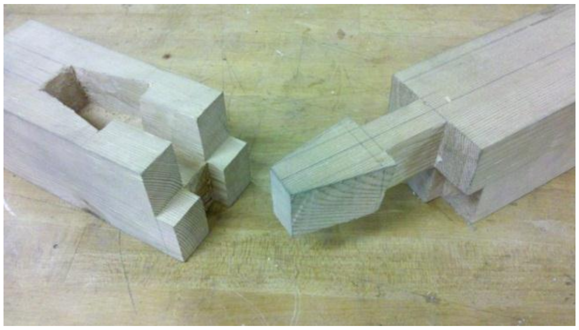


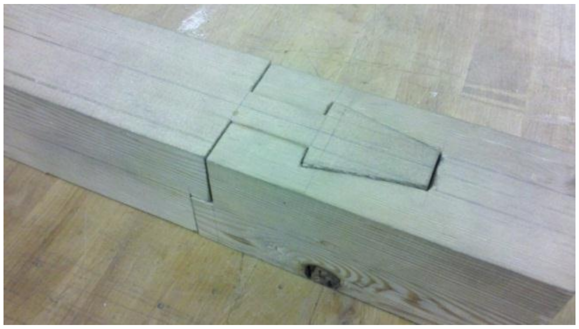






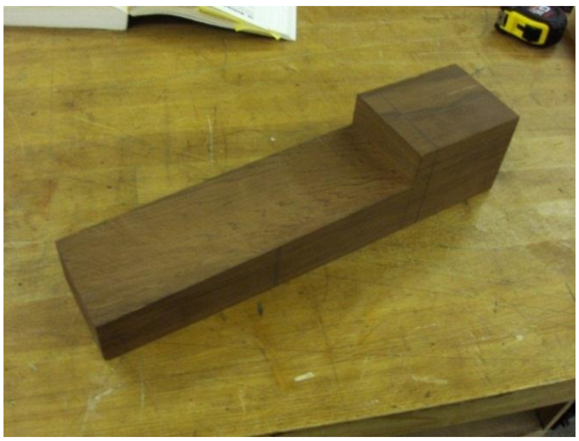


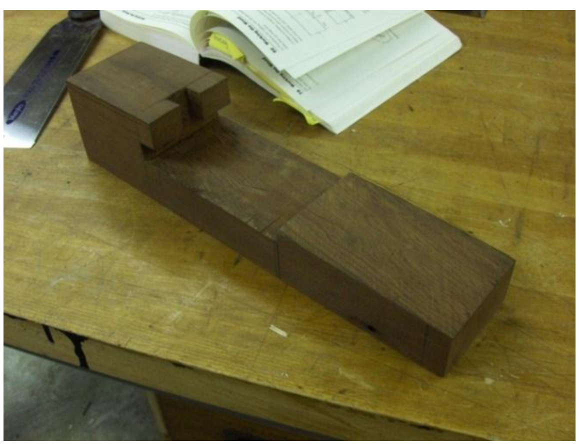


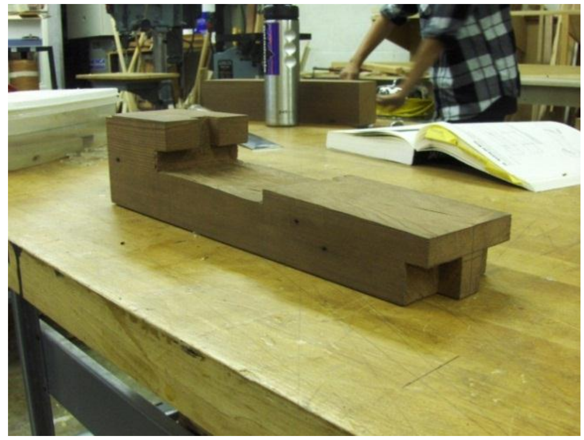


Also, cut from reclaimed Douglas fir wood, this joinery piece is a variation of a mudsill joint. It is also used to connect pieces in the axial direction of horizontal spanning members. Here, slight angles at the gooseneck of the male piece and the recess of the female piece make the joint slightly more difficult to cut and fit than its earlier variation described above. Again, proper cutting and chiseling must be done effectively in order to make the pieces fit properly. Also, when sawing deep and long cuts with a ryoba saw, such as is the case with the gooseneck, it is very important to rip (to cut with the grain) in a straight and level line. Because the cut moves with the grain the saw tends to pull, or follow the direction of the wood grain, especially if the saw is dull. An accurate, straight cut from the very beginning ensures that the blade runs straight and through from beginning to end. Cross cutting (to cut perpendicular to the grain) on the other hand is much easier because the saw is positioned across the grain and therefore does not tend to follow grain direction.

KAWANA TSUGI (blind dadoed, rabbeted and keyed scarf joint) – *tsugite end joint – used to join and extend pieces in its axial direction.*

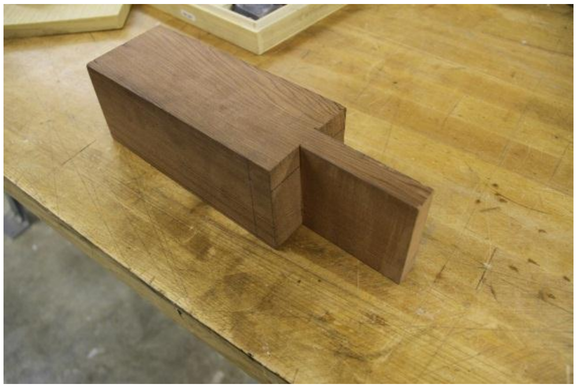


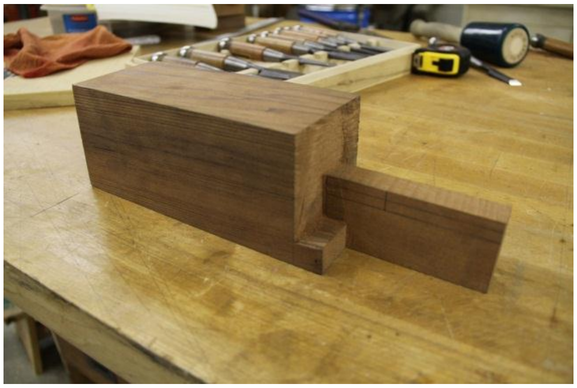




This particular joint was cut from reclaimed redwood. The joint may be used to connect column segments in the vertical direction or beams in the horizontal direction. This joinery piece was by far the most difficult to fabricate. The difficulty in fabrication was due to a number of factors. First, saw cuts were much longer and deeper than the previous joints mentioned. This fact meant that precision of work was a key factor in attaining the desired result of an accurate cut. Second, the two connecting pieces are identical – a mirror image of one another. Therefore, a mistake in one piece resulted in the improper fitting of the joint. Since mistakes were made in the sawing process, prolonged chiseling had to be performed to correct mistakes. While an unfortunate turn of events, lessons were learned in the process. When chiseling, it was found that there is a certain direction that the chisel is most effective. It is better to cut with a chisel with the grain than perpendicular to the grain. When chiseling perpendicular to the grain the chisel must be at its sharpest condition, otherwise force on the wood by a dull chisel will cause compression in the wood leading to a rough surface and broken surface on the surface of the wood. Having to chiseling perpendicular to the grain is inevitable in wood work. In this case, the technique of paring, moving the chisel along the wood in a forward and sideways direction all at once, can facilitate the process. Even when chiseling in the direction of the grain a person must consider from which side to chisel the grain. Grain patterns are never parallel and straight. In fact, throughout the length of the wood, grain patterns constantly shift and change. Given this fact it is important to try to chisel with the grain and not against it to again ensure that gouges and rips on the wood are minimized.

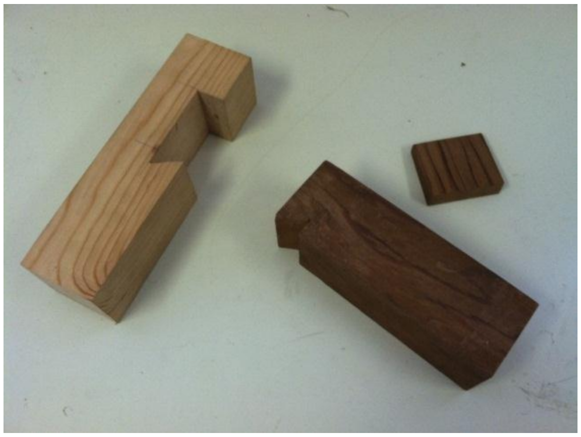
ERIWA KONE HOZO SASHIWARI KUSABI UCHI (collared haunch and tenon joint with a wedge) – *tsugite end joint – used to join and extend pieces in its axial direction.*





This joinery detail was cut from reclaimed redwood and the connection is used to join wooden members at a right angle. Such a connection can also be used to connect mudsills at a 90 degree angle from one mudsill to another, or it may be used to connect a column to a post. Here, it was learned that focus, awareness, and care must be followed when laying out cut lines for chiseling. Mistakes were made because of human error, which meant that the joint had to be cut and restarted many times over. It is mentioned by Paul Discoe, the author of *Zen Architecture: The Building Process as Practice*, that Japanese architecture is all about layout first and woodworking second. The improper layout of this particular piece led to such large errors that the pieces had to be cut time and time again, an unsustainable and inefficient work process that led to wasted material and another trip to the reclaimed wood stock house.

KUDA BASHIRA (discontinuous post)



This joint detail was cut from redwood and Douglas fir wood. The joint is used in-between columns to provide load support when plastering a wall. Horizontal *kuda bashira* members are set parallel to one another at a vertical distance in between posts. Wedges at both ends properly fix these horizontal members to columns. They are used for fixed wall sections that do occur in traditional Japanese residential buildings. Bamboo and mud plaster usually fill the wall cavities.

A comparison between redwood and Douglas fir gives evidence that redwood is a material much more suited to joinery construction than Douglas fir. Redwood is much easier to saw and chisel, and is lighter than Douglas fir. Douglas fir, although denser, is also very brittle when compared to redwood. Another fact that makes redwood a better wood resource for construction is that the natural oils contained in redwood deter termite damage, since termites do not like the taste of the oils. However, when considering reclaimed wood for wood-based design, it is found that reclaimed redwood is very hard to find, as opposed to Douglas fir which has been readily used in the past for building construction.

PART 4 – JAPANESE CARPENTRY AND THE METHODOLOGY OF BUILDING DESIGN AND CONSTRUCTION

THE METHODOLOGY OF JAPANESE WOOD WORKING

The methodology of Japanese woodworking is based on a learning system that entails years of commitment and determination of any individual interested in the craft. As mentioned earlier, the "secrets" of the Japanese woodworking craft were passed down from Master to apprentice through an oral tradition. These "secrets," or the technical skills of woodworking, varied from carpentry school to school, and from sect to sect. It was not until the Edo period that some of the "secrets" of the woodworking craft began to be recorded in writing by government officials as a means to establish a standard for residential construction. However, even with government intervention, much of the knowledge of woodworking was minimally recorded. This resulted in the loss of information and of the interest in the craft over time. Today, the knowledge of Japanese woodworking and the construction of the Japanese house is increasingly declining and steadily disappearing. It is the belief of this author that initiatives must be taken to preserve the knowledge of the Japanese craft of timber frame design and construction. A great part of the focus of this research document is to ensure the preservation and continuation of the knowledge of this form of architecture and construction methodology so that it may be put to use to improve contemporary timber frame design methods and architectural solutions to our built environment.

Below is a record of the experience and knowledge learned by this author, during a professional educational studio experience at Joinery Structures, under the guidance of Paul Discoe. The studio was accomplished in the hopes that the lessons learned about the dying craft of traditional Japanese timber frame design may be recovered from the past and be put to use to supplement this research document, and so that the knowledge gained from this study may be transmitted to people that share the same interest.

As mentioned before, the Japanese carpenter relied on the use of pre-industrial hand tools for the construction of all traditional Japanese timber frame buildings. There exists an extensive list of Japanese hand tools used in Japanese carpentry and timber framing. This section will only cover and discuss the hand tools that this author was exposed to during the learning process.

The following pages will provide a record of the things learned during the Professional studio as they occurred in chronological order. During the Professional studio at Joinery Structures daily tasks and projects were assigned as exercises to develop technical skill and knowledge of traditional Japanese woodworking and timber frame construction. The successful completion of each stage of learning offered insight and preparation into the next phase of educational development. Each phase of development varied greatly from the other, and so, the process of learning did not limit itself to a scope solely based on carpentry alone. The diversity of tasks, such as physical labor, the use of various pre-industrial Japanese hand tools, hand drawings, modern computer drafting and 3D modeling, physical modeling, and interpersonal discussions were all a part of the learning process that cultivated and developed not only an education in architecture and woodworking, but also to nurture the mind, body, and spirit as traditional Japanese carpenters once did in their craft, tradition, and woodworking philosophy.

TOOLS OF THE TRADE

LIST OF TOOLS:


Japanese Hand Axe


Japanese Adze


Crosscut Pull Log Saw


Ryoba Pull Rip and crosscut Saw


Japanese Crosscut Pull Saw


Japanese Chisel Hammer (15, 10, 5mm)


Japanese Timber Frame Chisels

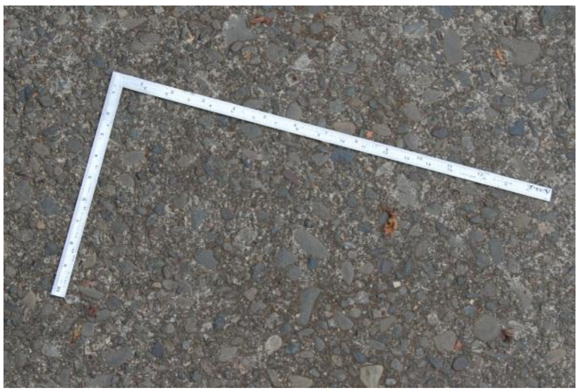

Modern Japanese Ink Line


Sharpening Stone


Polishing Plate


Japanese Hand Plane (60mm)

Japanese Scraper Plane



Shashigane Square

COMPLETE SET OF TRADITIONAL JAPANESE HAND TOOLS

PRACTICE AS A LEARNING PROCESS

Tool Care and Maintenance

The first step to learning Japanese woodworking begins with the care and maintenance of tools. Prior to any tool use one must first learn how to properly prep each tool so as to be able to use them correctly, safely, and to their utmost efficiency. Unconditioned tools can lead to problems and delays in the woodworking process, and the craft of Japanese woodworking is all about speed and efficiency. Poor tool care and maintenance may lead to accidental injuries that can potentially cripple the user, affect the lifelong working abilities of a woodworker. It may also lead to work errors that are irreversible. In the tradition of Japanese carpentry, when a mistake occurs, that mistake becomes a part of the end outcome of any work. To restart the work from the beginning, from a new piece of lumber, is considered wasteful. Described below in chronological order is a detailed record of exercises and projects that were assigned to this author during the Professional Studio experience at Joinery Structures.

Chisels and Hand Planes

The blades of traditional Japanese Chisels and Planes are made from two types of metal: soft and hard. During the forging process, the metal is heated, folded over, and pounded numerous times, much in the same way that a samurai sword is forged. The flat part of the chisel is made from hard metal.

This portion of the blade makes up the cutting edge of the blade. Its flat bottom is slightly grounded out and concaved. The concave is put in place to minimize surface area, which facilitates polishing and sharpening. If the blade were completely flat, more surface metal would have to be polished off during the polishing and sharpening process in order to maintain a consistent sharp and a flat surface edge throughout the length of the blade. From the edge of the cutting blade to the edge of the concaved curve there should only be at the most 1/8” of flat surface.

The typical angle of a chisel blade usually slopes at a ratio of 2:1 (note: blade angles may differ depending on the function of the tool). There exist various types of chisels and hand planes, varying in size and function: scraper planes, rough, medium, and finish planes, curved planes, chamfer planes, bench chisel, timber chisels, carving chisels, etc… Even though a woodworker can overtime acquire a multitude of specialized woodworking tools to be used for specific tasks, in Japan, it is thought that a good carpenter only requires a minimal set of tools to accomplish many tasks.

As it is usually the case with traditional Japanese woodworking tools, all new chisels and hand planes must be prepped prior to initial use.

When polishing and sharpening, finding a proper work surface is important in order to establish good working practices, such as correct posture and effective mechanical movement. A work surface at a waist level height, such as the log stump shown below, provides a sturdy work space from which to polish and sharpen tools.

To prep a chisel you must first flatten and polish the hard, flat metal cutting edge side of the chisel. This is done with a diamond polishing plate. There is no need to completely flatten the entire length of the flat surface of the chisel. Only about 1/2” needs to be flattened, if that much. This is done by setting the chisel hard surface down, and perpendicular to the length of the diamond polishing plate. Move the chisel in a forward and backwards motion through the entire length of the diamond polishing plate. It is important to keep the pressure on evenly throughout the first 1/2” of the chisel blade. Apply downward, evenly distributed pressure at the tip of the chisel blade with the tips of your fingers. Little or no pressure is applied with the other hand. The main function of the other hand is to guide the blade through the forward and back movement so at to maintain a smooth and straight line of travel throughout the procedure.

You can check if the hard edge of the chisel is completely flat and polished by turning the chisel over and toward the sun. Look for a reflective mirror-like shimmer cast by the metal. When the chisel is evenly flat, the reflective polished surface should be consistent throughout, from the edge of the blade, down 1/2,” and from side to side. If done correctly, you should be able to clearly see a mirror image of yourself on the polished surface of the blade.

The procedure remains the same when polishing a hand plane blade.

Suggested tip for polishing chisels only: Find a small stick, about 1/2” to 3/4" thick, by 1” to 1 1/2” wide, and 10-12” in length. Place the stick over the chisel, hands placed at both ends of the stick, with the center of the stick placed 1/2” from the edge of the blade. With the stick in place, apply heavy, even pressure onto the stick while balancing and focusing the pressure of the stick on the tip of the blade. The stick will allow you to place full body pressure onto the tip of the blade, something that fingers alone cannot effectively do. When polishing, the greater the pressure on the blade, the better and faster the outcome will be. This technique is not effective for the hand plane blades, because of their small size.

The butt end of Japanese chisels are outfitted with a metal ring that, when purchased new, will come loosely fastened. When properly fitted, the ring prevents the wooden handle from splitting when pounding the chisel with a traditional Japanese metal hammer. The first step to fastening the ring onto the wooden handle is to remove the ring. Once removed there are a number of different ways from which to go about fitting the ring onto the handle. When fitted properly the top edge of the ring should tightly sit no more than 1/16" bellow the butt of the wooden handle. The first way to fit the ring onto the handle is to sand off the inside of the ring with a round metal file. The second is to sand the handle itself with sand paper. The third is to shave off some of the handle with the side edges of another chisel (much like using a vegetable peeler on a carrot). The fourth is by far the best way, because it works with the properties of wood. This method is done by tapping the butt end of the chisel handle, along its circumference, with a hammer. Wood is cellular and has a memory. This means that, to a certain extent, wood can flex and compress, but still retains a memory of its original form. Tapping the butt of the chisel temporarily compresses the wood until the ring can be fitted properly onto the handle. Once the ring is in place, over time the handle will, to a degree, expand back to its original form. When expansion occurs, the wood applies pressure to the ring creating a very tight fit. You can use any of the methods mentioned above or a combination of two or more of the methods. Now, once the ring is fitted the 1/16" wooden nub extending beyond the ring must be tapped around its edges with a hammer. The point is to pound the edges of the protruding wood onto the ring so that it creates a mushroom like effect over the ring. The mushroomed butt further fixes the ring to the handle and becomes the hitting surface on the chisel where the hammer will strike.

The motion to sharpen chisels and plane blades is the same as when you are polishing. The difference is that when sharpening, the orientation of the blade to that of the sanding block is different. To sharpen one can move the chisel or plane blade along the sharpening stone in one of two ways: either at a 45 degree angle to the length of the sharpening stone, or straight on (parallel to) the length of the sharpening stone. You must sharpen blades from the soft metal, angled side down, to the point that a slight and fine wire edge develops on the polished side of the cutting edge of the blade. Later that wire edge is sanded off much in the same way as you would when polishing, but using the sharpening stone.

Suggestion for sharpening hand plane blades: One may sharpen a plane blade in the same fashion as one would go about sharpening a chisel. However, it is better to sharpen hand plane blades in a back and forth motion with the edge of the blade perpendicular to the length of the sharpening stone. This is because a newly purchased and unconditioned plane blade has sharp edges at its corners. This sharp edge can potentially create fine, unwanted lines along a board when being planed. To overcome this problem one should try to sharpen the blade in the orientation shown below, and using the same sharpening stone over and over again. Overtime, a slight concave should form on the surface of the sharpening stone. Sharpening the blade over this surface time and time again will eventually curve the edges of the blade slightly and fine tune the edges of the plane blade so that it does not mark the wood while planing.

Sashigane – The Japanese Square

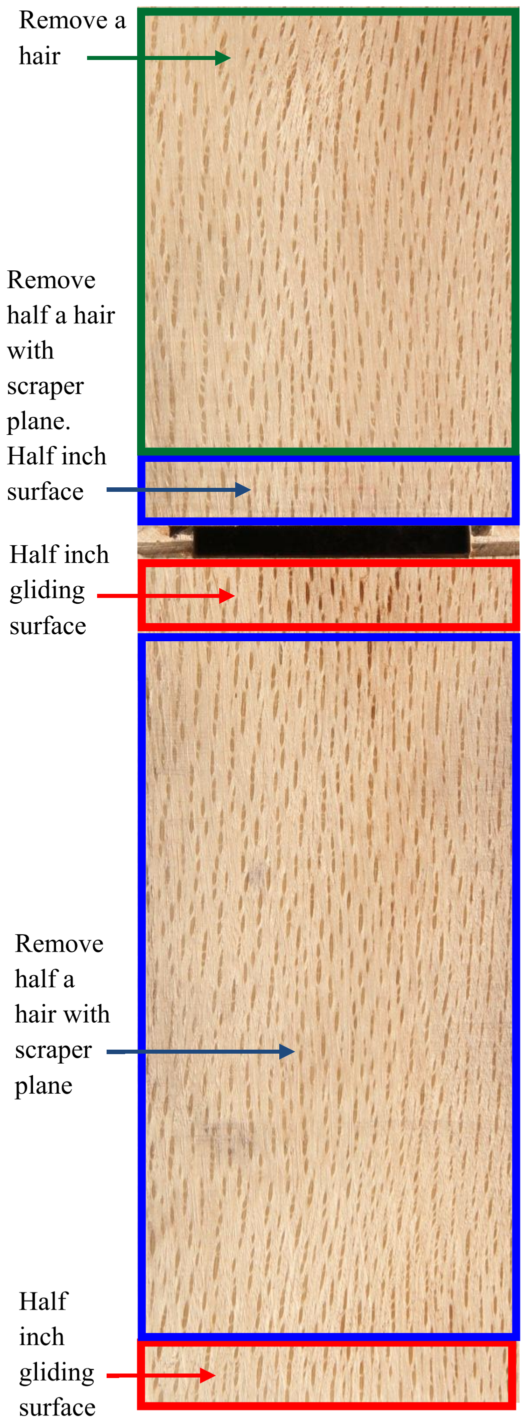
The *Sashigane* is the traditional Japanese framing square and ruler. There are considerable differences between a traditional Japanese framing square and an American steel square. The most notable difference is in their size. The American steel square is considerably larger and heavier. A typical American steel square usually measures 24" x 16." For its purpose, it is very suitable for contemporary light timber framing of a house, since most framing studs are typically spaced out at a dimension of 16" and 24" on center. Traditionally the Japanese square is based on the Japanese *shaku* measuring unit, which is equivalent to 30.3cm (a little less than a foot). However, today you may purchase a Japanese square in centimeters and inches. Not only is the Japanese square smaller, at its long length measuring 20", but it is also pliable and flexes easily. This feature helps in drawing straight lines in curved surfaces such as logs. The Japanese square also has raised edges. The raised edges help to prevent smearing when laying out marks with ink. Traditionally, the Japanese used ink and not pencils to mark their lines. The most notable feature of the Japanese square is on the reverse side. On the reverse side there exists a scale known as the *kaku-me*. The *kaku-me* is a measuring system based on the square root of 2. This measuring system facilitates the calculations of the slope of hip rafters, as well as other incident angles based on the square root of 2.

Conditioning the Hand Plane Body

When first purchasing a planing block the blade sits very tightly along its sloped slot. This is because most good blades are hand forged. Since each blade is hand forged, there are subtle inconsistencies which occur from blade to blade. Good hand planing blocks are also handmade. Therefore, inconsistencies also occur in them as well. To properly fit the blade into the plane body, ink the side of the blade that butts against the sloping surface of the planing block. When you slide the inked blade into its proper slot and then remove it, the ink will leave behind ink spots on the high areas of the surface of the blade slot. By using a chisel to scrape off the high points on the surface you slowly open up more and more of the blade slot, widening it so that the blade is properly fitted. Repeat the procedure over and over again until the edge of the blade is snuggly fit, and can be seen just a hair extended past the throat at the bottom of the planing block. The fit must be snug and not too tight or too loose. A tight fit can potentially cause damage to the blade when tapped in place. If the blade is too loose it means that you have opened the throat too far. In this case you have caused yourself much more work and effort, since to correct the problem you will have to make very hard adjustments to the plane body by adding wood. It is a long and tedious process taking hours of work and should be avoided for as long as the planing block will allow.

The hand plane shown above is a 60mm general use plane that is readily used and a first purchased tool for any woodworker. The scraper plane is another readily used plane. The scraper plane offers a variety of functional uses. One of its uses is to condition the sole or planing surface of other hand planes. To use a scraper plane one has to orient it perpendicular to the length of the planing block, across the grain and not with the grain. Slide the scraper plane it in a forward and back motion making sure that the scraper plane lies flat to the sole of the plane being conditioned.

The specifications to condition the sole of the plane is as follows:



Scraper planes are also useful in planing areas of a board where an abundance of knots occur and for leveling off slight high spots on any wood surface.

Traditionally planes were initially only outfitted with one blade. It was not until about 200 years ago that planes started being outfitted with two blades, a main cutting blade and a chipper blade. In the past, over 200 plus years ago, the quality of wood used by the Japanese was of a better grade than the wood used today. Because of this, a single sharp blade was enough to cleanly extract shavings while planing, without ripping chunks out of the wood. This is because the wood used was old growth timber, consisting of dense and tightly packed grains. The ripping of wood occurs in places where the grain density is low and where the grain direction changes, such as in and around knots. The chipper blade was introduced as a result of the diminishing availability of good quality wood. Lumber used today is of a lesser quality and tends to rip more easily when planing. If the ripping of wood occurs while planing, the chipper blade chips off the pulled, ripped chunks, facilitating the glide of the blade through the rough parts of the wood. The chipper blade also prevents the main blade from vibrating, which is one of the main causes why wood rips while planing.

PROJECT 1 – Hand Hewing a Log into a Beam

This project allowed for a study into how to mill a round log into a square beam using pre-industrial Japanese milling methods. The following tools were used in the process: a log crosscutting saw, a Japanese hand axe, an ink line, long nails, and two straight wooden sticks each measuring approximately 3’ in length.

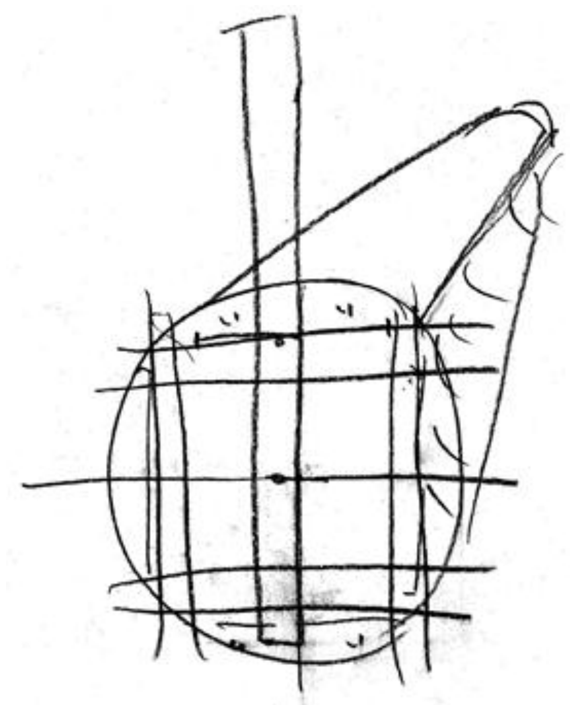
The log used for this project was made of second-growth redwood. A Japanese pull crosscutting log saw was used to saw the log roughly to length (Note: If the handle of a saw becomes loose over time, you may reset it by dipping the metal portion of the blade handle into soy sauce, and quickly back into the handle while it is still wet. Overtime the salt in the soy sauce will make the metal rust and expand and the sugar will act like glue and bind the metal to the handle.)

In the Japanese woodworking tradition the measuring of any dimension always begins at the center line. This is very, very important! If measuring a 3’ line segmented into 3 equal parts, say into 1’ segments, it is important to measure each segment from the center line out and not from the beginning of each segment. Measuring from the center line out ensures that small discrepancies in measuring do not compound into large margins of error. For example, if you make a measuring mistake at each segment, say 1/4”, and you measure each segment from segment to segment, and not from the center line, in the end you will have compounded a measuring error of 3/4” more than the desired length of 3’. If however, you measure each segment beginning from the center line, and you make the same error of 1/4" at each segment, your total length will only be off by no more than 1/4" than the desired length of 3’. This is important in building construction because large margins of error can cause catastrophic mistakes in structural design and costly setbacks to correct errors. As a rule of thumb, always measure twice and cut once!

After looking over the log, it was estimated that a section of lumber approximately 12’x7”x7” could be extracted from the log. Initially it was thought that a dimensional piece 12’x8”x8 could be extracted from the log. However, irregularities found on the log made it hard to extract that size.

There are tools made specifically for peeling bark off logs. However, for this project those particular tools were not required, since the bark peeled easily off just by pulling it by hand. After the bark is removed and the ends of the log are cut to length, one must look down the entire length of the log and at its ends to ascertain the best point or center from where to begin to layout the dimensional square beam. It is important to thoroughly study all sides of the log, and even turning it over if necessary. Tree trunks do not grow in a perfect cylindrical shape. Before cutting down a tree, or using a log for a specific purpose, you must look at it and make sure that it is of an appropriate dimension for whatever your needs are. Trees are a renewable but limited resource and should not be used wastefully.

Once you have examined the log thoroughly, mark a center point at the narrowest end of the log. From there, use a sashigane square to draw vertical straight line through the center you have just marked. Use one of the straight 3' sticks procured for the project, and nail it with two nails to one side of the newly marked vertical center line, leaving the majority of the length of the stick extended vertically above the log. Move to the opposite end of the log and find the center point of that side. This time, with only one nail, fix the other 3' stick to the same side of the other stick at the other end. Afterwards, visually align the edges of the sticks so that they are flush and parallel to one another. In doing so, one is able to reference the center line at one end of the log in order to find the center line at the opposite end of the log. With this done, one can begin to draw out perfectly aligned squares, one at each end of the log. The same thing was done to find the horizontal center line for each end of the log. However, the first horizontal line measured was done with a squaring tool against the wooden stick in order to establish an accurate horizontal 90 degrees angle perpendicular to the vertical line. The other steps remained the same.



Now that a center point and two center lines (horizontal and vertical) have been established at each end of the log, a square can be laid out on both sides. Since the dimension of the square is 7"x7," measure 3.5" from the center line out to both sides of each of the reference center lines to draw the perimeter of the 7" square. Extend perimeter lines of the square all the way up to the edges of the log. Move the 3' sticks to the perimeter lines of the square that you have just marked and visually check if the perimeter of the squares are parallel by aligning the sticks again. Once aligned, snap your ink line across the length of the log and connect the end points of the squares. Snapping an ink line takes some practice. Chalk lines are not good for this purpose because the line snapped is not as accurately defined and will rub off with time. Since the log is round, and not a flat surface, the vertical 3' sticks at each end will help to guide the line to its proper marking on the log. After inking a line on both sides of the log you can begin to chop away the wood with an axe.

There are a number of ways which one can go about chopping the log with an axe. The first way is to stand at one side of the log while chopping down with the axe on the opposite side of the log. This method ensures safety, to a certain degree, because the log acts as a barrier between you and the axe. However, it is not the most efficient and effective. Another method of wielding an axe is the traditional Japanese method which requires you to walk on top of the log while chopping away at the wood. Traditionally this method is done barefooted, or wearing a *tabi* which is a Japanese sox with a built in toe sleeve and sole pads. Barefooting provides more friction and stability when walking along the log. It also ensures focus and attentiveness on the task at hand from fear of chopping off one's toes off. There is also a third way, which is to straddle the log while standing, having each leg on each side of the log and swinging the axe down to one side of the log. This third way is relatively more dangerous because the force of the swinging axe can sometimes carry the momentum of the axe toward your leg. This method works better when using a short broad axe, as opposed to a Japanese long axe. A short broad axe affords more control.

All three ways of wielding an axe were attempted. The first way, having your body on one side of the log while swinging at the other side, was found by this author to be by far the safest method.

To chop the log in this method one must first move along the length of the wood and score the wood by striking it at an angle. Trials showed that an angle slightly less than 45 degrees from the length of the log works best. This angle allows the axe to penetrate deep into the wood with the least amount of effort. Any angle less than 45 and the axe does not bite into the wood, causing deflection Any angle greater than that and the axe does not score the wood deep enough and it feels like you are hitting solid rock. Scorring the wood first helps to raise large chunks of wood that can be easily removed by flaking the wood. First score the wood along a relatively long section of the log. You can later make another pass and flake the wood off. Flaking requires that you strike the wood at a slightly more acute angle than you would use when scorring the wood. However, at the moment of impact, you purposely deflect the axe along the same line of the length of the log in order to shave off chunks of wood. This is very hard to get used to so be sure to move along cautiously until a level of comfort is attained.

When working a log into a square beam the goal is to get the log as square as possible from the moment you begin using an axe. You must also try to get as close to the reference ink line without going past it. The closer you can get to the line, the easier it will be to later plane the wood. This first method of chopping (standing to one side of the log while striking the other side) is a fine way to go about the procedure. However, there is a limit to this method, which is the limited angle at which a person can vertically strike the log. In this method one is limited to a shallow angle. And so, the log must be rolled over and over again, working the log from different sides, and resetting your sticks multiple times to turn the log into a beam.

The traditional Japanese way of walking over the log is by far the most technical, efficient, and effective way to go about the procedure. This method allows you to stand right over the log and the reference ink line. By standing over the log you increase the angle at which you can vertically drive the axe to the side of the log. With practice you can consistently chop at a fairly straight vertical, eliminating the need to roll the log over and over again and reseting the work as mentioned above. When performing this method it is important to always keep your arms at a set length of extension without extending them too far (you will lose your balance and accurateness) or by pulling the axe toward you and shifting the angle of your back (you will raise the axe and swing at your legs if you do so). If you maintain balance, a set posture, stroke, and focus the axe should "technically" never hit you.

Hewing requires as much of a level of precision as chopping with an axe. An axe is used to chop a log into a rough square. Hewing is done to clean the rough cuts on the beam left by the axe, and to further finish the log into a beam so that it is ready to be planed.   In Japan, hewing is traditionally done with an adze. Instead of digging into the wood, and ripping of chunks as you did with an axe, your intention when hewing is to plane the wood down as level as possible, cleaning off any marks or indents left by the axe on the surface of the beam. Essentially you are very roughly planing the wood.

The adze mechanically works in the same way as an axe, by swing it up and down. The difference is that the adze has a considerable curve at the top of the handle and the cutting blade is shaped more like a plane – the blade being oriented at a 90 degree angle relative to an axe. Most adze handles are procured in nature from branches with a natural curve. The curve of the adze handle is not hand carved. When hewing with an adze the appropriate mechanical body motion is to walk backwards along the surface of the log while hewing the walking surface ahead of you – unlike with an axe where you chop the lateral surfaces of the log. To prevent the adze from hitting your legs, lift the toes of your front foot so that if the adze deflects, it will hit the sole of your foot and not your shins.

When using an axe or an adze it is important to pay attention to the grain patterns of the wood. Especially around areas where there are knots. Whenever possible, the procedure must be done with the grain and not against the grain. If you hew or chop against the grain, the wood will tend to chip and rip off, leaving behind gashes and deep grooves on the wood. At the edges of the log, large pieces of wood may rip, leaving a permanent unwanted dent on the wood. As mentioned before, in Japan, if you make a mistake, you do not start over. Rather, the mistake you made is left as a part of the final product. One cannot cut down another tree just because a mistake was made. It is more important to learn from your mistake by being more mindful of your work the next time around.

Sharpening an axe is much like sharpening a chisel or a plane blade. The only difference is that instead of passing the blade over the sharpening stone, you pass the stone over the blade of the axe. Place the axe over a corner edge with the blade's cutting edge extending beyond the edge of the surface. Pass the stone over the cutting blade in a forward and back motion along the length of the cutting edge of the blade until it is sharp. Repeat process on both sides and be cautious of where your fingers are on the sharpening stone at all times

In traditional Japanese woodworking you will more likely use the sharpening stone more than any other tool. Overtime, constant sharpening on the stone will distort the shape of the stone block. Therefore, you must periodically condition the surface of the stone so that it is maintained at a relatively flat and level surface. In order to flatten the surface of the stone just soak the stone in water and pass the stone over a diamond finishing plate. Diamond finishing plates are factory made and therefore offer a surface that is true to being level and flat. You will know when the sharpening stone is flat once the stone begins to stick to the diamond plate (you will feel the suction), and when the coloration (shadows) on the surface of the stone is even throughout. (Note: once a stone is soaked in water it is best to always keep it submerged in water when not in use. If you constantly wet and dry the stone it will make the stone prone to cracking and sharpening stones do not come cheap.)

The throat of newly purchased hand planes will come in a variety of settings. The condition of the throat of a plane will designate whether the hand plane is a rough, medium, or finish plane. In most instances, the smaller the throat opening of the plane, the closer it will fall in the finish category (type of blade and the angle of the blade is also a factor). The wider the opening of the throat, the more it will fall closer to a rough or medium plane setting. If you only have one hand plane available, it is best to set it to a medium setting so that it can be used as a general purpose plane (note: the difference in the width of the throat opening between a finish plane and a medium to rough plane is very slight, about 1/64). To open the throat of a hand plane simply use a chisel to enlarge the throat opening. Be sure not to open the throat too much. It will ruin the plane and you will have to fix it by adding wood to the plane body which is not easy to do.

Traditional Japanese hand planes are made of wood and therefore are very sensitive to climatic changes. Most plane bodies are either made from white oak or red oak. Overtime, the wood will swell, shrink, warp, bow, and twist depending on the climate condition. These changes to the body of the plane can occur in a matter of weeks to overnight. Therefore it is always important to always check the state of the body of the plane prior to each use, and to condition it whenever needed. Also, remove the blade from the plane every time after a day's work and always place the body of the plane on its side when not in use to prevent damage to the sole of the plane and the blade.

To set the blade into the body simply tap the blade into its slot with a hammer. You will know when the blade is set properly when the blade passes through the throat of the plane just slightly (about one 1 to 1/2 hair). The blade must also be set evenly throughout the width of the planing surface of the plane. To set the blade evenly, simply lightly tap the blade's body from side to side until the blade is set evenly. As mentioned before, it is always important to remove the blade from the body or to retract the blade when the plane is no longer in use. To do so, simply tap the upper corners of the planing block with a hammer. The vibration of the hammer strike onto the body will set the blade loose. You will know when the blade is loose from the body when the sound of the blow changes to a different pitch. Make sure never to strike the edges of the sole of the plane body. Doing so will ruin the planing surface of the body.

When planing a beam it is good to first begin by quickly removing the excess rough surfaces on all sides of the beam. This will help set a planing reference ink line that is sharp, accurate, and visible. Once the ink line reference marks are set in place you are ready to begin planing.

The pull force when planing should come from the core and not your arms. When the proper body mechanics is achieved, by the end of a workday one should feel sore around the core and not the arms. Also, the path of the plane should move along the entire length of the surface of the beam with minimal pauses. Each pause leaves behind blade marks on the surface of the wood. The way your feet move when planing the board is also very important. You should evenly pace backwards, abdomen engaged, at a smooth and even glide. The height of the surface of the beam should be set at approximately waist height for correct and effective body posturing.

It is easier to first plane the outer edges of the surface of the beam down to the ink line. This procedure will leave a round high spot at the axial center of the beam, which is later planed off. It is much easier to do it this way then to attempt to perfectly plane the entire surface of the wood all at once.

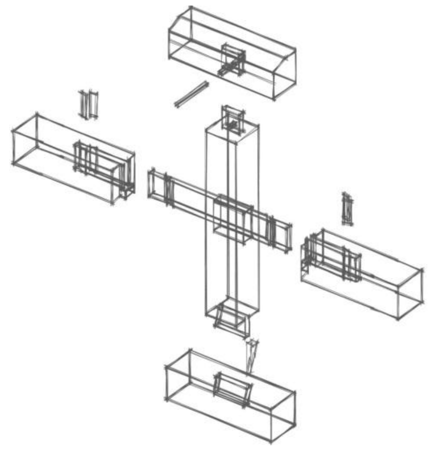
The first surface should be perfectly flat, level, and smooth before moving on to another surface. To check for that one should use the sashigane square. Use the straight edge of the square and place it level against the newly planed surface of the beam at approximately 1' intervals along the entire length of the beam. You will know when the surface is true and flat when no light or gap can be seen between the surface of the beam and the straight edge of the sashigane. Any light penetrating through that space will mean that the surface is not level. Only after the first surface is planed to precision can you finally move on to the next surface. If the first surface is not precise, than that surface will throw off the planing for all of the other surfaces, since you will reference the square-ness of all other surfaces from that first planed surface.

Another important thing about planing is that you do not accidentally create a twisted, uneven surface through the length of the board when planing, especially at the ends of the beam where other joints meet. A significant twist on beams and posts will significantly impact right angle connection, throwing off the alignment of any building structure. To check for a twist on the surface of a beam simply place two straight sticks of equal length at each end of the beam and visually check if the sticks align. It is also visually helpful if you paint the stick at the far end black. These sticks are called winding sticks and they help you to check for any warp, twist, and bends on a beam or post.

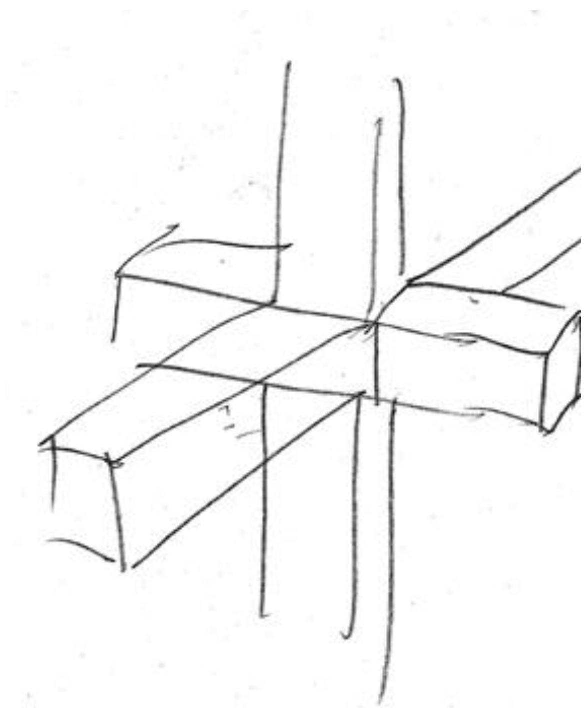
Although beautiful as a decorative accent to any wood project, knots are a big inconvenience to work with. Knots occur in places where a branch once grew out of the trunk of a tree. In and around knots the grain patterns are tight and shift in multiple directions, making it very hard to work with. Using a chipper blade on a plane greatly facilitates the planning process on a knot, but it is still not an easy task. The chipper blade functions in two ways. First it chips away any chunks that the main blade may pull, preventing large chips from being gouged out while planing. Second, it prevents the main blade from vibrating as it is pulled along the surface. Surface tension between the blade and the surface of the beam causes the main blade to vibrate. When fitted, the chipper blade reinforces the main blade, acting as a counter vibration element. The vibration and movement of the main blade is what sometimes causes wood to be lifted and ripped while planing.

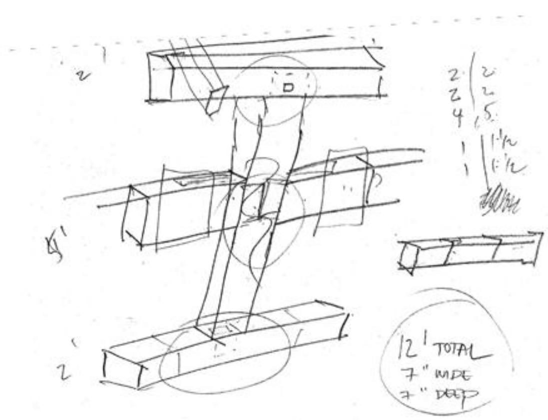
When planing, you must constantly check the beam for any unevenness on the surface. There is a "correct" sound you should hear from the plane when it is appropriately set and cutting well. The sound of a good running plane can be closest described to as a swooshing sound, almost like a zipper being pulled, only much more delicate and less raspy.

PROJECT 2 – Joinery Medley



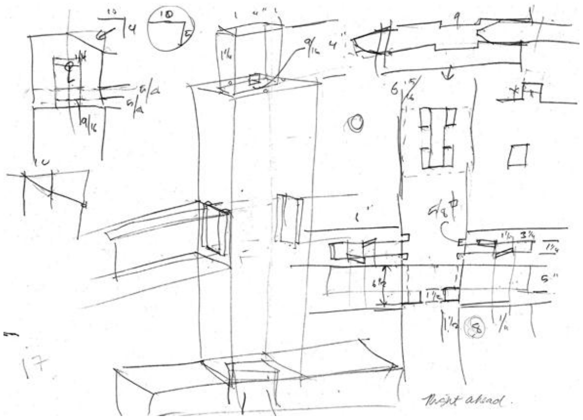
The "Joinery Medley" project is designed as a series of individual joinery studies, which when put together, makes up a full structural wall section detail of a two story Japanese timber frame house. The intent of the project is to allow the student to learn the most basic and common Japanese joinery components readily applied in traditional Japanese timber frame construction. The exercise is also aimed to provide hands-on woodworking experience and practice, teaching the novice student the basic layout of joints and their fabrication using pre-industrial Japanese methods and tools. The project described below began with sketches and a general description of the various functions of the basic joinery components that make up the Joinery Medley piece. The previously planed log provided the material for construction for the Joinery Medley project.





In the Japanese tradition pins used in pin joints are square and not round. In contrast, Western cultures use round pins instead of square ones. This is due to the fact that Western cultures discovered the invention of more sophisticated drilling tools and metal working technologies earlier on in their history than the Japanese did. The pre-industrial Japanese drill is made up of a long wooden handle, with a long metal neck that terminates at a tiny point that is the drill bit. This small drill is only used to make small holes for smaller pin joints. The hole is made by placing the handle of the drill between the palms of your hand and by rubbing your hands back and forth much in the same way as anyone would do when making fire with a stick. Pressure is constantly applied downwards. The rest of the hole is carved out and squared by using a small chisel.

Making the pin square as opposed to round makes perfect sense in the Japanese tradition, since it is easier to chisel a square hole than it is to chisel a round and cylindrical hole. Mortises are the female piece of a specific type of joint while tenons are the male piece. When making the mortise it is important to make the depth of the mortise deeper than the length of the tenon to allow for the expansion and contraction of the tenon piece. The extra space should be no more than 1/4". As a rule of thumb the length of a tenon should be equal to its dimensional height. Making the length of the tenon longer that its height, or vice versa, does not give the tenon any added structural strength. When cutting a tenon on an exposed overhead beam, the tenon is usually cut 1/2” above the bottom plane, or surface, of the beam. This ensures that any cosmetic defects in the joint are hidden from sight when viewing the structural connection from below.

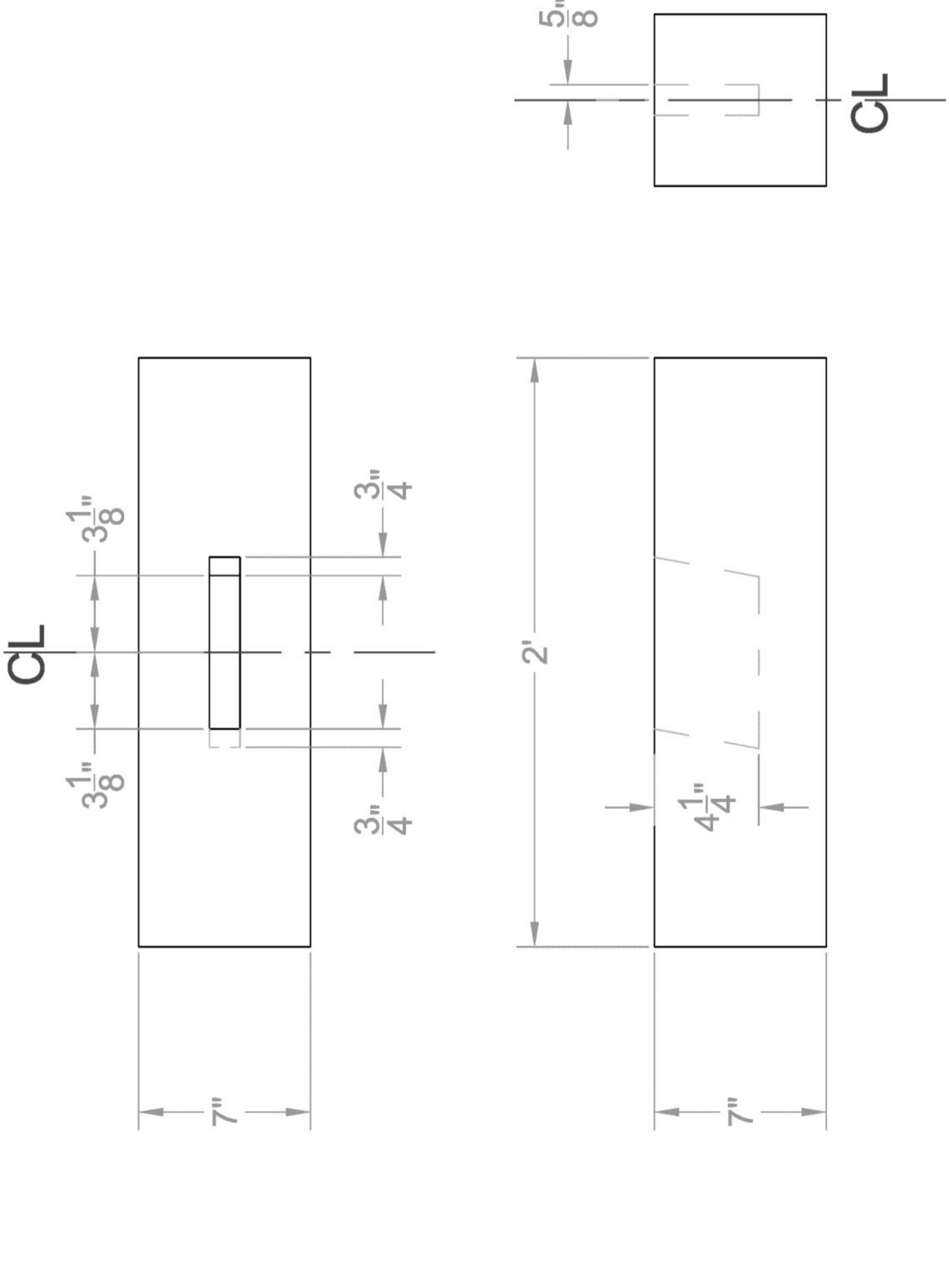


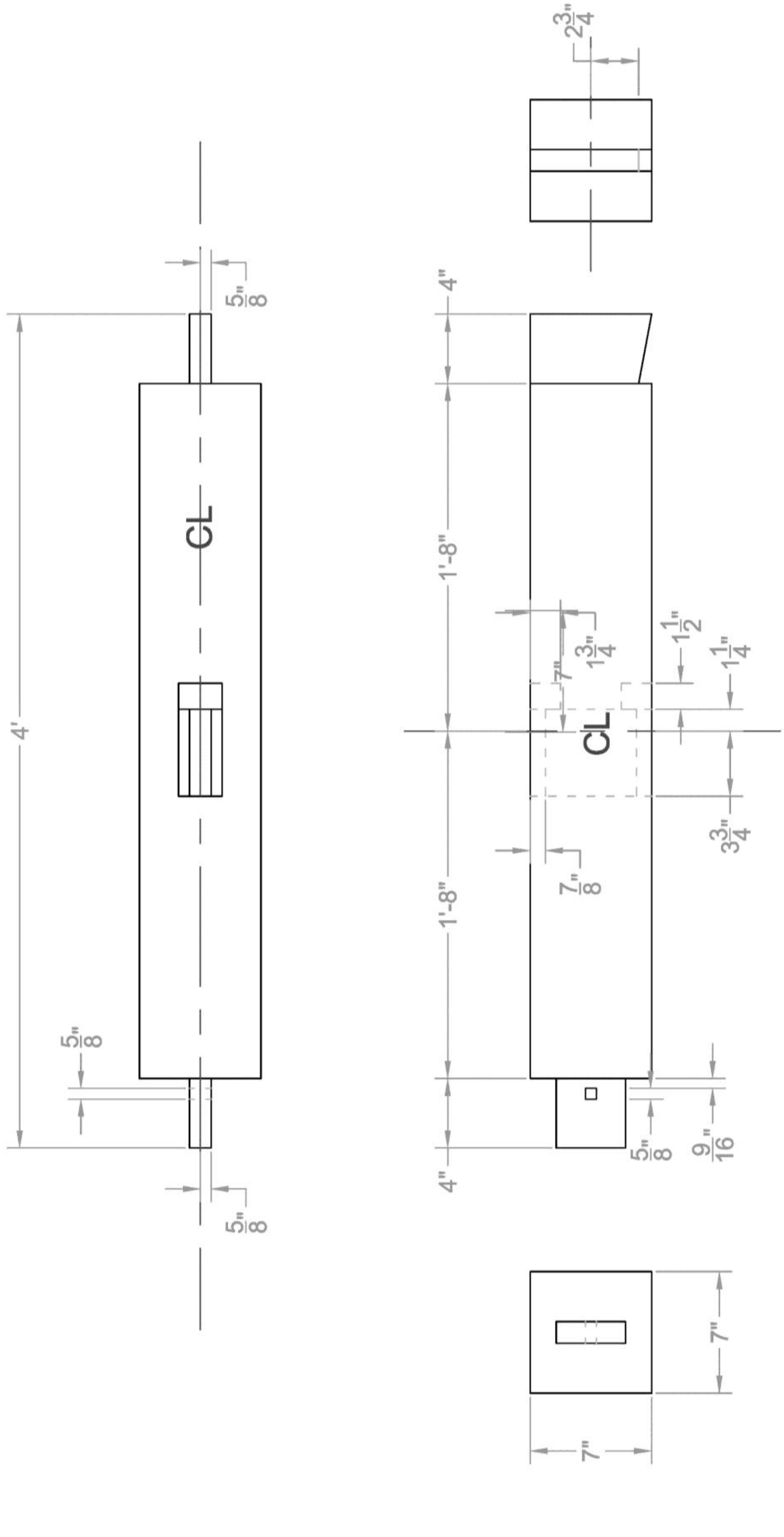
Again, it is important to mention the importance of the center line even when dimensioning drawings. There should always be a center line marked in drawings. The center line on a drawing is marked as CL. When drawing or laying out dimensions, every measurement will originate from the center. In cases where a center line is not needed, dimensions should always stem from the same surface edge or planar edge.

Rafter beams, or *ketas*, are beams that are chamfered at one edge, at an approximate slope of 10:4. This chamfer allows rafter pieces to rest flush to the beam. The slope of the chamfer is designated by the slope of the roof. Traditionally, the roof of a single story Japanese house has a roof pitch of approximately 10 to 4. However, if the house is a two story house, then the first floor roof will have a pitch of 10 to 4, while the second floor roof will have a greater pitch, of about 10 to 5. The use of different roof pitches is done simply for aesthetic reasons. If the roof of both stories were made to be of equal pitch then the perspective of the roof structure would look distorted and unbalanced from an observer's point of view looking up at the roof from ground level. Now, if the pitch of the second story roof is steeper, then the entire roof outline will look more balanced and less distorted from the same observer's perspective.

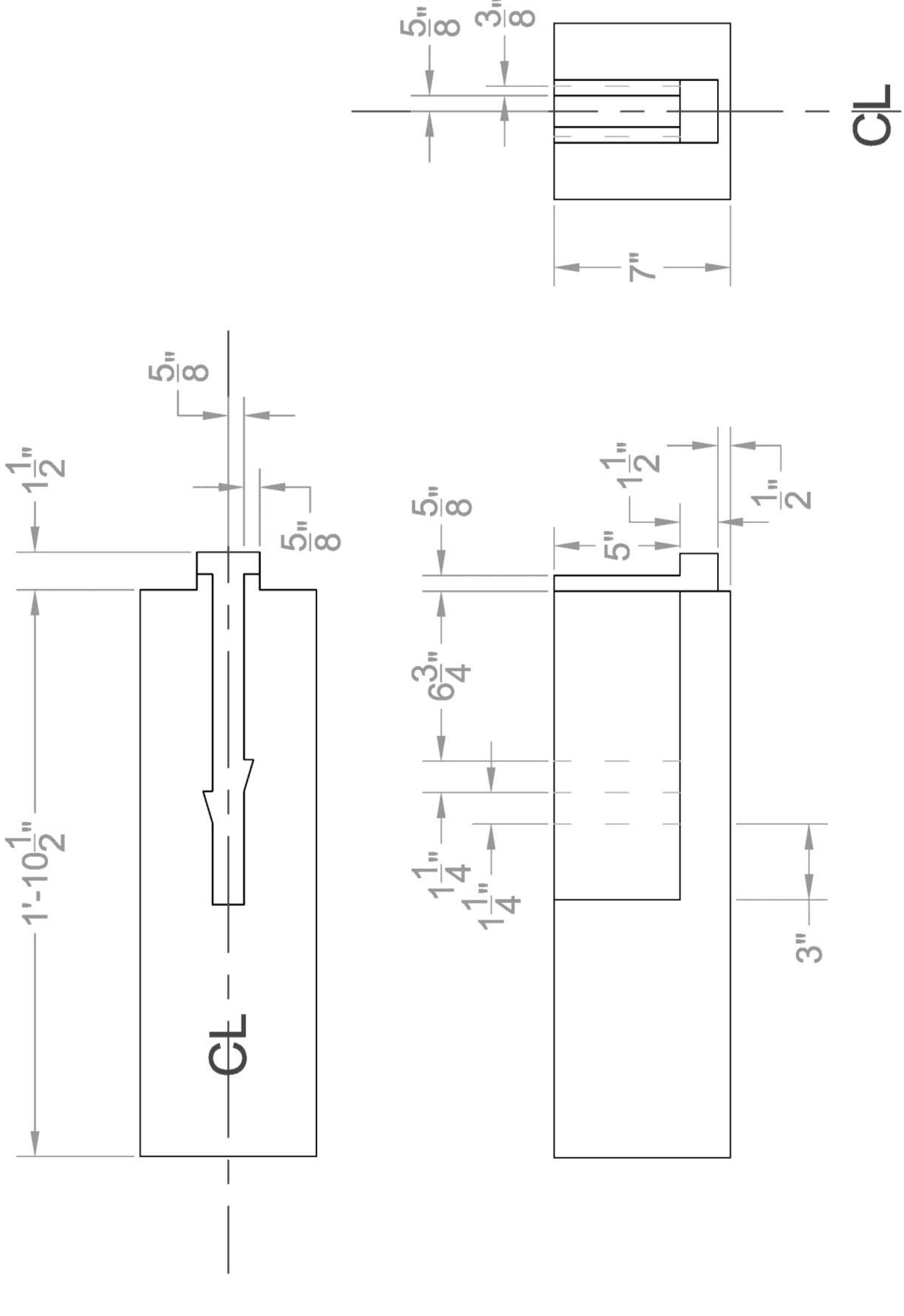
Traditionally, the layout of any joint starts with the layout of a story pole. A story pole is a long and narrow stick where all dimensions of a particular joint are measured out in sequence along the edge of the stick. The story pole acts much like a ruler. Its purpose is to facilitate and speed up the dimensional layout of multiple joints. Story poles help reduce the amount of times a person has to measure any dimension in a given project. The benefits of a story pole are most noticeable in the construction of large structures, such as a house, where a large number of structural elements are of the same size and dimensional cut. Once the story stick is created, mark a center line on all sides of the beam using an ink line. When drawing and extending lines perpendicular to the length of a beam, always make sure to designate one surface on the beam as your point of origin for all other lines. Clearly mark the surface where your lines will originate from so as not to forget which surface is your surface point of origin. From the surface of origin, extend lines laterally along each of the lateral sides of the beam. Once that is accomplished, connect the lines at the bottom surface of the beam. If the beam is perfectly square the lines should connect at the bottom surface of the plane. If the lines do not connect, it means that the surfaces of your beam are not level and square to one another.

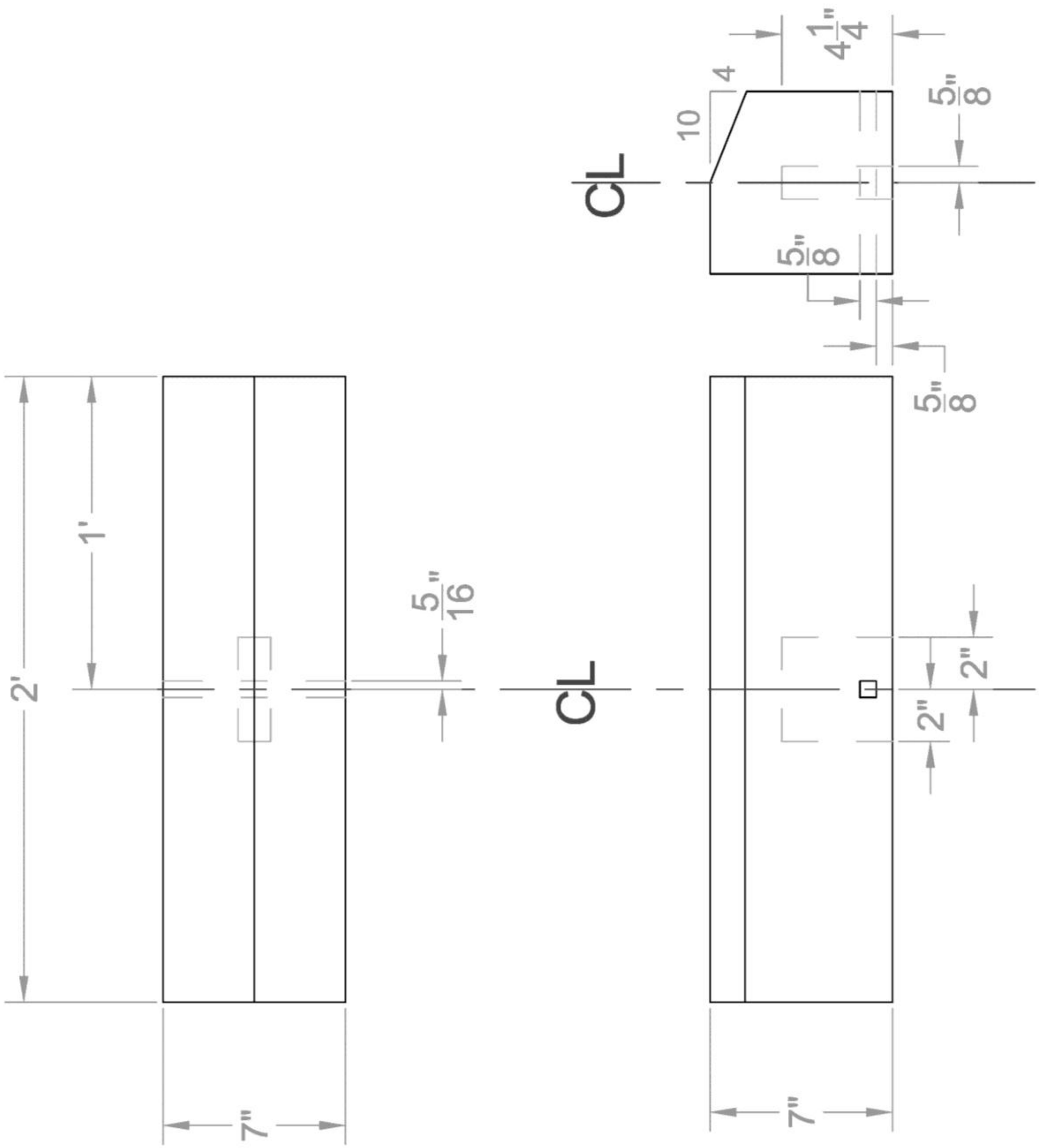
The Japanese house is based on a modular post and beam system of construction. As mentioned earlier, this modular system is based on either of the *Ken* systems of measure, which is based on the distance between post to post measured on center. As the *ken in kyo-ma* system is a variable of the

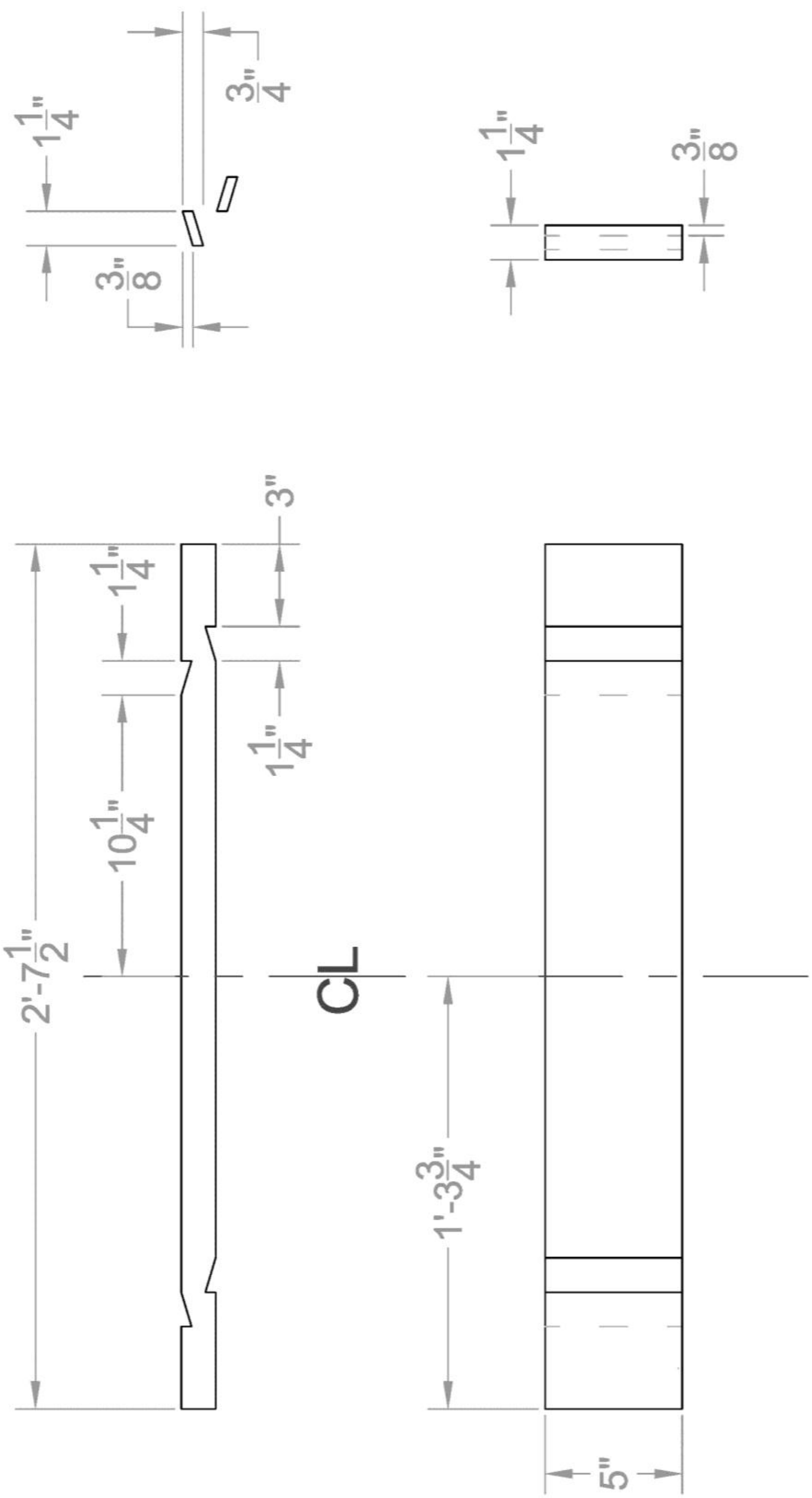

5/8"
CL
3 1/8"
3/4"
3 1/8"
3/4"
7"
2'
4 1/4"
7"



2 3/4"
5"/8
4"
4'
CL
1'-8"
7"
1 3/4"
1 1/2"
1 1/4"
3 3/4"
7"/8
1'-8"
5"/8
5"/8
9"/16
4"
5"/8
7"
7"

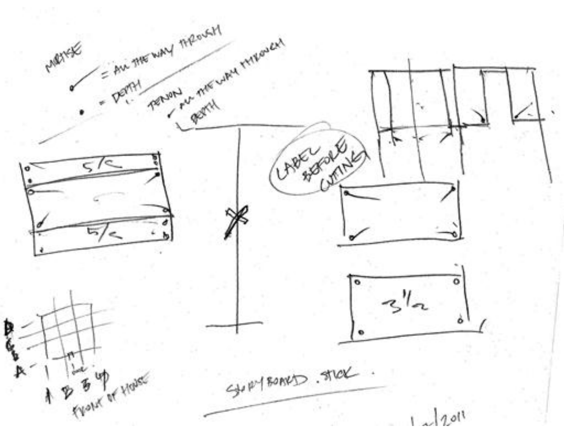

5/8"
3/8"
CL
7"
1 1/2"
1'-10 1/2"
5/8"
5/8"
CL
5/8"
5"
1 1/2"
1/2"
6 3/4"
1 1/4"
1 1/4"
3"


2'
1'
7"
7"
CL
CL
5/16"
2"
2"
5/8"
5/8"
5/8"
4 1/4"
10
4


1 1/4"
3/4"
3/8"
1 1/4"
3/8"
3"
1 1/4"
1 1/4"
10 1/4"
2'-7 1/2"
CL
1'-3 3/4"
5"

opening between columns, only the *inaka-ma* system with center-to-center measure is discussed here. When drawing out a layout grid for a Japanese house, always have the front door facing the edge of the paper closest to the reader. Along the X-axis you mark numbers at the center line of each post. You will do the same for the Y-axis. However, along the Y-axis you will use letters instead of numbers. This grid is very important! The grid will serve as a blueprint to labeling and organizing each joint and structural member of the house during fabrication. This labeling system also ensures organization during storage, transportation, and on-site assembly.

There exists a marking guideline for the layout cut depths of tenon and mortises. Mortise: marking dots at each corner plus numbers at the center = depth of mortise; dots at each corner with lines extending from each dot and toward the center = cuts that travel all the way through the wood. Tenon: dots at the corner with a line extending outwards = cuts all the way through. Line extensions from the width of the mortise with diagonal lines extending inwards and number at the center line = width of tenon.



When sawing it is imperative that the initial cut is accurately made. That initial cut will serve as a guide to the line of travel the saw will take for the rest of the sawing process. If not done properly, the saw will eventually run out of course. Once the saw begins to shift directions, it is very difficult to realign the saw to its correct and intended path of travel. Grooving shallow saw lines along the reference cut line helps to guide the blade in the right cutting path. First begin by holding the saw at an angle on the far edge of the surface plane facing up, and begin a shallow cut. Use your thumb along the side of the blade to guide the initial cut until the saw begins to cut smoothly through the wood. After, shift the angle of the blade downwards and along the reference cutting line and cut the wood to the opposite edge of the beam. Rotate the beam on its axis 90 degrees away from you and repeat the process until the beam has been cut all the way through. Hold the end piece so that the wood does not chip in the final moments of the saw cutting through the wood.

When using a saw to crosscut for a tenon it is very important not to cut beyond the depth line of the tenon. If that happens, when chiseling, you will run the risk of wood chipping beyond the desired depth. Wood will tend to split first in the direction of the grain, and second to any fault line that may exist in the wood. By sawing the tenon beyond the desired depth you unwantedly create a fault line. And so, because the fault line extends beyond the desired depth, when chipping with a chisel, the wood may chip and terminate at the fault line depending on how the grain of the wood is responding. It is therefore important to pay attention to the initial ripping pattern of any piece of wood when chiseling. Every time you work with a new piece of lumber, or just a different side, be sure to examine its grain pattern. Grain direction can provide foresight as to how the wood will rip under pressure.

After chiseling the wood into a tenon, clean its surfaces by pearing any excess wood with a chisel. Pearing is a technique used to shave off fine flakes of wood. When pearing wood, push the chisel forward and diagonally all at the same time. By doing so you are pushing the chisel into the wood while also slicing the wood diagonally with the edge of the blade, flaking off very fine and clean shavings without chipping at the wood. In a sense you are planing the wood with a chisel instead of a plane. Along the process, constantly check for the square-ness of each side with a sashigane square to ensure accuracy. You may also use a plane to level off any excess wood, but a chisel will work just as good when the technique is mastered.

A western square can be used to lay out perpendicular lines across the beam. The western square is the ideal tool for the job, offering great accuracy. However, when working within the Japanese tradition, use a sashigane instead of the western square. You can get the same results with a sashigane as you would with a western square. Although, using the sashigane as a squaring tool requires a little more technical practice and hand dexterity, since the sashigane is more pliable than the western square, and, therefore, poses a greater challenge to master its use. Also, when working from job site to job site, limiting your tool box to only a set number of tools will facilitate transportation and work efficiency on the job site. A good woodworker will be able to do multiple types of jobs with only a limited number of tools. The sashigane can be used as a square, ruler, and slope finder. The western square can only be used as a square.

To use the sashigane as a square hold the sashigane at the 12 inch mark. Hold the long side of the sashigane as close to the edge of the surface you are using as a squaring reference plane, making sure that the edge of the sashigane lies flatly against the plane and as close to the edge as possible. Then draw your perpendicular line along the other edge of the sashigane.

When laying out proper widths and depths of any joint it is important to consider the types of chisels being used. Japanese chisels have a standardized set of widths that correspond to the width standards of the most common dimensions used for mortises and tenons in timber construction. This correlation between tool size and cut size help facilitate the cutting of each piece, effectively speeding up the efficiency of the work. Also, the width of a sashigane measures out to be 5/8”. In traditional Japanese timber framing the most common width of a tenon and mortise is 1-1/4.”

When drawing out the width of a 1-1/4" tenon or mortise from the center line, simply place one edge of the sashigane on the center line and draw a line using the other edge. Do it for both sides and you will get a 1-1/4" dimension for a tenon or mortise that lies on center to the center line. It is much quicker than having to measure 5/8" over twice to one side to draw a parallel line that measures 5/8" from the center line.

When chiseling a mortise it is important to maintain good posture to ensure proper technique. If you are right handed, hold the chisel with your left hand and the chisel hammer with your right hand. Stay seated in an upright position with both legs to the right of the beam. Choke up on the hammer handle, rather than holding it as if you were striking a nail. When chiseling, your hammer strike is more of a dead blow than a swing. Lightly mark, or rather score the wood with the chisel along the edges of the mortise's layout lines. This will ensure that the wood does not chip beyond the layout lines when first striking the wood. After that you want to begin chiseling the depth of the mortise. Here, begin 1/8" to 1/16" from the layout line and work the chisel down perpendicularly. This is because, when chiseling, the chisel will tend to dig into the wood and shift directions in the direction of the angle of the blade of the chisel. By setting your chisel slightly away from the edge you ensure that the chisel does not shift too far beyond the layout lines of the mortise. If you undercut wood, you can always cut some more. If you over cut wood, it becomes very difficult, impractical, and sometimes impossible to add to the wood. Once you've marked a depth, work the chisel along the length of the mortise moving away from you and at an angle. Make sure that your body posture is correct and that the chisel and hammer are always aligned to a center, such as the center line of the beam plane. You can later check for the depth of the mortise by using the sashigane rule. You can also check for the square-ness of the mortise by laying the long edge of the sashigane along the plane of the beam and lining up the other edge of the sashigane to the mortise's edge. Look down along the vertical edge of the sashigane and make sure that the surface of the wall of the mortise is evenly aligned on a plane to the edge of the sashigane. Another interesting thing about the sashigane is that, at its tips, the marked dimensions end a 1/4" prior to the tip of the sashigane. This is purposely done for mortising. Mortises are usually 1/4" inch deeper than the length of a tenon to allow for the expansion of the wood. When measuring the depth of a mortise with a sashigane, simply measure it to the depth desired in reference to the numbering system on the sashigane and it will automatically take into account the extra 1/4" needed for the gap between the end of the tenon and the depth of the mortise.

There are three ways in which a person can go about cutting wood. You can undercut, overcut, or cut right on the line. Cutting right on the line takes tremendous skill and years of practice. Most people either tend to overcut or undercut. When carpenters collaborate on a project with each other it is important that carpenters communicate well and observe each other's tendencies in their preferred, or style of work. Communication is the key to working together. If someone is undercutting a tenon, then the mortise must be overcut so that the dimensional discrepancy is corrected. Before starting on a project it is important to communicate with one another whether someone will be undercutting or overcutting a joint. Off course, cutting right on the line is ideal, but that rarely ever happens.

When cutting a mortise, or any cut that pierces through the wood and out the other side, it is important to chisel the wood half way from one side, and begin the same process on the opposite side. If you drive the chisel from one side and all the way through to the other side, what ends up happening is that once you reach the other side, the wood will completely split and break off. To prevent this from happening you can do what was mentioned before – to cut the hole halfway in and begin the same process on the other side, or you can place a piece of wood on the underside of the wood being cut. This sometimes prevents the wood from splitting. The wood underneath the beam acts as a continuation of the wood, temporarily extending the depth of the beam. This method works, but is not great.

Never place any wood on the ground. In the Japanese carpentry tradition there is a level of respect that should be given to wood. This idea stems from Zen Buddhism belief and value of human's close affinity to nature and life. Also, when you place wood on the ground debris can become imbedded in the wood, often times scratching the wood, making it tough to remove and leaving unwanted surface marks. Rocks and other hard types of debris stuck to the wood can also damage tools.

Ripping wood with a crosscut saw is not a very good idea. There is a reason as to why crosscut and rip saw blades are made differently. If using a rip saw to crosscut and vice versa, the saw will feel dull and it will often scar and damage the wood, leaving an unpleasant surface.

In some cases you will find that when cutting mortises, a chisel will often crush the surface walls of a mortise where the chisel is driven down perpendicular to the grain. This will often occur when working with soft wood. A person may not initially foresee this, but when chiseling soft wood often times chisels need to be sharper than chisels used to chisel hard wood. This is because the grain density of soft wood is not as tight as the grain density of hard wood. Pressure of a dull chisel on soft wood will crush the wood before cutting through it straight and clean. To prevent this from happening you can do a number of different things. First you can wet the wood using a brush and water. For some reason the water is absorbed into the wood and acts as a binding agent between the grains. Another thing you can do is to keep a small bamboo cup stuffed with cloth and saturated with camellia oil to dip your chisel into it prior to every time you drive the chisel into the wood. Camillia oil will act as a lubricant between the chisel and the wood, which also prevents the wood from breaking and crushing. Camillia oil is also applied to the metals of wood working tools to keep them from rusting. This was often done at the end of every work day by traditional Japanese carpenters as part of the maintenance of tools.


CAMELLIA OIL

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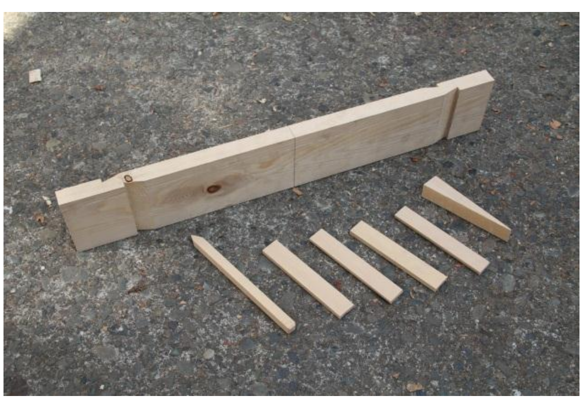
There is always some fitting and cleaning that is required to be done to each joint. The fitting of each piece should not be too loose or too tight. It should fit snuggly to one another to the point where a large hammer can be used with light force to fix them in place. Never strike the hammer directly on the wood. You should find a woodblock, place it over the striking zone, and with the hammer strike the wood block and not the finished piece. It is also smart to get a woodblock that covers a large surface area, since a small block will also mark the wood if struck, especially if the block of wood is of a harder quality than the finished piece of lumber.

Always check that the interior walls of a mortise are level using the sashigane. For mortises that do not penetrate all the way through you can use the edge of the sashigane by placing its long length on the surface of the beam, and by sighting down the other edge of the sashigane against the wall of the mortise to see if you have under or over cut. For mortises that penetrate all the way through begin by checking the level and square-ness of each wall as mentioned above. After that slide the long edge of the sashigane through the hole and place it against the wall to check for any high spots.

The most important detail to cutting a mortise is to try to get the walls as perfectly square as one can to the edges of the mortise. However, that is often difficult, so the most important thing is to make sure that, at the very least, the outter edges of the mortise are clean and to size acurately. There can be slight interior discrepancies inside the mortise, but even so, they must be kept at a minimum. When chiseling mortises you do not have to worry too much about its appearance, meaning whether or not there are chisel marks on the walls or at the very bottom of the mortise hole. However, trying to get them clean is a challenge, and so it is suggested to trying to make them as clean as possible. It is good for practice and in the Japanese carpentry tradition, repretition is the key to improving a skill.

It is very important to be able to, or to work your skills to a level where each cut can be made precise to fit from the start. The joinery pieces used in this project are to scale at the joints but not in their actual length, making them easy to move around, pick up, and do dry fits. In reality, each joinery piece would be much larger in size and heavier, making it virtually impossible to regularly dry fit each piece at a job site.

Since the beam is 7” wide, the length of the pin was cut to 10”. At one end of the pin the edges were slightly chamfered. The other end was made to a point so that it could easily be driven through the hole. To make the sharp edge simply place the blade of a chisel at about 1” to 1 1/2” from the end of the chisel and strike the end of the pin down on a wooden surface while holding the chisel to the wood, driving the chisel down with the wood until it cuts through the wood on an angle. When done to all four sides, you will get a nice clean point. The extra length can be cut and cleaned once the pin is set in place. Pins and wedges should be made from a harder wood than the joining members.

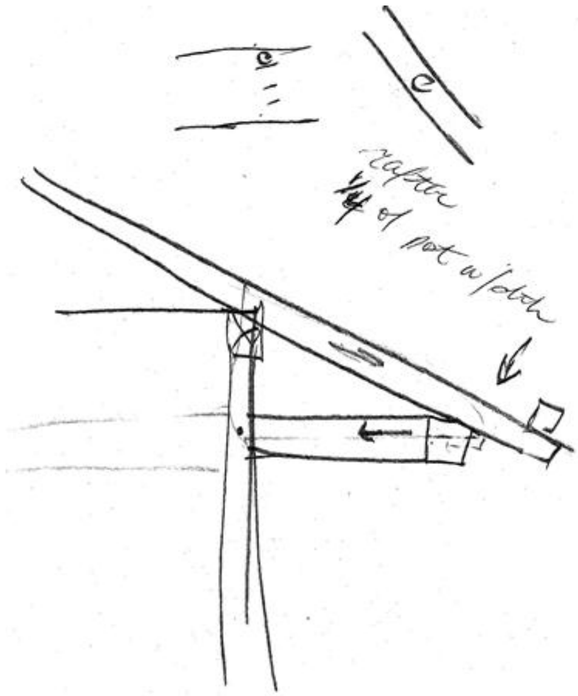


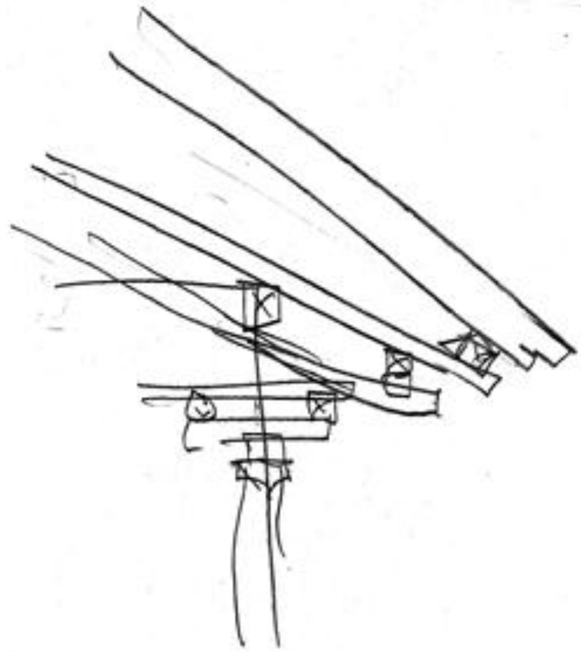


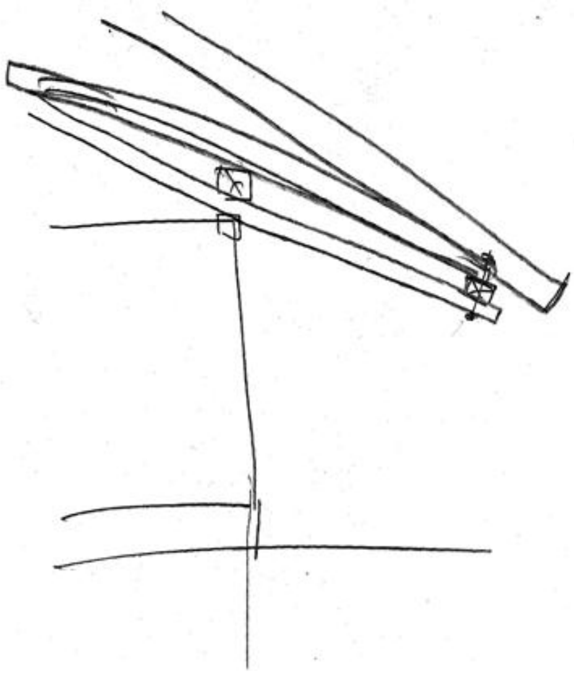




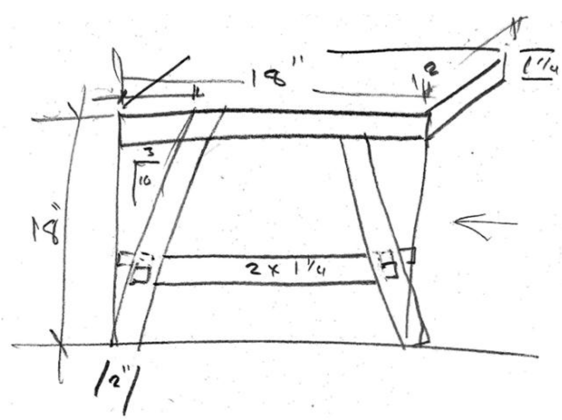

PROJECT 3 – Battered Stool



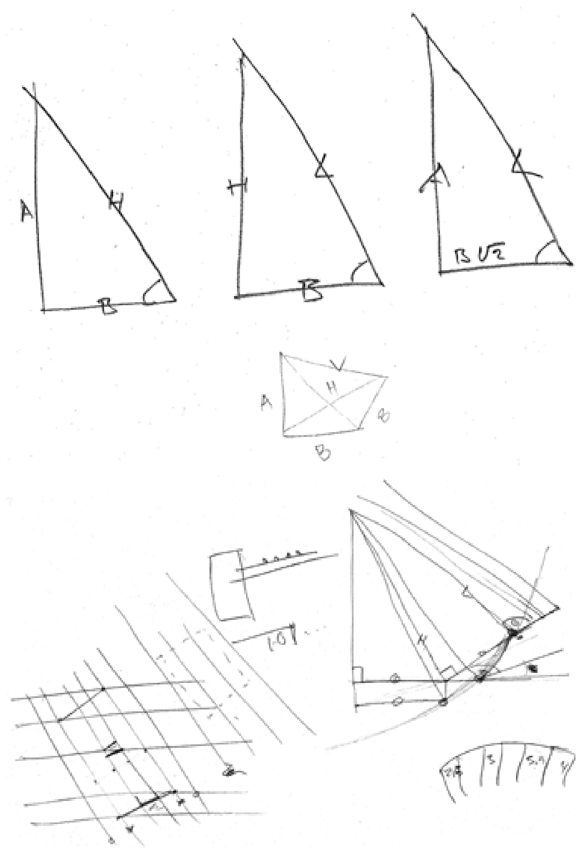


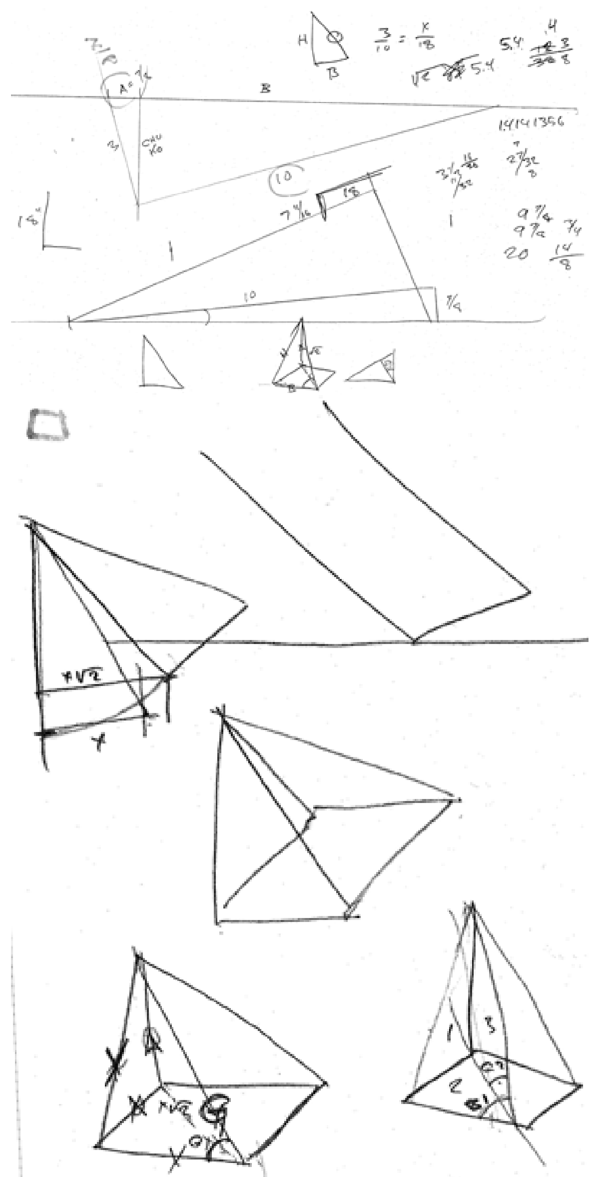


During the Professional Studio, a conversation about Japanese roof structures led into the development of the battered stool project. The construction layout and calculations used to make the battered stool follows a similar principle when calculating and designing the hip joints of a Japanese roof. The battered stool project is given to temple carpentry apprentices in Japan as an exam. The stool must be drawn, laid out, and constructed in 8 hours for you to pass the exam. Failure to do so prevents the student from moving ahead in carpentry school.

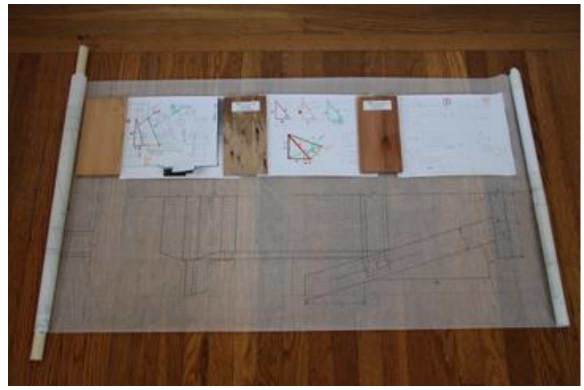


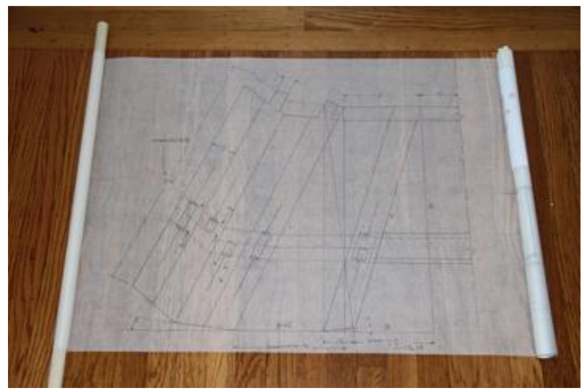
The battered stool looks simple but it is a geometric mindbender. Most of the presently available books that offer insight into the construction of the battered stool are written in Japanese, making it even more difficult to understand when one cannot read Japanese. The construction of the battered stool is a geometric puzzle based on compound angles that are all founded on the using of the Sashigane square and its kaku-me, square root of 2 formula, and the Pythagorean Theorem geometric formula.

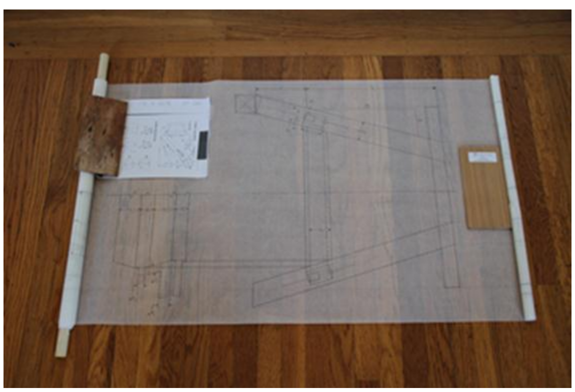


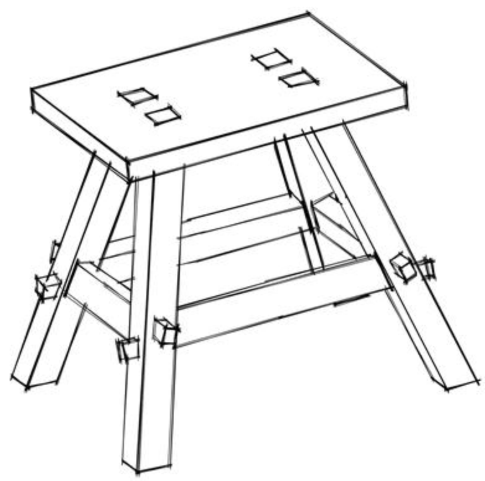


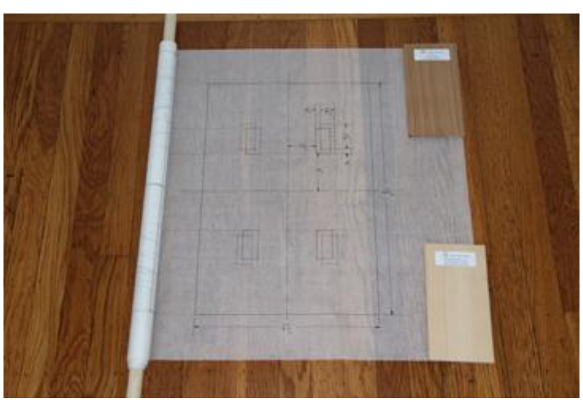
The use of comtemporary computer drafting software and 3D modeling helped guide and speed up the learning process for the construction of the battered stool. Traditionally it would require months of training to prepare to take on such an advanced design and construction project. However, computer aided design facilitated the design and layout process by minimizing the margin of error that can occur during the design and layout phase of this construction project. Drawings provided by Japanese books were redrawn using 2D drafting software. In this drafting medium the angles and dimensions that make up the batered stool were worked with and refined. Later they were inputed and virtually pieced together in a 3D computer modeling software. Discrepencies in the 3D model gave evidence to discrepencies in the dimensions and angles in the 2D computer drawings. By going back and forth between source drawings, 2D reproduction drawings, and 3D modeling, the construction and layout drawings of the battered stool were accurately produced and made ready for the physical fabrication of the battered stool. Without this process, the battered stool project would not have been accomplished in the amount of time available (1 month). Review of the process gives evidence to the benefits of integrating traditional Japanese timber frame construction methodology with contemporary computer aided design technology in an effort to facilitate this type of timber framing today.

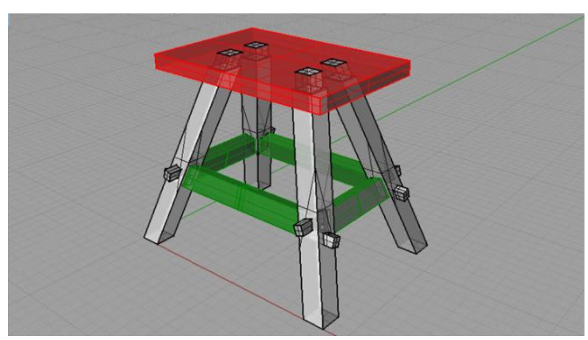


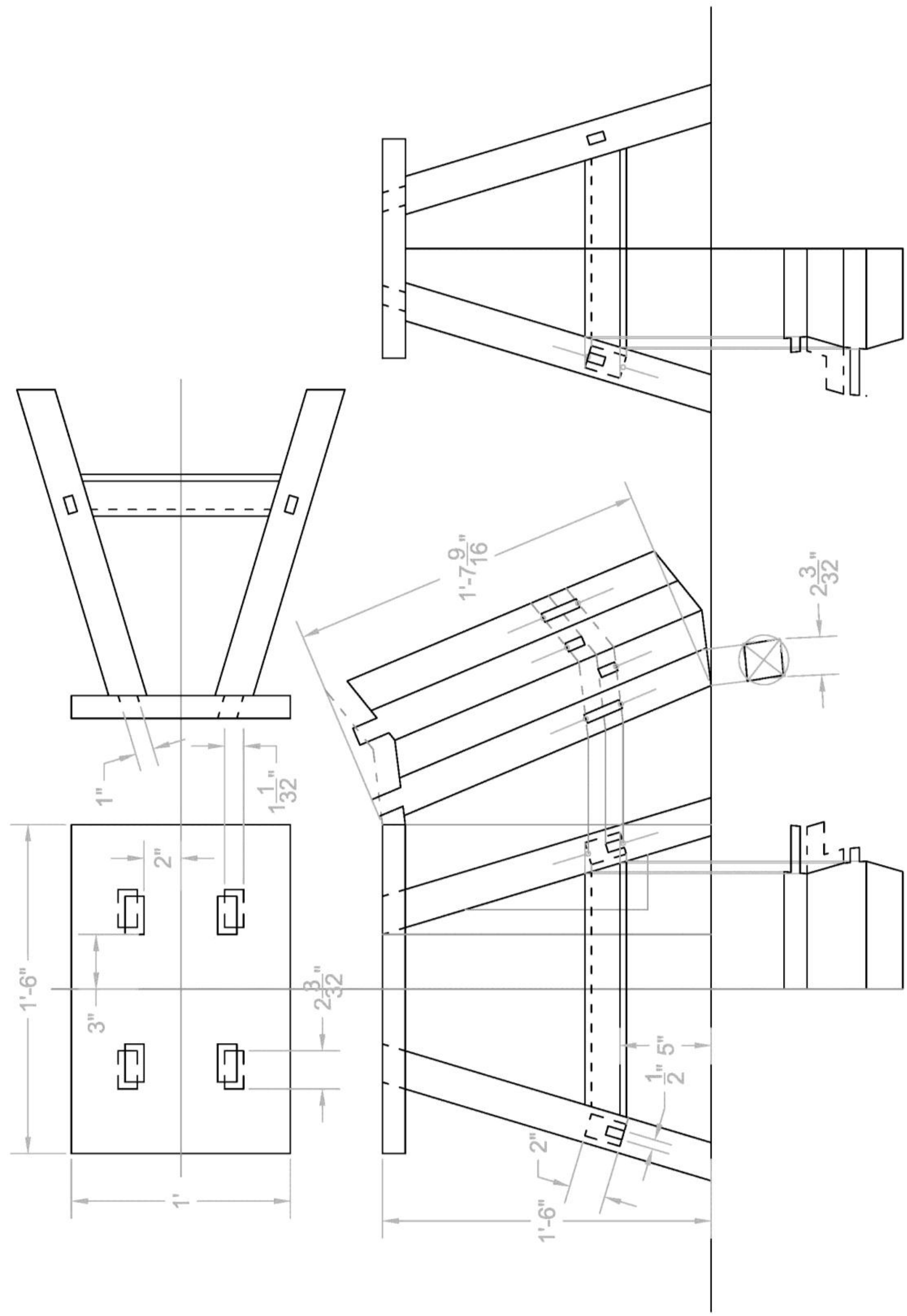




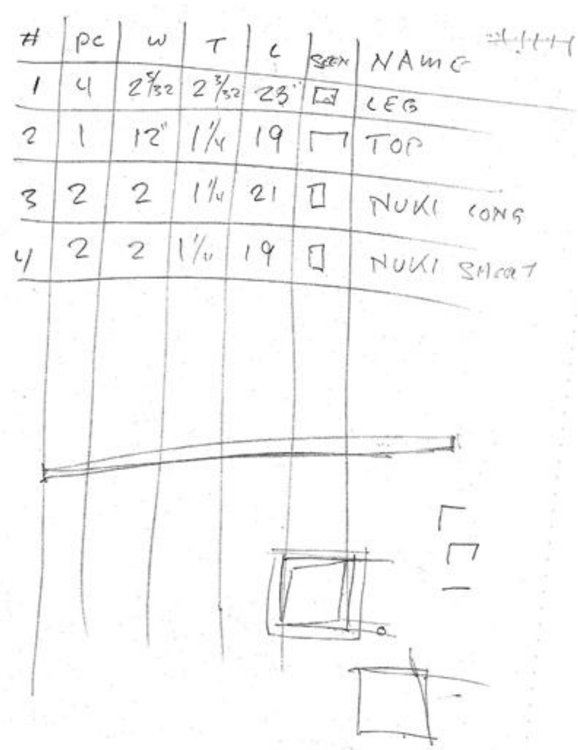







1'-7 9/16"
2 3/32"
1"
1 1/32"
2"
1'-6"
3"
2 3/32"
5"
1/2"
2"
1'-6"
1'

The first step prior to the layout and construction of any wood based project is to create a materials list. In a traditional Japanese materials list, the the first column marks the item number. This number usually refers to the position of a structural piece as it is related to the grid of a house in reference to the front door, as was I explained earlier on. For this furniture project, the use of simple numbers, such as 1, 2, 3, 4, etc…, was sifficient given the project's small material need. The second column marks the number of pieces needed for each structural piece. The third column marks the width, the fourth marks the thickness, and the fifth marks the length. The sixth column marks the "scene". The scene refers to the number of sides that the lumber will be seen by a person once the piece is set in place. A square denotes that all four sides of the lumber are visible; a single line shows one visible side; and so on and so forth. The last column marks the name of each piece.



For structural pieces of a house, the list begins with the listing of vertical members, followed by the horizontal members. Other materials are listed according to size, from large to small.

The materials list gives you a sense of the amount of dimensional lumber that will be needed for the project. This list can help estimation of material need and cost for a design project, eliminating material waste from over-purchasng and lumbering.

Cypress is not the best wood for furniture making. However, cypress was used for this project since it was available in abundance for use in the study exercise. Although easily manupulated due to its soft materiality, cypress has a tendency to move a lot under different climate conditions, meaning it tends to warp, bow, and twist, making it not such a suitable material for furniture making. Also, most quality furniture is generally built from hard woods rather than soft. This is because furniture is put through a lot of stress in its lifetime. Hard woods are more resilient to the wear and tear that furniture must endure on a day to day basis. Soft woods will chip and ding easier that hard wood.

At first, the cypress pile picked out for the project looked more like trash than workable wood. Although the lumber looked weathered and rotted from the outside, once the surface of the wood was planed down to about 1/8", the hidden lumber showed itself to be of usable quality and aesthelically pleasing. This is often the case with reclaimed wood.

Traditionally, one side of the story pole is marked with the vertical lengths, while the other side is marked with horizontal lengths. The dimensional width is usually not marked.   Below is an example of the story poles used for this project.

As mentioned before, the chipper plane is a new woodworking invention in Japanese hand tools. It was adapted because of the decreasing quality of wood. Good lumber is hard to find these days. The grain from wood today is less dense, and there are more imperfections found on its surface causing wood to chip and rip when planing. The chipper plane prevents that by rolling the shaving and breaking it off before it gets too large and before the primary blade begins to dip deeper into the wood.

The chipper blade also had to be conditioned and properly fitted into the body of the plane To fit the chipper blade into the body of the plane merely shaved off the sides of the plane body where the chipper blade rests on. One only has to shave off enough wood from the body of the plane to allow space for adjustment of the chipper plane from side to side once set into the body.

Once the primary blade and the chipper blade are set into the body use a Kanasuchi hammer (a smaller hammer, than the standard Genno chisel hammer, with a dull pointed and tapered end) and tap the chipper blade into its position. The flat surface of the chipper blade should lie flush to the flat surface of the primary blade. The cutting edge of the chipper blade should lay a half a hair back from the edge of the main blade.

At some point during this project the tip of the blade of the scraper plane broke off. This meant that the blade had to be reconditioned, reshaped, and resharpened. This required a great expenditure of time. If a blade's edge breaks off it requires major re-conditioning to get it to a working condition again. Traditionally, you would use a process called *tapping out*.   When tapping out you place the blade's flat side on an anvil, and with a hammer you would carefully tap the top soft metal of the blade. Tapping on the soft metal of the blade pushes and bends the hard metal down to a flat state. Then you would polish and sharpen for hours until the blade is re-conditioned for use. This process is difficult and requires lots of skill and training in metal work.

An easier way to go about re-conditioning a broken blade is by first grinding the edge of the blade past the break to a straight and flat surface. During the process the blade will heat from the friction between it and the grinder. Make sure to dip it in water to cool the metal, and do not apply hard pressure on the blade against the grinder. Grind the broken edge to about 1/32" thick. After this, you must grind out the flat surface of the blade to create the concave on the flat surface side. This can be done with a grinder or a Dremel electric grinder. The Dremel will work best.   After all of these steps have been followed, you can polish and sharpen the blade to a workable edge and begin planing again.

Although the stool looks simple to construct it is actually more difficult to build than the joinery medley. This is because the stool is battered, meaning that the legs are angled inwards in more than just one angle, creating compound angles in multiple joint connections. Also, because the legs are angled inwards from two different directions, the shape of the base of the leg, and along its vertical dimension, must be changed from a perfect square into a parallelogram. This must be done to accommodate the appropriate fitting of horizontal braces across the leg. If the legs were not changed from a perfect square into a parallelogram, then the joints of the horizontal members would also have to be cut at compound angles, making the horizontal braces much more difficult to construct and figure out its proper layout. By changing the shape of the leg into a parallelogram, you eliminate the compound angle at the joint where the leg meets the horizontal bracing. In doing so, you are left with just one angle to worry about when cutting.

To create the parallelogram first lay out the shape on both ends of the leg from the center out and used a hand plane to plane each leg into its appropriate form.

Cutting each leg to its appropriate length by eye requires a level of precision and skill which is only acquired through practice and repetition. The fact the the legs must be cut at compound angles adds difficulty to the task. In Japanese carpentry, as with any other business, time is money. There are many tricks that the Japanese have developed over time to speed up the process of cutting wood and facilitating other woodworking processes to save time and money. In this case, to facilitate the cutting process, one should cut a jig with the angle desired to serve as a guide to cut all the legs to exactness. You can cheat and cut the jig using a compound miter saw or by taking your chances and trying to cut a jig by hand to the correct angle. To use the jig as a guide simply clamp the jig on the wood and cut the wood with a ryoba saw while laying the flat part of the blade onto the jigs surface and begin cutting.

Now this method worked perfectly for angles less than 90 degrees but not for angles greater than 90 degrees. This is due to the natural force of gravity. In angles less than 90 degrees the side of the blade rests true to the surface of the jig. In angles greater than 90 degrees, the blade tends to run away from the jig’s flat surface even if you try to maintain the blade of the saw on the surface of the jig. And so, when cutting angles greater than 90 degrees, opt to cutting each piece without the use of the jig. This process is more difficult and takes a longer time longer, but the results are better

After cutting the legs to size, begin to cut the tenons of the legs.

Chiseling is much easier and precise when you use the force of your entire body onto the chisel, instead of just using arm strength. For some reason it is much easier to control your entire body pressure onto the chisel than simply relying on your arm strength. There are three different basic types of chisels that a person can choose from – bench chisels, timber framing chisels, and heavy timber framing chisels.

Bench chisels are usually used for smaller, more refined work, such as for making jewelry boxes and other smaller projects. Timber framing chisel are used for heavier wood work as the name denotes. Both bench and timber framing chisels have a ring at the butt end of the wooden handle where you can strike with a Japanese metal hammer. The third type of chisel, the heavy timber framing chisels, has an extended wooden handle that does not come outfitted with a metal ring. This type of chisel is designed specifically so that you use the chisel by applying body pressure onto the wooden handle to drive the chisel into the wood. They are much larger than standard bench and timber framing chisels and do not rely on the use of a hammer to drive the chisel onto the wood. Most carpenters in Japan do not own heavy timber chisels. Instead they use timber framing chisels in the same way that a heavy timber chisels would be used. In Japan the more you can do with a limited set of tools, the better you are considered at what you do.

Cutting the mortises in each of the legs where the tenons of each horizontal brace slips into is a challenge. This part is difficult because not only do you have to cut each tenon on a 16 degree angle to account for the battered angle of the legs, but you also have to account for the parallelogram shape of each leg with a 5 degree angle change from 90 degrees. Again, a jig to guide my chisel into the wood at the appropriate angle will facilitate the process. As mentioned before, it is best to make the walls of the mortise as level as possible to ensure proper fitting of the tenon pieces. However, what is most important it the have the outside edges of each mortise cut as close to perfect as possible. The inside can be slightly concave or rough since you will never again see the interior of the mortise once everything is fitted together. Having the interior convex or slightly bumped out will make it difficult to fit the tenons during assembly. While cutting mortises and tenons it is important to constantly check the accurate sizing of each cut. One can either rough-cut every piece all at once and later check for cut accuracy, or check as you go along. The cuts will almost never fit properly, and so, every single piece must be checked and double checked before assembly.

The stool top mortises penetrate all the way through the wood. In consideration of this one must be cautious not to rip the wood from the other side when cutting the mortises. As mentioned before, it is best to cut the mortise half way through and redo the process from the other side. When cleaning each mortise, it is best to move carefully and pear the wood gently with the chisel. This stool top was made from cypress and this type of wood is very soft and tends to rip easily when chiseling with the grain. Make sure to sharpen your chisel regularly.

Prior to laying out, cutting, and fitting each piece, make sure to mark each side and each corresponding piece to their proper location. For this project, corresponding pieces were marked and matched with a star, a circle, a square, and triangle respectively. This marking system helps to maintain together each corresponding mortise and tenon. If they are not maintained togetther then you run the risk of losing track of which piece belongs to which side and you will end up messing up the entire project. Needless to say that is why marking each piece in Japanese timber framing is so important.

Assembly of the stool is not an easy task. The construction of the stool is made in such a way that it is a one-time assembly procedure. Once you fit the pieces together, it is very difficult to take them apart.

For instance, the tenons of each horizontal brace not only overlap one another but they also slightly intersect by fractions of an inch. When fitting them they will actually hit one another. The weaker one will give way to the stronger tenon. Once installed, they are fixed and locked together as a key and cannot be removed without damage to one of the pieces. Also, the battered aspect of the stool makes assembly much more difficult in that all of its pieces must be assembled together in one shot because of the angles that all components come together at.

Once the stool is assembled, use a saw to cut off the extended tenon pieces. The best way to prevent saw marks is to lay a flat piece of cardboard over the leg surface and prior to sawing. When sawing, the blade will rest along the surface of the cardboard which will prevent saw marks on the actual wood. This process will leave a little extension of the tenon which can later be planed off.






When fixing surface imperfections such as chips and cracks there are a number of ways to go about the procedure. One is to simply use wood putty, which can be bought at any woodshop. The second is to apply a light layer of glue over any crack. Let the wood dry slightly, but not entirely, and use sand paper to sand over the area where the glue was applied. When sanding, the saw dust will mix in with the glue creating a homemade type of putty (Note: this method is not at all useful in large gaps or cracks, as was learned from experience.) Another way to fix a crack or gap it to cut the area with a chisel and making a fitting of the same shape and wood type to later be place into the chiseled area. Cut or plane the remainder of the extended fitting. This last method is by far the best since the end result is much more aesthetically pleasing. Also, if oiling, lacquering, or staining the wood, the first two methods, of wood putty or glue and sanding, will not take the oil, lacquer, or stain the same way as the rest of the wood will. The last method will and it will ensure the best looking result. If you want to get serious about blending the fitting with the wood choose the same lumber with the same grain pattern and thickness that will blend with the surrounding wood.

PROJECT 4 – Keta and Hip Rafter Detail

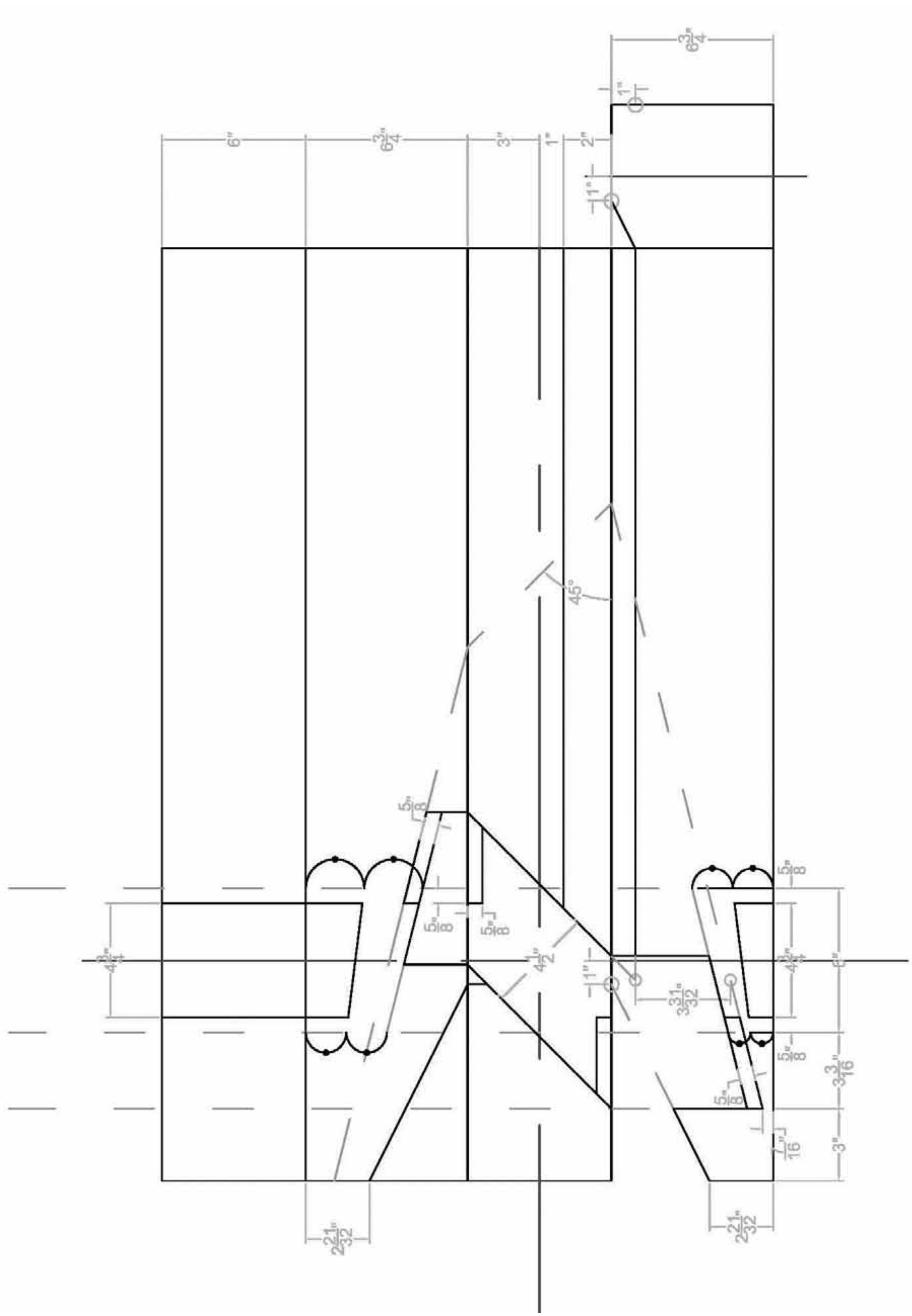
The decision to build the keta and hip rafter detail stemmed from the completion of the battered stool project. Since the whole point to build the battered stool was to learn how to find hip rafter angles, it only made sense to apply the knowledge learned and actually make the physical detail of the corner joint. The detail is composed of two corner rafter beams that come together and overlap at a 90 degree angle, and where the hip of a roof rests on at a 45 from the two and at a slope. Below is an image of Joinery Structure's Rikyu Kit House, where the same detail can be found.

The start to this project followed the same steps as the start to the battered stool project – with 2D reproduction drawings and then with 3D modeling. The idea of "mizu," literally translated to "water" in English, is the measurement off the axial center of a rafter beam that designates all measurements of the rest of the structure of the Japanese house. For this project the standard measurement of the mizu was 1" off the vertical axial center of the rafter beam and 1" down and off the top of the beam. This measurement is critical to ensure a proper slope of the rafter beam and how it relates to the slope of the roof at the hip.

In first assembling the joints in Rhino 3D mistakes were found in the initial 2D construction drawings that were corrected prior to the actual physical fabrication of the joint.

For some reason, initial 3D construction showed that the slopes of each joint did not match. After some investigation the error was discovered. The error was that the construction drawings for each piece were not elevation drawings at all, which was what it was first assumed to be. They were in fact layout drawings, meaning that the side, top, and bottom views of each drawings look like elevation drawings but are actually not. They are in fact drawings as one would lay out on the surface of a beam. This makes complete sense since traditionally the Japanese lay the dimension of each joint on the surface of the beam. Traditionally the Japanese layout foldout surface drawings of each side of a joint and not how they would actually be viewed in an elevation drawing. In the Japanese way the slope is not presented on the surface drawings, while in our traditional drawings, that of elevations, the change in slope is clearly shown on the drawing. This means that any recess on a Japanese drawing is drawn from the surface and not as it would actually be seen in a 3 dimensional model. After figuring this out , the appropriate changes were made to the 3D model, making all the pieces fit together as they should have from the beginning.

Much like Japanese caligraphy, there is a progression of steps, or phases, in which the order of the joint must be cut and followed. Mistakes made in the cut order can lead to production errors that can affect the cutting procedure and proper fit of the entire joinery component. By cutting joints in the wrong order, sometimes you will cut away layout lines which are meant to be used later as reference lines to another cut. Luckily, some mistakes are rectified by redrawing other reference lines, but in doing so the process to cut the joint becomes longer. Also, when laying out cut marks on the joints it is important to layout and measure a minimal amount of lines as possible from the centerline. Too many lines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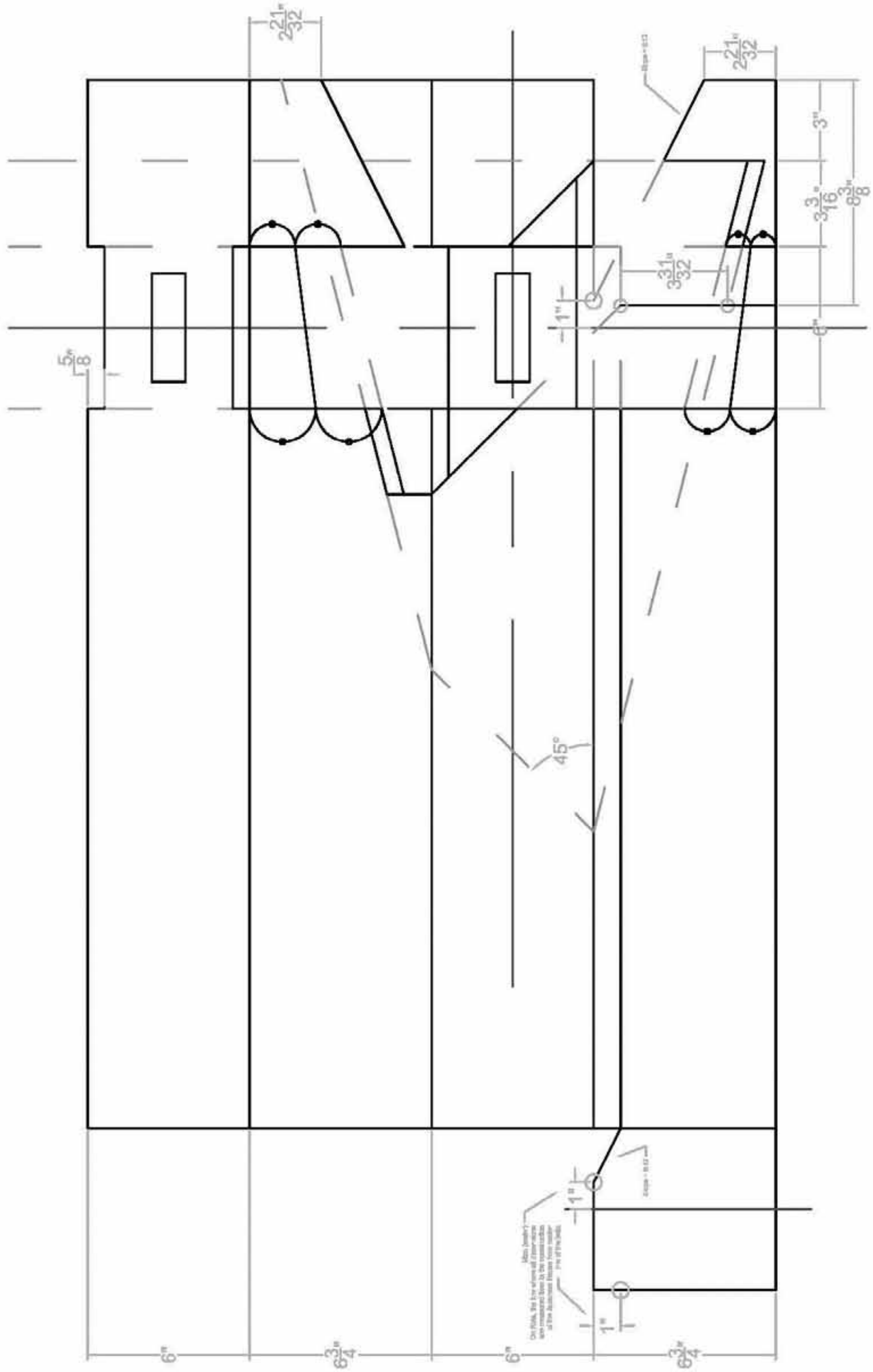
3"
1"
2"
1"
45°
5/8"
4 3/4"
4 1/2"
3 31/32"
6"
3 3/16"
3"
7/16"
2 21/32"


2 21/32"
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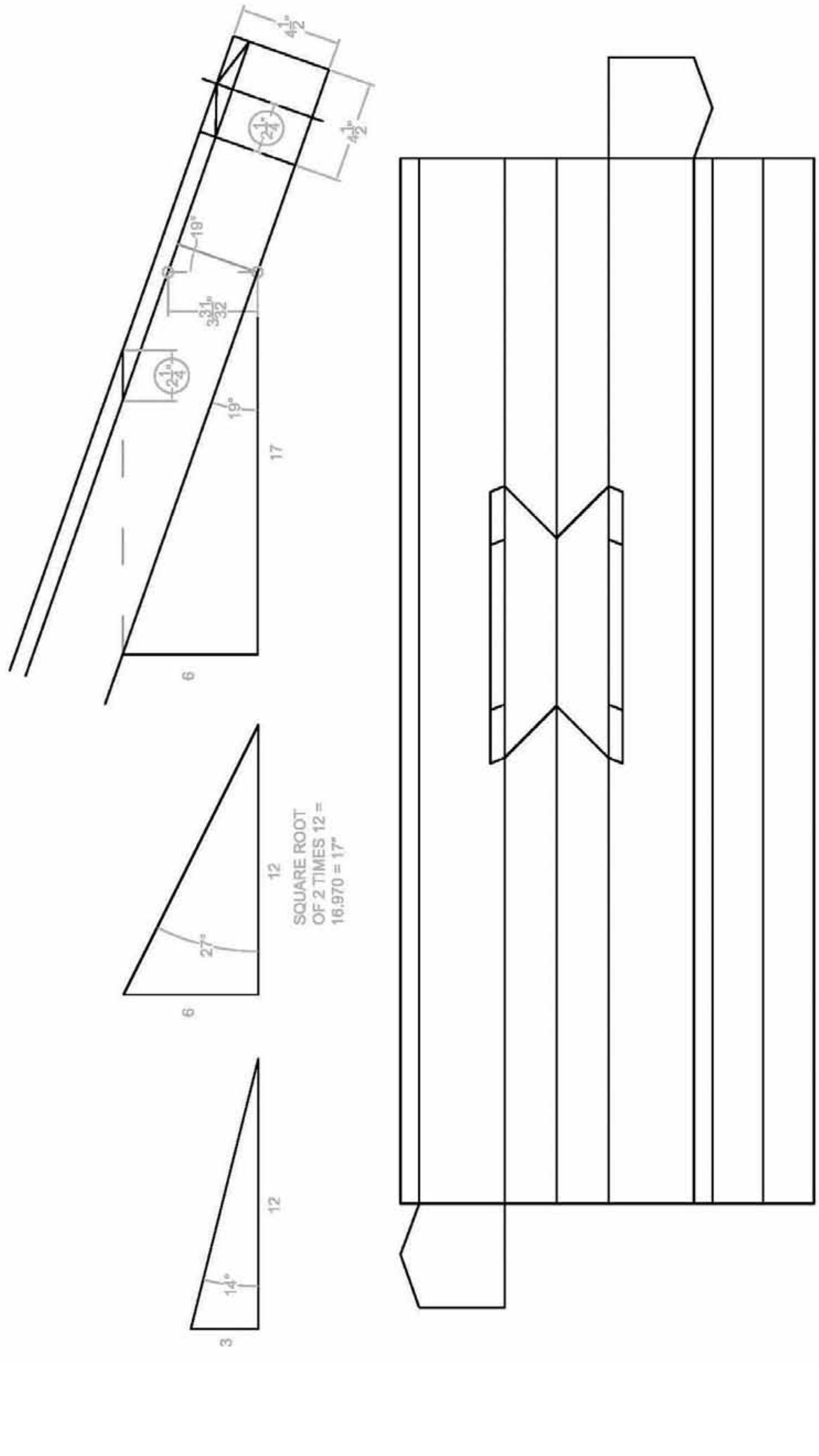
4 1/2"
2 1/4"
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17
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12
27°
6
SQUARE ROOT
OF 2 TIMES 12 =
16.970 = 17"
12
14°
3

can become a nusance and confuse you after a while. If layout lines are drawn with a graphite pencil make sure to erase lines that you no longer need. If laying out with a pen then you must take extra caution at every step of the way.

Getting accuracy of cut for compound angles is very difficult. This is because when cutting with a saw or chisel one must take into account the various angles that make up that one particular cut. To facilitate cutting it is better to consider one angle at a time and chip away at the wood carefully from one angle, and later cleaning the joint from the other angle. Constantly checking the level of the cut along the process with the sashigane square is the key to not making mistakes along the way.

PART 5 – ALTERNATIVE WOOD RESOURCES FOR SUSTAINABLE DESIGN

RECLAIMED WOOD

Alternative wood resources, such as reclaimed wood, have become more and more popularized as a material for sustainable building design and construction. Reclaimed wood is procured from salvaged lumber from deconstructed homes and other structures that have outlived their purpose. Deconstruction is an affordable and sustainable alternative to conventional demolition. In deconstruction, a building is taken apart piece by piece so as to preserve and salvage the materials used to build the house. Deconstruction can salvage up to 80 percent of building materials. These building materials can later be processed, and prepared for resale to be reused. Reclaimed lumber provides a new resource of wood materials available for construction that does not compromise our limited forest resources, since the wood acquired is not "virgin" (meaning timber freshly acquired trees) and therefore does not exploit existing natural resources. Once reclaimed wood is processed for reuse, it offers a store of high quality lumber that is aesthetically different that may be used for various applications in sustainable building design and construction.

As mentioned before, Hawaii lacks adequate natural forested resources for the procurement of fresh, virgin timber for construction. However, companies, such as Reuse Hawaii, are now starting a new local trend in architecture and design by providing alternative wood material resources for construction in offering deconstruction services and the sale of reclaimed wood.

Reuse Hawaii is a Local, Oahu based, non-profit organization that specializes on building deconstruction projects throughout the Island. Since opening in 2007, Reuse Hawaii has kept over 1000 tons of building demolition materials out of landfills, by salvaging reusable materials from deconstructed homes, and processing them for a new application as an alternative and green material resource for building construction and other purposes. Materials salvaged from deconstructed projects found at Reuse Hawaii are not limited to reclaimed wood, and include copper wiring, copper gutters, glass, interior fixtures, and appliances.

There are many benefits to using reclaimed wood. One of the benefits of using reclaimed wood is that the lumber salvaged from these types of deconstruction projects are often over 40 years of age. This type of reclaimed lumber is often considered to be of superior quality, since the trees milled back in the 60's for building construction were often of a better grade than the lumber milled today. Many of the interior studs found in these old homes are graded as CVG, or Clear Vertical Grain.

Another benefit of using reclaimed wood is that home owners that decide to deconstruct their homes, instead of demolition which create a large surplus of waste materials, are offered tax write offs for deconstructed salvaged materials that can be reused or recycled.

Deconstruction of homes is greener, more sustainable than the old method of demolition, because it requires a higher level of finesse, or methodical process, rather than brute force to break down a house, therefore lowering noise levels and creating less dust debris and settlement on deconstruction sites. According to Reuse Hawaii, “65-80% of the volume of the house may be recovered from deconstructed homes. This can lower demolition waste materials going to state landfills by over 75 percent.”[36] “Off all the waste material produced in Hawaii 35 percent is construction and demolition waste that is potentially recyclable.”[37]

The benefits of using reclaimed wood can be attested by looking at some of the deconstruction projects that have recently occurred in the Island of Oahu. One example is the deconstruction project which occurred in Punahou School. In the project “Punahou reclaimed maple gym flooring (tongue and groove, 20,000 square feet of flooring), and Douglas fir sub-flooring was acquired. Wood salvaged from the Punahou gym project represents nearly 113 trees and nearly 29,000 cubic feet of material diverted from a landfill.”[38]

Another project made from reclaimed wood, which was shown in James Cultler’s guest lecture at the University of Hawaii at Manoa, School of Architecture, on May April 4th 2011, is the residence of Bill Gates, the founder of Microsoft, that was primarily built of reclaimed Douglas fir wood salvaged from an old sawmill. The project is a good example of how successful sustainable initiatives can lead to real life architectural design achievements.

SALVAGED WOOD

Salvaged wood, as opposed to reclaimed wood, is lumber that is acquired from trees gathered from development sites. Here, it is important to make the distinction between lumber that is saved from a pre-existing development site, than from trees felled for the sole purpose of wood acquisition.

Salvaged lumber is usually of a better grade than reclaimed wood because it is derived from trees that either, grow in nature, or that come from second growth trees (trees that have been planted of replanted by humans and do not grow from nature). The lumber acquired from salvaged wood is of a better grade than lumber acquired from reclaimed wood, since salvaged wood is in essence virgin and therefore freshly cut from a tree. This fact means that salvaged wood can be lumbered into larger and more specific dimensions, to suit a particular need.

Joinery Structures, based out of Oakland, California, has been providing, since 1988, services in architectural and furniture design, as well as tree milling, that focuses on the use of salvaged wood as its primary material resource. Most of the lumber provided is salvaged from in and around the Bay area. Some of the salvaged lumber procured by the company includes second growth redwood, elm, d fir, black acacia, Monterey cypress and pine, walnut, poplar, burl redwood, camphor, sycamore, and cedar. Joinery Structures is a leading American design-build architectural firm that specializes in the design and construction of traditional Japanese style residential architecture and structural design. Since its founding, Joinery Structure has completed a multitude of timber frame projects. The list of projects includes the design and construction of various Zen Buddhist complexes around the world, small-scale local residential projects, and most notably, a large residential complex built for Larry Ellison, located in the Bay Area of Northern California, which was

[36] Reuse Hawaii – KHNL News Coverage, 2010
[37] Reuse Hawaii – KHON2 News Coverage, 2010
[38] Reuse Hawaii – KHON2 News Coverage, 2010

designed in the Old Japanese Feudal shinden zukuri style.

MANUFACTURED LUMBER

Manufactured lumber has been around and available for a long time. This type of lumber is artificially made from wood laminates using high tech glue composites. The list and types of manufactured lumber available for construction are large and vary greatly from one application to another. There are many benefits in the use of manufactured lumber. For one, manufactured lumber can provide alternative wood resources for construction that cannot be found in nature. Laminated woods can be customized and produced to specification increasing the design potential of any architectural project. Also, the process of laminating wood adds increased strength to wood. Typically, laminated wood will provide greater strength to any lumber dimension when compared to lumber milled from a single piece of the same wood and of equal dimension.

The down side to manufactured wood is that the manufacturing process requires a large expenditure of embodied energy in the production of such types of lumber. However, if more efficient, proper and sustainable measures are taken in the process of production, manufacture wood can reach a level of use and attention in the architectural realm that can greatly change the current sustainable design trend.

BAMBOO

Bamboo does not fall in the same category as wood, however it does poses some of the inherent structural strengths and material qualities that are found in wood. Bamboo is a fast-growing, highly renewable plant material that is often used in interior design. Presently, bamboo is mostly used as an alternative flooring material to wood, since it is cheaper and more sustainable. Traditionally, the Japanese have made and used bamboo nails to install flooring and roofing on their timber frame structures. The image below is an example of a bamboo nail which was used in the installment of *sawara* cypress shingles over the roof of a newly renovated shrine in Japan 1987. The image was provided by Magi Sarvimaki, an architecture professor at the University of Hawaii at Manoa.

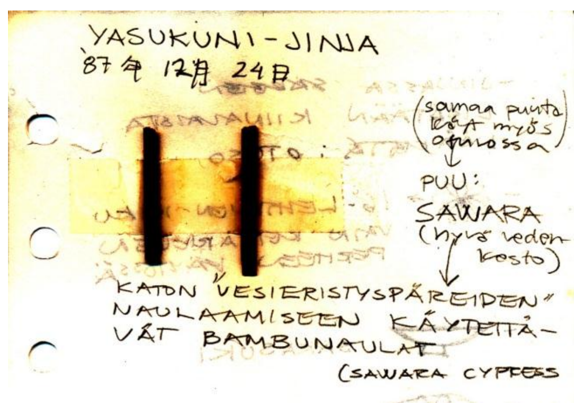


Figure 32: Bamboo nails
Source: Courtesy of Magi Sarvimaki

She described the following about the acquisition of the nail detail: *"The date I visited the Yasukuni Shrine was December 24, 1987 (Christmas Eve!), when the shrine was under renovation. One of the things going on was the new shingle roof, built of Sawara Cypress and nailed in place with these bamboo nails; the longer one is about 1 in. long. The carpenter very reluctantly gave me those (and I wouldn't have dared steeling anything from the site) but after some consultation with the deities decided* *that it was approved by them. One reason was that I had attended the purification ritual with my Japanese supervisor and was wearing the white coveralls like all the workers, too; according to my note on the other side, the workers have the purification ritual every morning at 8:30."*

The problem with bamboo is that, in its procurement and production, it does not provide a good source of large dimensional material resource for construction that offer a grade of material sufficient enough for heavy structural load bearing application. Its load bearing capacity is currently limited to its original physical state. Once that integrity is lost, or altered, bamboo loses much of its structural capability and integrity.

Although bamboo technology has yet to reach its potential, in the future it may in fact display itself to be a quality grade material that can be used for a growing number of architectural applications. Therefore, it would be of benefit to keep a close eye on the current state and future direction that bamboo may play in the realm of building design and construction.

PART 6 – DESIGN PROJECT: Ehukai Community Pavilion

DESIGN INTENT

The intent of the design project is to build a timber frame structure at the North Shore of Oahu that will not only serve the surrounding community as a whole, but will also reflect in its design the unique lifestyle and culture found in the area. The design will look at: (1) the methodology of traditional Japanese timber frame construction, and Japanese architectural design elements and construction solutions that complement the temperate, warm, and beautiful natural landscape of Oahu's North Shore (2) The subtle, simplistic, and unimposing design qualities of Hawaiian plantation houses, and (3) design consideration to locally available alternative wood resources for the construction of the small-scale timber frame structure.

HAWAIIAN PLANTATION HOUSES

The Hawaii plantation house is the local vernacular typology that exhibits the cumulative historical influence and heritage of the diverse local community of Hawaii. These simple residences display the diverse ethnic and multi-cultural past of the immigrants who migrated to Hawaii during the Plantation Era seeking work and opportunity, which began in the mid 1800's and extended up until the 1940'. The ethnic backgrounds of the people who used these houses range from all over the world, and include Hawaiian, Chinese, Portuguese, Puerto Rican, Japanese, Okinawan, Korean, and Filipino. Within each ethnic group there are visibly distinct variations in each of the ethnic group's Hawaiian plantation house types. The basic construction of these building structures, generally remain the same throughout. Most structures are light timber frame, single walled, and are elevated on posts.

The distinct differences in house design from one culture to another lies in the interior layout of the building, which was modified according to the cultural needs and preferences. However, variations in building form can be seen, in the structural composition of the roof framework, in the slight details of structural construction, and in the ornamentation of the building envelope.

Although not many original plantation houses exist today in their original form and furnishing, the Hawaii Plantation Village in Waipahu, Oahu, currently houses a multitude of renovated structure and replicas of Hawaii's plantation homes and a village, in their attempt to preserve a portion of Hawaii's plantation historical past. Hawaii Plantation Village is a physical manifestation of the architecture of Hawaii's Plantation Era.

Figure 33, 34, 35: Plantation Houses at Hawaii Plantation Village, Waipahu/36: Interior of a Plantation House at Hawaii Plantation Village, Waipahu
Source: Fig. 33: *Trivago.com*. http://www.trivago.co.uk/waipahu-62293/park--botanical-gardens/hawaii-s-plantation-village-164556/picture-i62312 (Accessed April 26th 2011)
Source: Fig. 34: *Discover-Oahu.com*. http://www.discover-oahu.com/hawaiis-plantation-village.html (accessed April 26th 2011)
Source: fig. 35: *To-Hawaii.com*. http://www.to-hawaii.com/oahu/museums/hawaiiplantationvillage.php (accessed April 26th 2011)
Source: Fig. 36: Flickr.com. http://www.flickr.com/photos/m3nidad/3736331676/in/photostream/ (accessed April 26th 2011)

In consideration of the research topic of this thesis, it is important to consider the architectural history of Hawaii, and to integrate or reinterpret this history in contemporary local architecture so as not to lose a portion of Hawaii's past.

Some of the basic features of Hawaii Plantation houses are reminiscent of the Japanese style of architecture. One example is the *lanai* (veranda or patio) feature found in most Hawaii plantation houses. This design feature may be somewhat similarly compared to the *engawa* which was used throughout the history of traditional Japanese residential architecture.

DESIGN

The design concept will be driven by the Japanese concept of "en," which, was mentioned earlier in the document as having the multi-dimensional meaning of bond, relationship, and affinity depending on its grammatical usage. Though the concept of "en" is derived from the Japanese language, the meaning of the prefix can be used to define the nature of Hawaii's multi-ethnic culture, and the bond, relationship, and close affinity of its local inhabitants to nature and its preservation.

LOCATION

The North Shore of Oahu is often referred to by the local community as "country." In contrast, the South Shore is referred to as "town." Together, the words "town and country" provides some clarity and understanding as to why the North Shore and the South Shore have appropriately been given the aforementioned names. Known as "country," the North Shore evokes images of an underdeveloped and rural area where life moves at a much slower pace than it would in the bustling and contrasting life of a populated town. Coupled with the general paradisiac sentiment that Hawaii, as the name alone can induce, the island of Oahu being termed as the "Gathering Place," and the North Shore being termed the surf Mecca of the world, one can easily imagine how beautiful, laid back, alternative, and pristine of a place the North Shore is. The local community of the North Shore is a unique breed. Most who live in the area prefer an outdoor lifestyle that is active and in balance with nature. The popular movement and sentiment of the local community is the propaganda to "keep the country country." Care and the preservation of nature is paramount in the livelihood of those that are privileged enough to live in such a beautiful place. Hence, when considering the built environment one must consider a design scheme that is considerate of the strong and active relationship between people and nature, the built environment and the natural environment, and the interdependent relationship between both.

CLIMATE AND DESIGN CONSIDERATIONS

The climate of Oahu is a temperate tropical climate where little fluctuation in climate occurs seasonally, even between summer and winter. The average temperature between summer and winter differs by only a few degrees Fahrenheit. In Oahu, as it is the case in all islands of Hawaii, considerable temperature differences occur in elevation. The higher the elevation, the colder it gets. For the most part, local daily weather forecast offers two main daily weather conditions, "partly cloudy" or "mostly sunny." The most notable climate change that occurs in Oahu annually is the rainy season, which generally speaking falls between the months of December and March. However, rainfall is generally brief and light, with heavy rainfall usually occurring late February to late March. Hawaii is also known for its Trade Winds. Trade Winds blow in a north-easterly direction and usually average 5-15 mph. These winds occur almost daily and frequently push the humid air out to sea, help keep humidity levels at a comfortable low. Kona winds, in contrast, move in the opposite direction and usually bring rain and humidity. The highest temperature ever recorded in Honolulu was 95 (1994) degrees Fahrenheit while the lowest being 52 (1902) degrees Fahrenheit. The average temperature in Oahu is between 73 and 81 degrees Fahrenheit. (Note: As a "not so accurate rule of thumb, but worth knowing," is that for every inch of wood, it takes one year for that one inch to get seasoned in natural air. Now, this rule of thumb may hold true in temperate climates where wood is exposed to a regular or controlled temperature and humidity levels. In places where climate fluctuates a lot, the seasoning time may be greater or shorter depending on climate conditions. It is also important to note that when building with timber, it is best to season the wood at the same climate where the building is being built for an extended period of time (a minimum of one year). Doing so will ensure that the timber is seasoned and well adapted to the specific climate of the building site, so that the wood does not change (swell or shrink) unexpectedly. There are available fast drying kilns that can dry lumber in a matter of weeks, sometimes in periods as short as two weeks. However, drying wood at such a fast rate is not ideal because it affects the organic structure of the wood making it much weaker.)

CAUTIONARY ENVIRONMENTAL CONDITIONS

EARTHQUAKES: Unfortunately Oahu does experience earthquakes from time to time. This is because Oahu, as with all the islands that make up the Isles of Hawaii, were at some point or another born from the same “hotspot.” Hotspots usually occur at geologic locations of plate tectonic boundaries. However, in the case of the Hawaiian Islands, the active hotspot is caused by a mantle plume located far away from any active plate tectonic boundary. An active hotspot causes seismic activity which in turn causes earthquakes. The big island is currently the center of Hawaii’s Hotspot. Periodic Volcanic activity causes earthquakes that affect all Islands of Hawaii, including Oahu.

HURRICANES: Hurricanes rarely occur in Hawaii. Since 1950 there have only been 5 hurricanes that have affected the Islands of Oahu. Since 1946, 6 Tsunamis have been recorded to affect the Island chain.

SITE AND SITE ANALYSIS

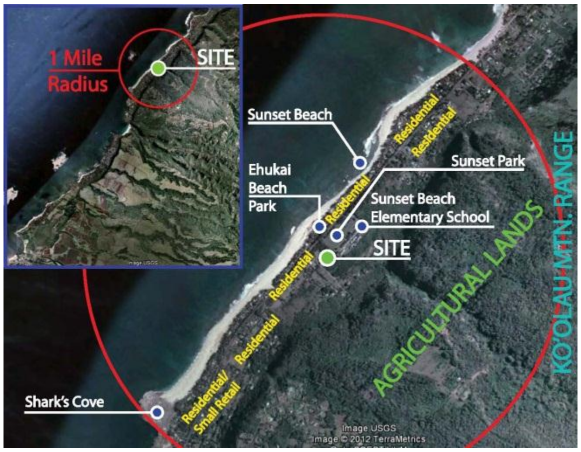
Site

The site is located on the northwest coast of the North Shore of Oahu, popularly known to surfers as the 7 Mile Surf Strip. Its specific location is set across Kamehameha Highway, diagonally across from Ehukai Beach Park.

Site Analysis: 1 Mile Radius

The one mile radius community surrounding the site is mostly composed of residential homes. Along the coast line there are a multitude of popular surf breaks (Banzai Pipeline and rocky Point at Ehukai Beach Park and Sunset at Sunset Beach Park being among the most well-known surf breaks). During the winter the beaches bordering this one mile radius are filled with locals and tourists that go to the beach to watch the large waves that hit the coastline, creating great conditions for world class surfing competitions and daily surf sessions. To the southwest, tourists can appreciate snorkeling at Shark’s Cove and shop at small local retail shops. Not too much further southwest there is a Foodland, one of few grocery stores that are situated at the 7 mile strip of the north shore. There is not much to the east of the site for the exception of agricultural lands and the Ko’olau Mountain Range. North east of the site is composed of more residential homes, and further up there is a

Mormon community and a Bingham Young University (BYU). The Town of Kahuku is just a few miles further north. Kahuku is known for its



shrimp farming and the tasty shrimp trucks that border Kamehameha Highway and entice tourists and locals alike for a plate lunch stop. Kamehameha Highway, a two-way single lane car road, is the only major road that allows access to and from the site. During the weekends, surf competition days, and the winter season traffic is usual and unavoidable throughout most of the day.

Site at a Close glance

As mentioned before the site is situated diagonally south from Ehukai Beach Park, and just a short walk across from Kamehameha Highway. Bordering north of the site there is Sunset Recreational Park and Sunset Elementary School. East of the site is mostly agricultural land and the Ko'olau Mountain Range. Residential homes border the south and west boundaries of the site. Parking is minimal and limited to street shoulder parking, the small Ehukai Beach Parking lot, and roadside parking along the narrow residential roads.

(Site boundary marked by yellow outlined box)

Sun Path Diagram

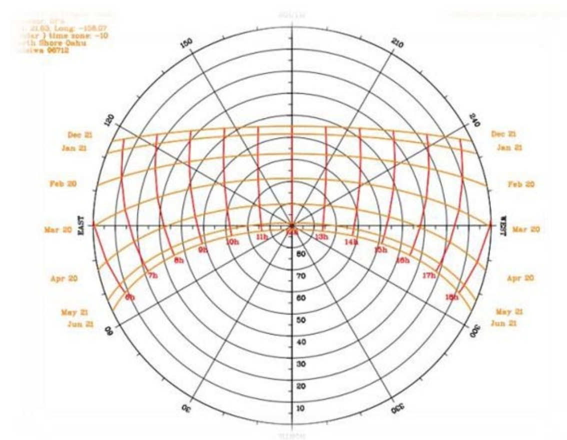


Figure 37: Sun path diagram
Source: *Solardat.uoregon.edu*
http://solardat.uoregon.edu/SunChartProgram.html (accessed April 24, 2012)

The sun path diagram displays the annual path of the sun over a specific coordinate location. This diagram helps the designer in establishing the proper orientation of a building's exterior envelope and its window and open-walled features in order to maximize passive interior day-lighting conditions. To use the diagram simply place its center over the location of the site and follow the annual path given by the diagram.

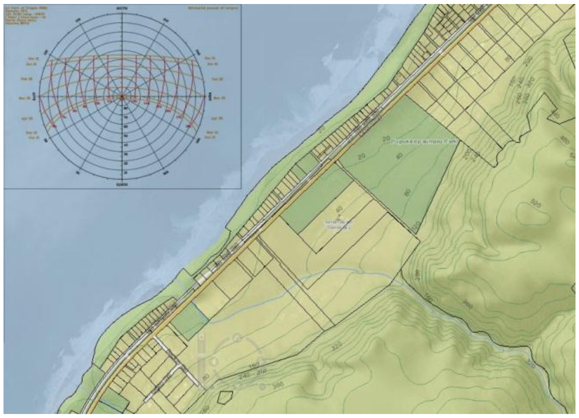


Figure 38:
Source: *Honolulu DPP Parcel Zoning*
http://gis.hicentral.com/FastMaps/ParcelZoning

SITE PLAN

(Close-up Site Plan found in Part 7 of the document)

EHUKAI PAVILION DESIGN FEATURES

Piles – Preservation of the natural environment is one of the main focuses of the design project. Hence, the pavilion will be raised off the ground and placed on piles that will rest above large rocks set to the ground. The rocks will serve as the pile foundation on top of which the building will rest on. This raised system (or pile-dwelling) is typical of traditional Japanese architecture and complements the context and design intent of the Ehukai Pavilion Project very well. Set on Piles the pavilion will minimize the footprint of the building, lessening the building's environmental impact onto the site. Raising the structure on piles also enhances the passive cooling potential of the building, as raising the floor level opens up airways under the building from which natural ventilation can pass through to cool the building during warmer climate. Air can travel under the building and through the floorboards and tatami mats, cooling the building's interior.

The Floor Plan – Typically the standard post-to-post module for a traditional Japanese residence is 6'x6' on center. Instead of using the standard Japanese module, the post-to-post module for the Ehukai pavilion will be increased to 8'x8' on center. This not only complements the western cultural taste for larger, more spacious rooms, but it also increases the functional space of the main hall, allowing the space to be converted and function as a small performance area when necessary. The floor plan is composed of two main rooms, the primary public hall (the training, or performance space) and the secondary semi-private space; with smaller rooms wrapped around two adjacent sides of the building. One of the adjacent rooms will serve as a private reading room, while the rest of the spaces will serve as storage and circulatory spaces.

Engawa – The design of an engawa is a distinct Japanese architectural design feature. As mentioned earlier, the engawa acts as an intermediate space between the interior built-environment and the exterior natural environment. As an intermediate space it blurs the boundary between inside and outside. Functionally the engawa serves the dual function of covered corridor from which an interior occupant can move about to and from different spaces within the building, and as a veranda, an exterior space where people can occupy the outside of the building and enjoy the outdoor surroundings. The use of the engawa truly complements the climate and local lifestyle of the North Shore. One of the main features and daily occupied spaces in local homes is the "Lanai." In essence the lanai is the same as a porch or veranda. The use of a lanai can be traced back to the plantation homes built during the plantation era in Hawaii. The difference between the engawa to that of a porch, veranda, or lanai, is that the engawa lacks a fence, or rail. This engawa features further serves to connect interior and exterior spaces. Traditionally the Japanese often sat at ground level. If the engawa were to be wrapped around by a fence, or rail, then the fence or rail would obstruct the line of sight from a person sitting indoors looking outwards.

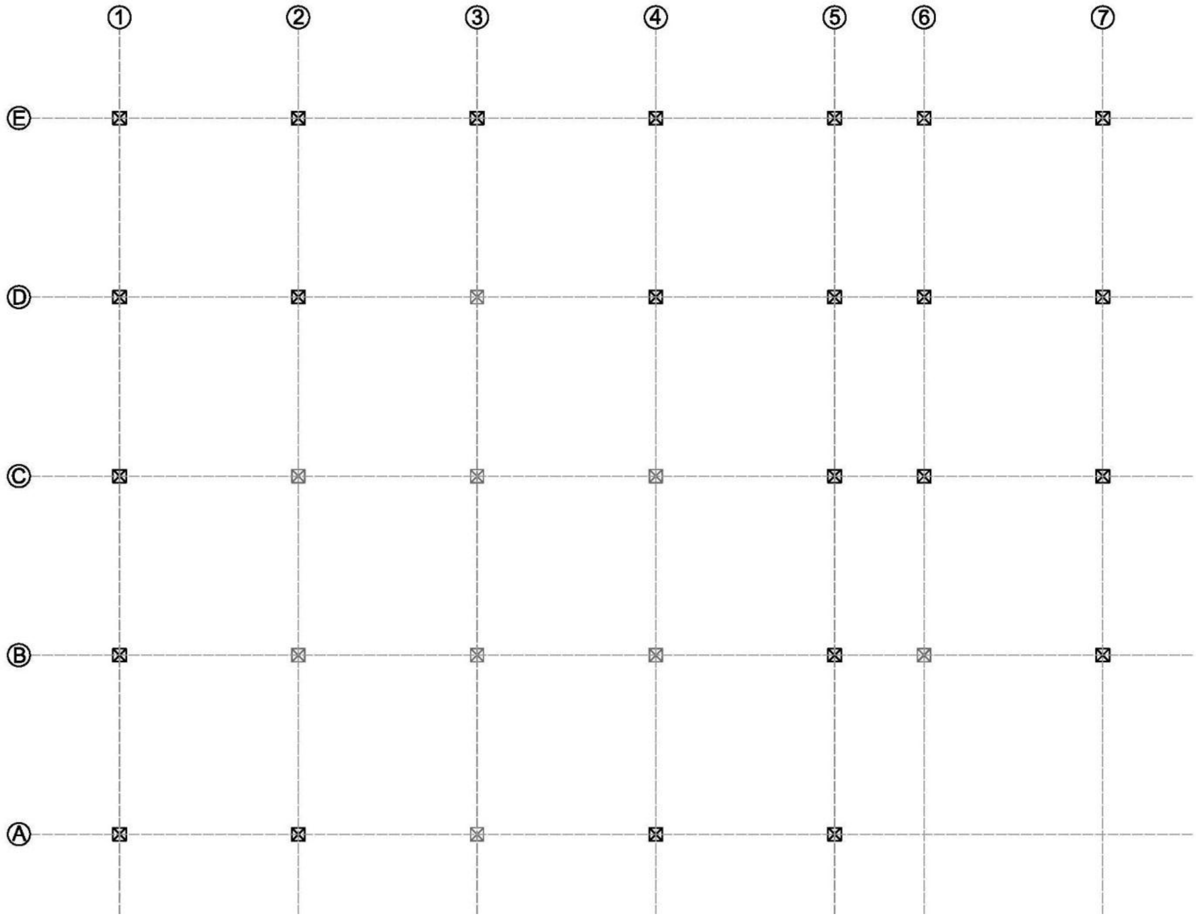
Roof Form and Structure – To minimize visual impact of the building structure on the site and on the surrounding context, the roof will have a minimal slope pitch (4:10) and its form will be simplistic in design. In this manner, the roof will be less imposing on the landscape. This design choice is influenced by the Hawaiian plantation homes of the Plantation Era, which for the most part were subtle and low.

The roof structure of a traditional Japanese timber frame structure is perhaps the most complex section of the building structure to design and build. Japanese roofs are often heavy, designed with large projecting eaves that are supported by hidden systems of cantilevers. Traditionally the Japanese have favored the use of false roofs that hide the structural support of the roof entirely. The structure of the roof form will follow the roof structures typically found in Japanese farmhouses, or *minka* houses. In this typology, exposed roof rafters were most commonly found in minka dwellings and lower income residential houses. In most cases, the occupants of such type houses lacked the income and resources to purchase raw materials to build a false roof and to hide the roof structure. Also, the use of Hare, or natural round horizontal rafter beam supports, was a design feature most readily used in low income residences. Hewing round logs into square beams takes a level of work and refinement, which at the time not everyone could afford. For the design of the pavilion the roof structure will be left exposed and 3 hare rafter beams will span the Primary space to support the structural frame of the roof.

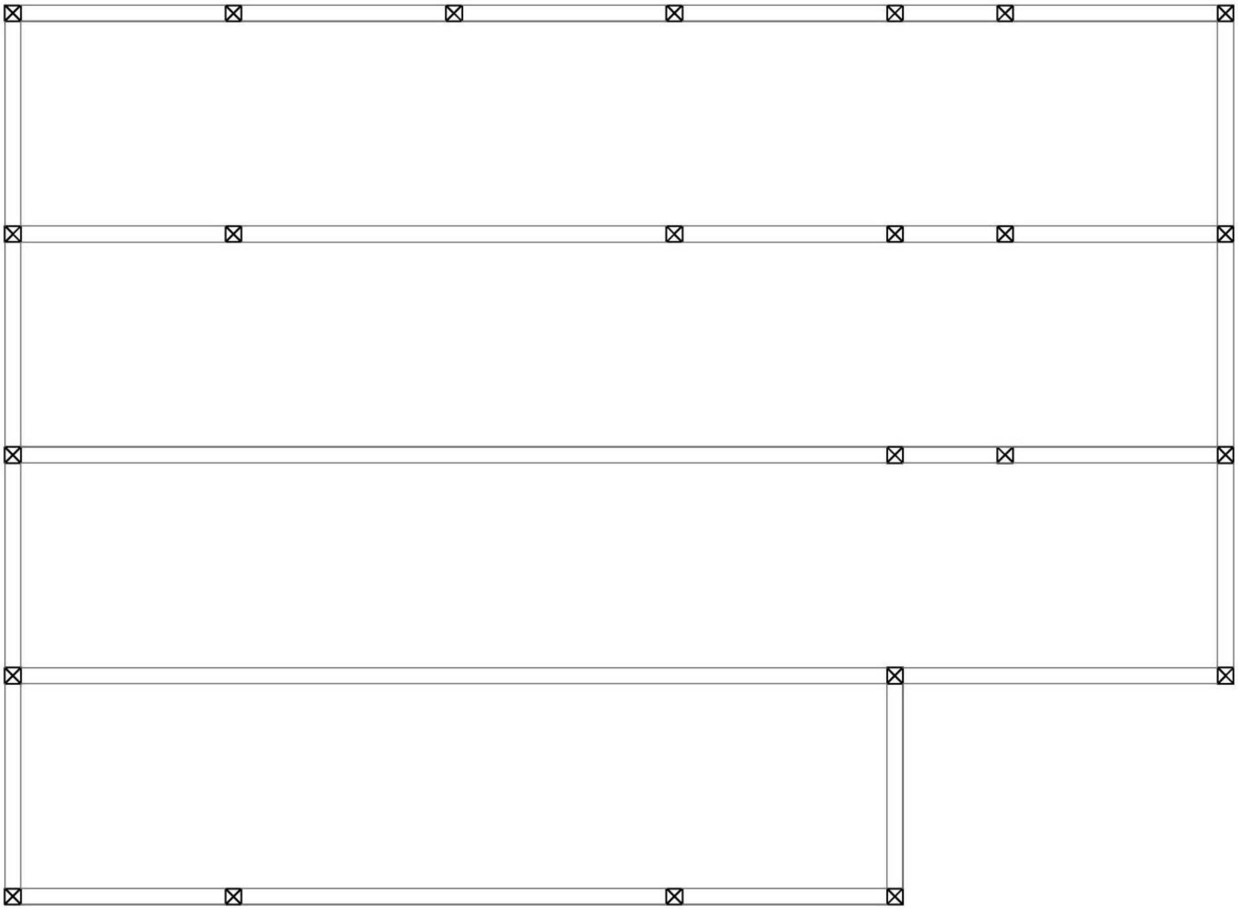
Built-in Furnishings – One of the hallmarks of the Edo period *shoin-zukuri* style of residence is the built-in decorative alcove and furnishings. The Ehukai Pavilion includes a decorative alcove and built-in furnishings in the main hall. The office space includes a built-in desk and shelves.

Walls and Movable Partitions – The interior and exterior wall treatment will include fixed walls, shoji screens, and fusuma wall partitions. Fixed walls will be used to provide shear resistance to the building structure. Movable-sliding shoji screens will be used to add flexibility to the exterior wall treatment. Shoji screens can be opened and closed depending on the ventilation and natural lighting needs of the occupants. These screens may also be completely removed in the case that the Main Hall is to be used as a performance stage. The ability to be able to completely remove the screens will allow viewers seated outside the building to view the performances on the elevated hall as if it were a small theatrical theatre.

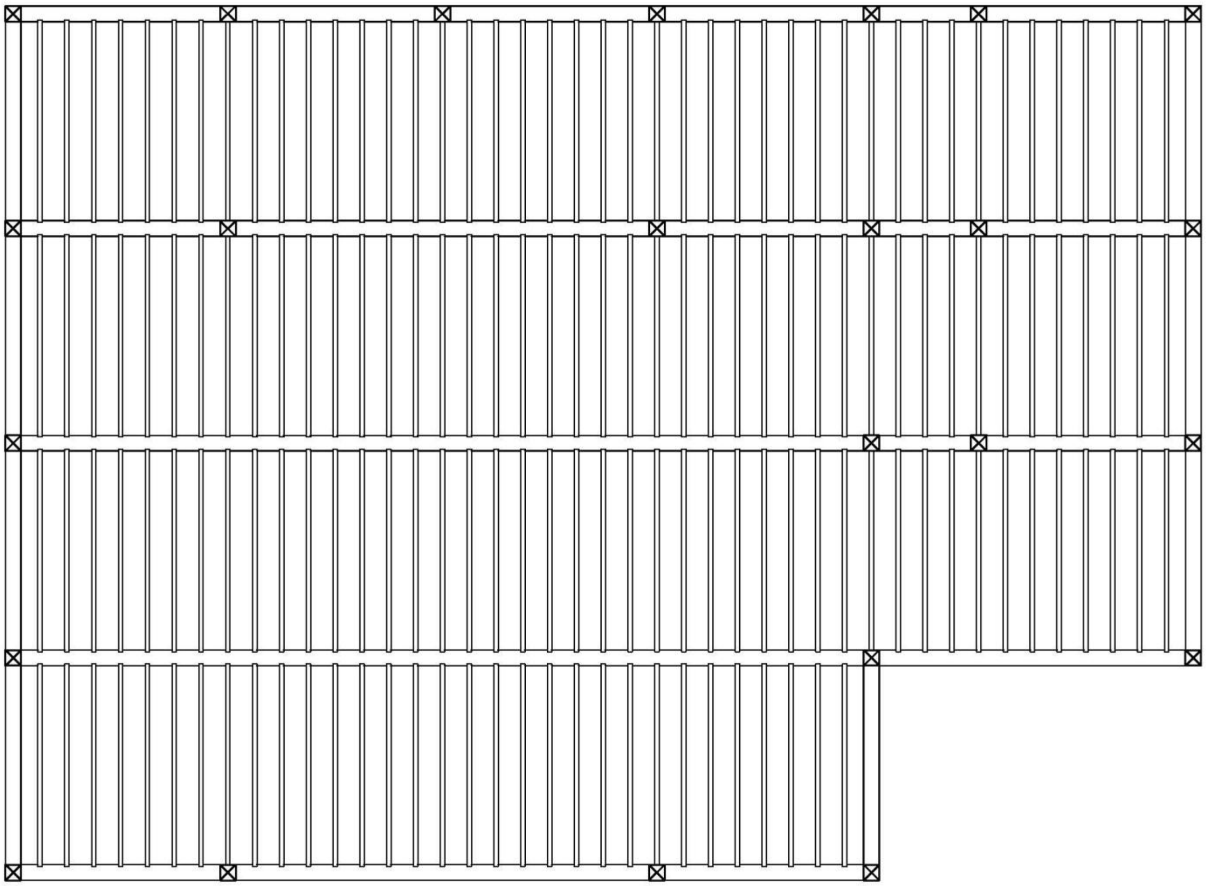
PART 7 – PLANS, SECTIONS, AND ELEVATIONS



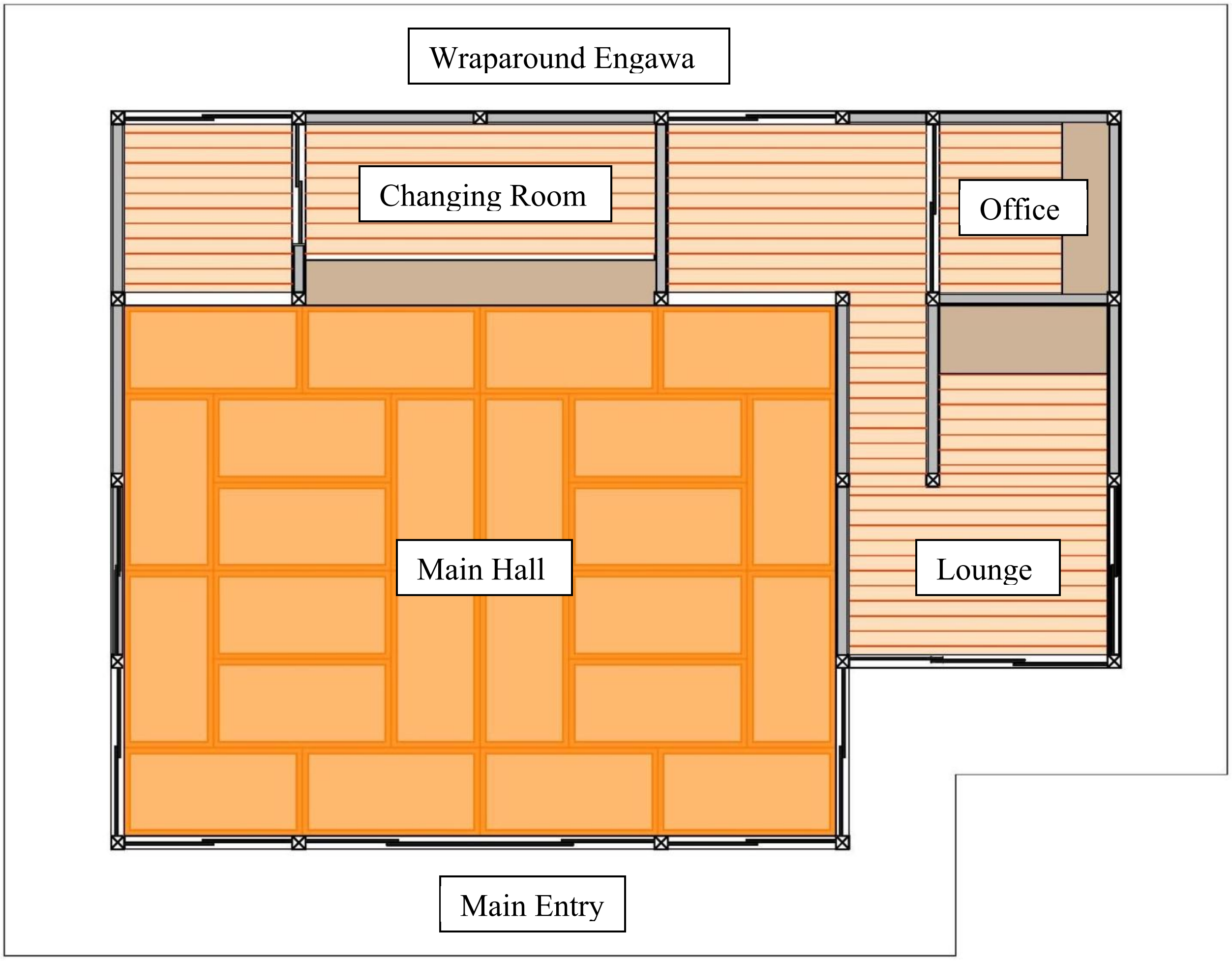
POST (*HASHIRA*) MODULE 8' X 8'



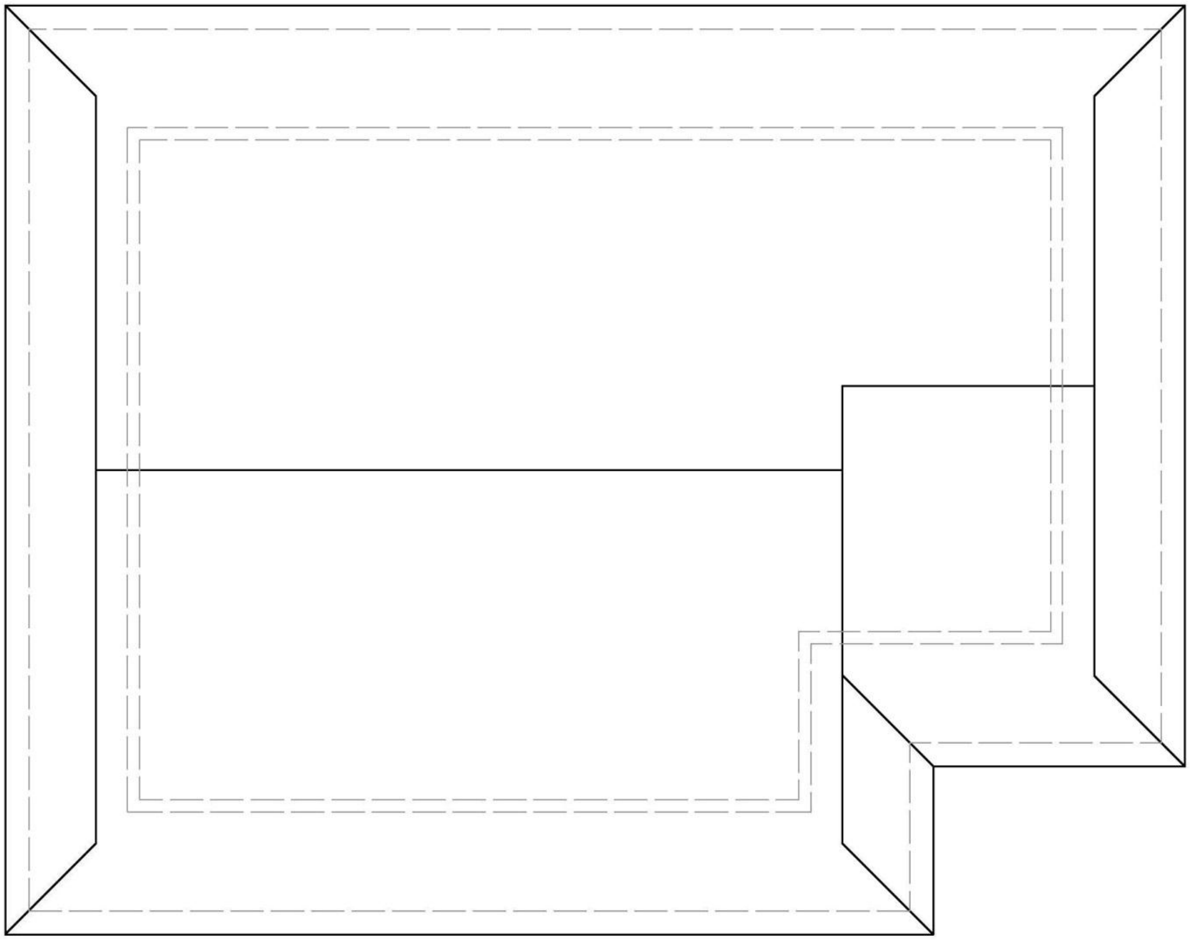
GIRDERS (*OBIKI*)



FLOOR JOISTS 16” ON CENTER

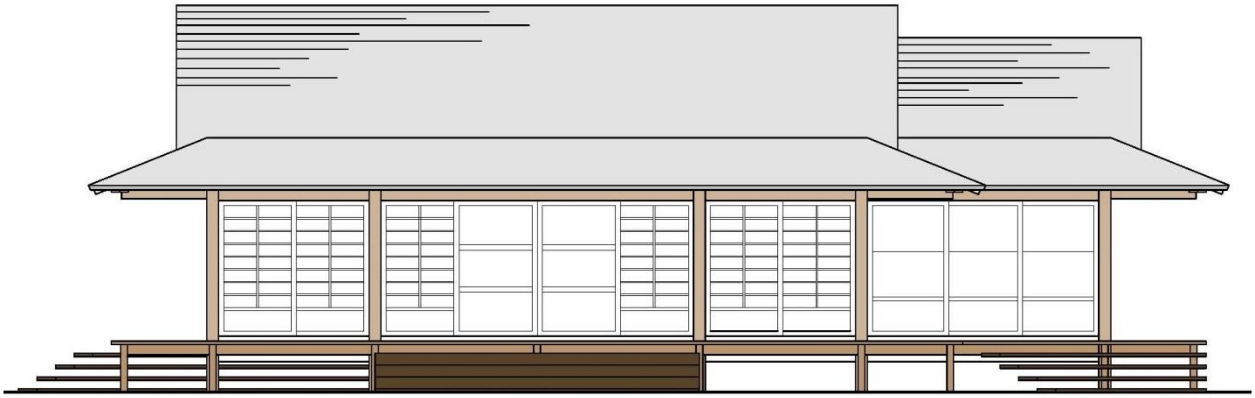

Wraparound Engawa
Changing Room
Office
Main Hall
Lounge
Main Entry

FLOOR PLAN



ROOF PLAN

SITE PLAN

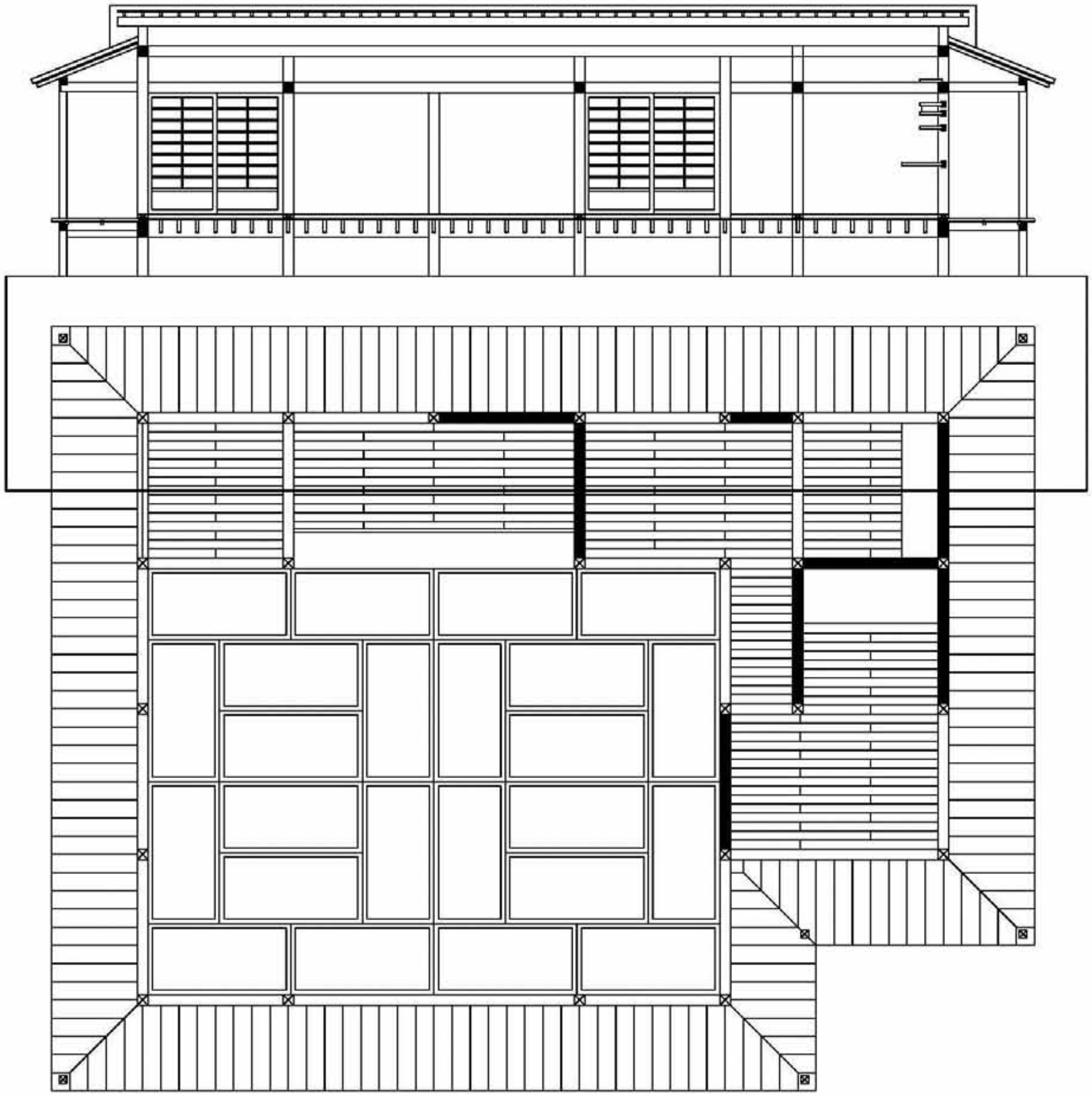


FRONT ELEVATION

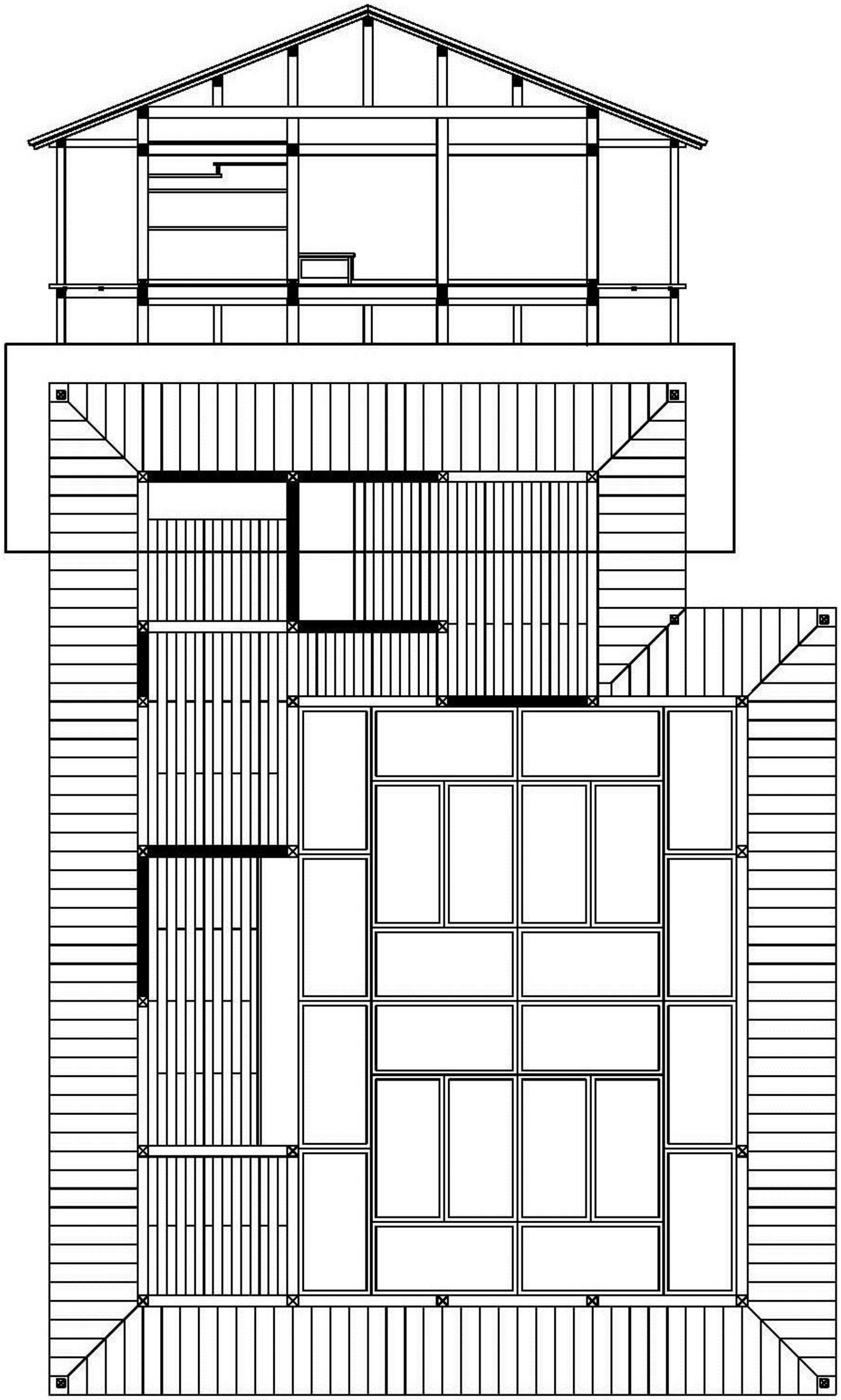
BACK ELEVATION

NORTH ELEVATION

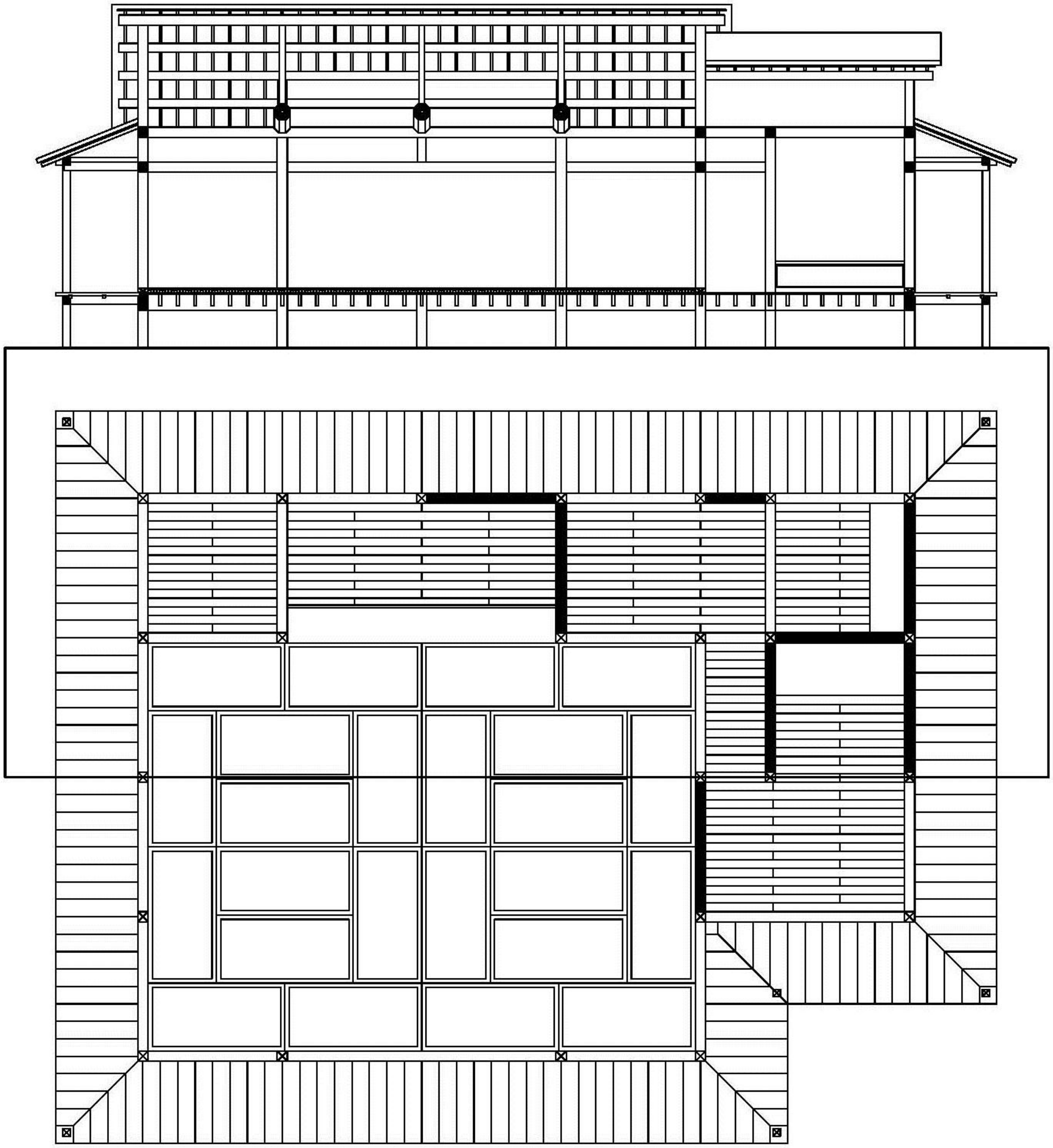
SOUTH ELEVATION



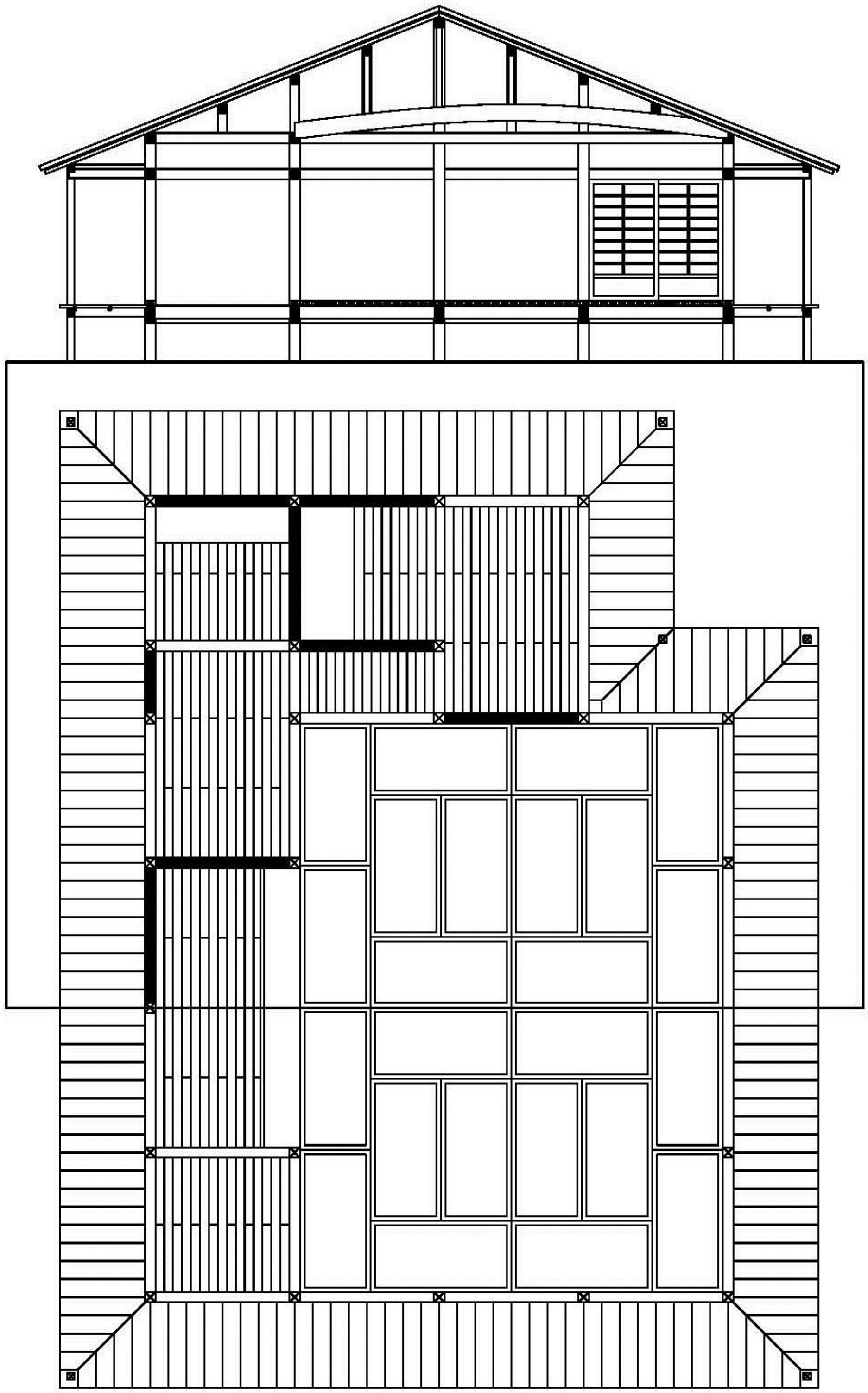
SECTION 1



SECTION 2

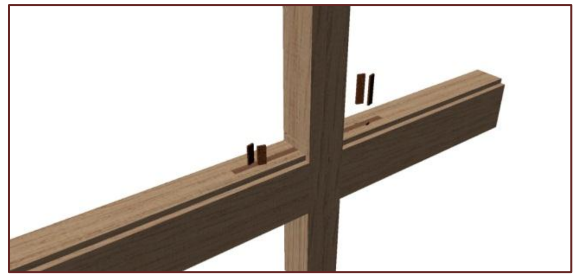


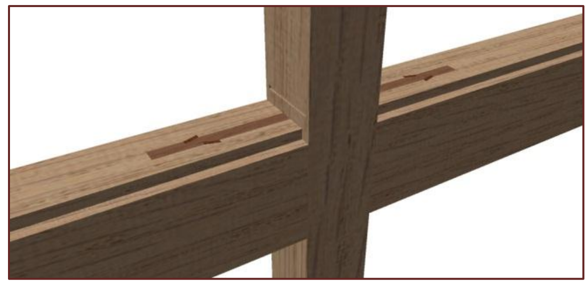
SECTION 3

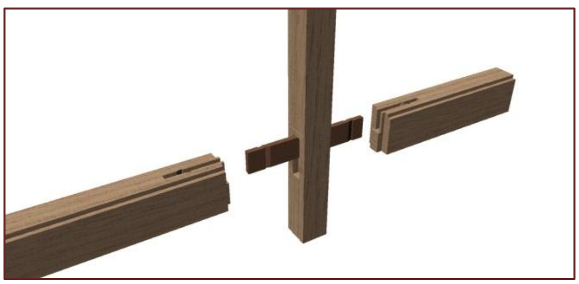


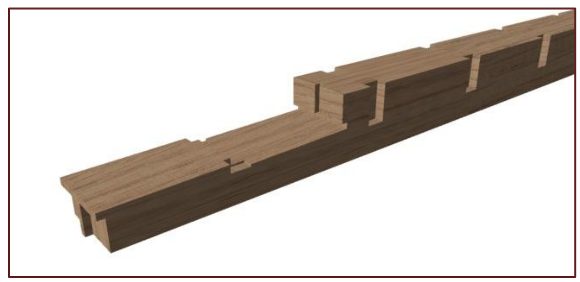
SECTION 4

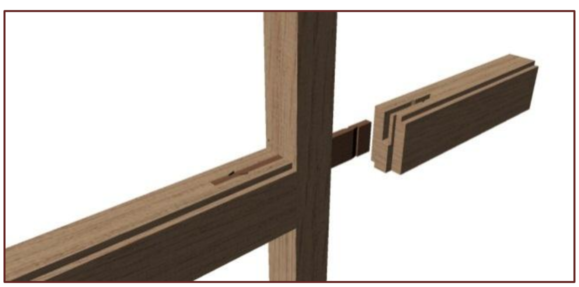
PART 8 – JOINERY DETAIL & PAVILION CONSTRUCTION

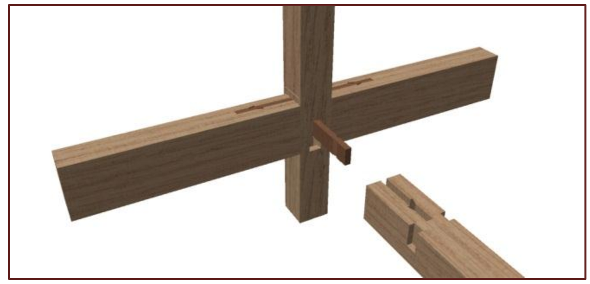


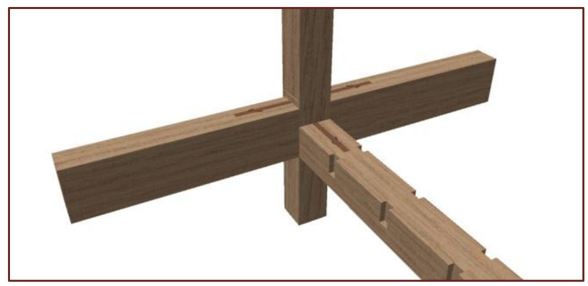


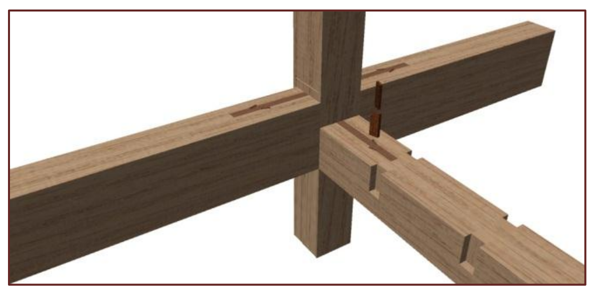


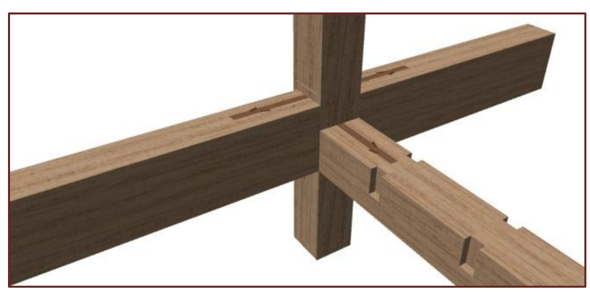


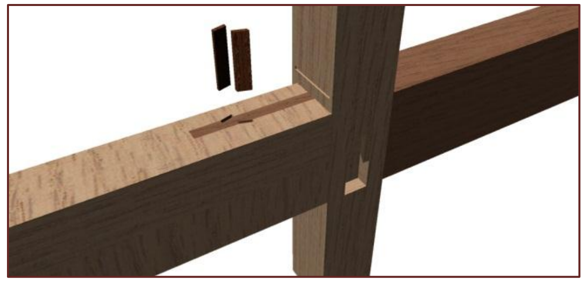


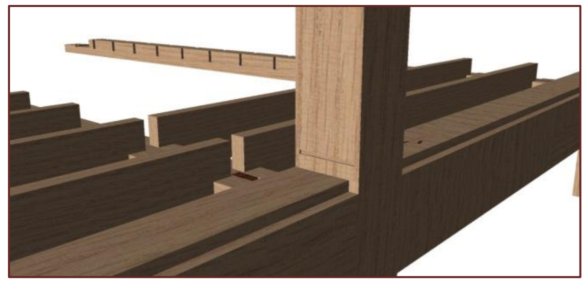


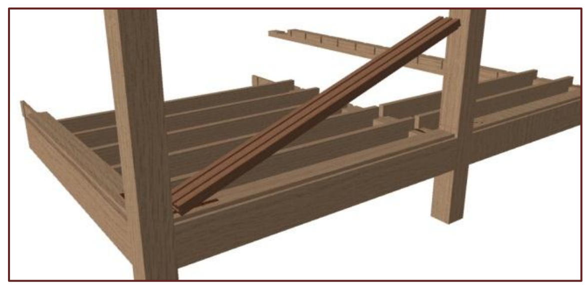


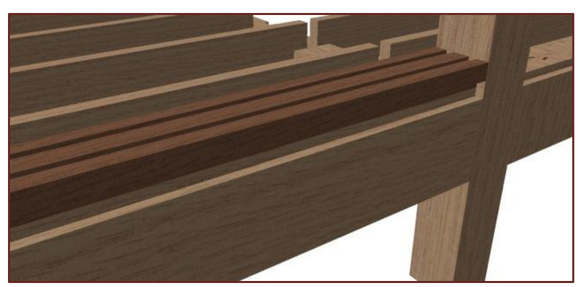






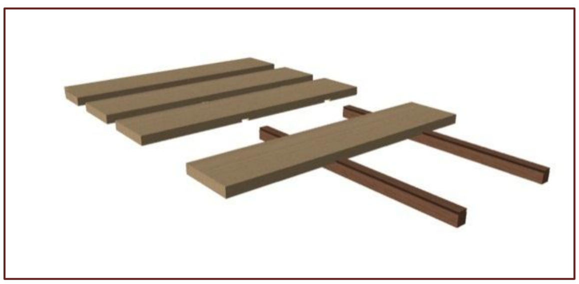
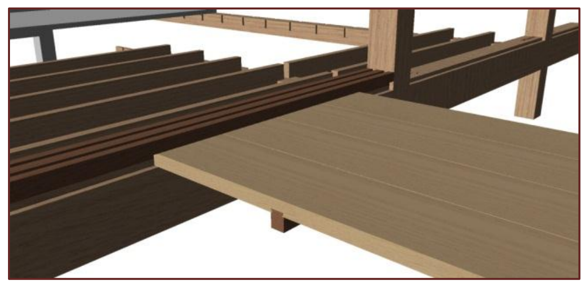


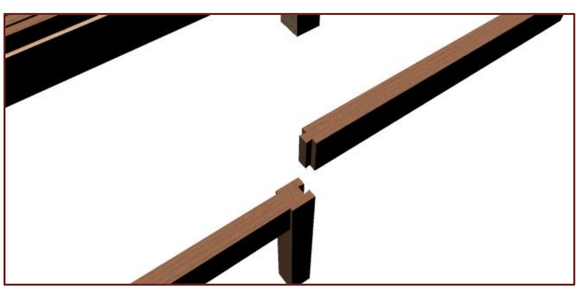








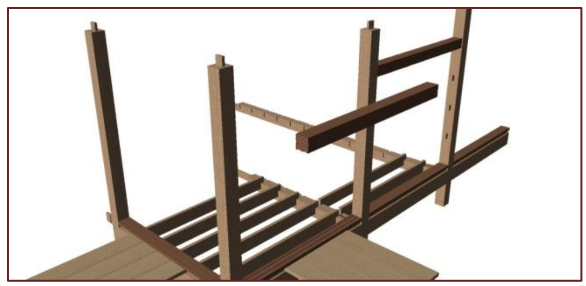



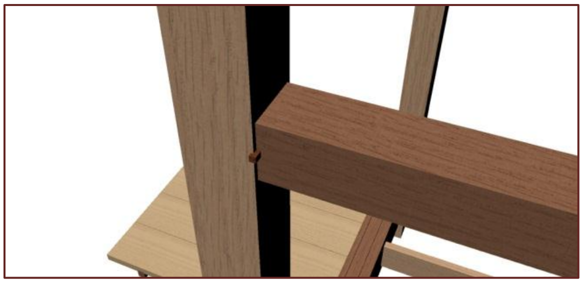


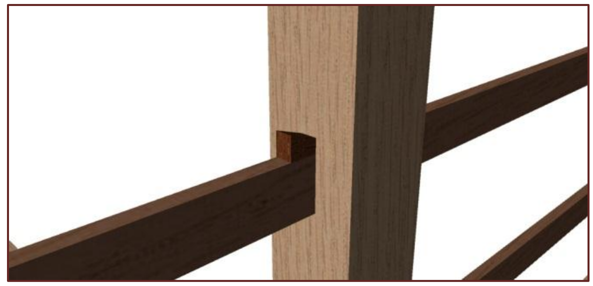


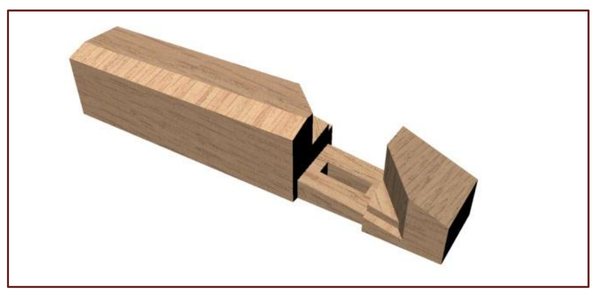


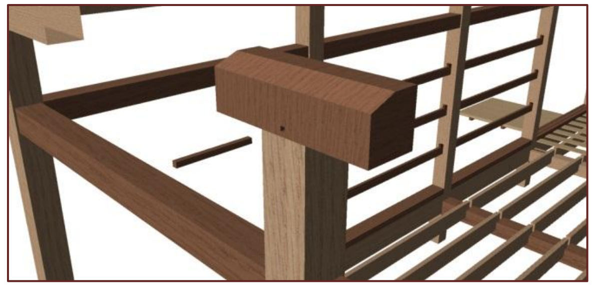


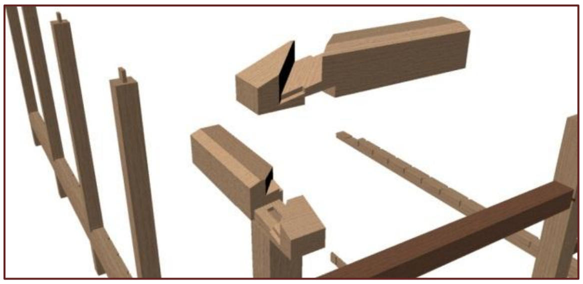


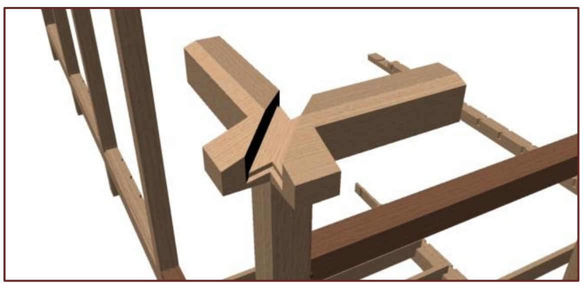


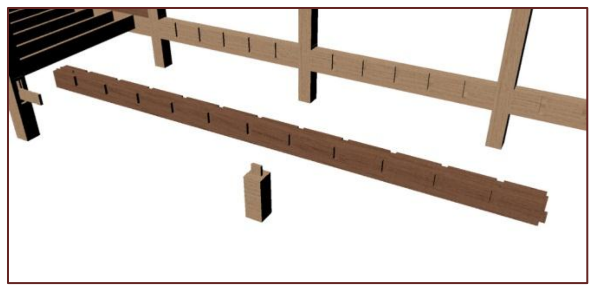


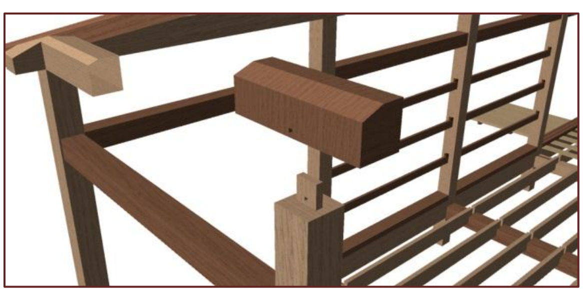


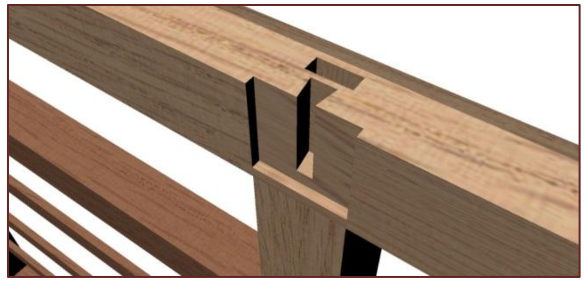


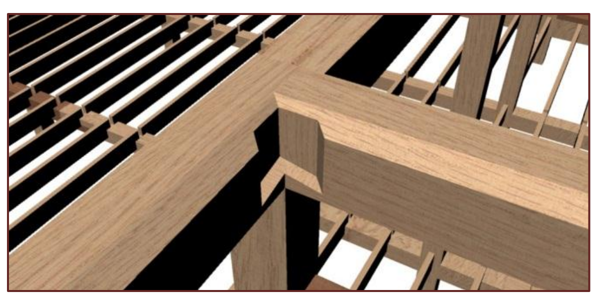


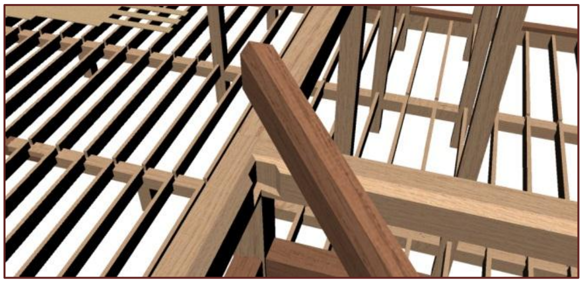


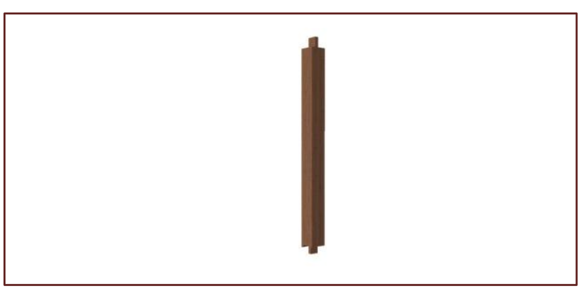


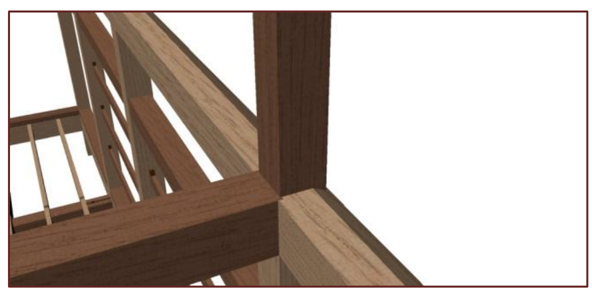


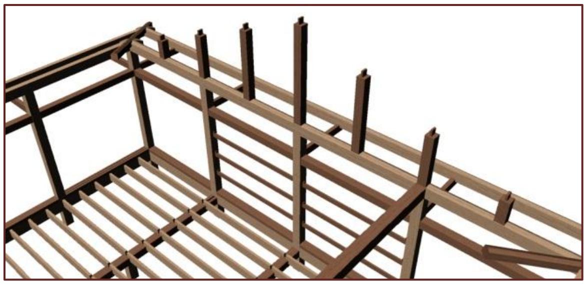


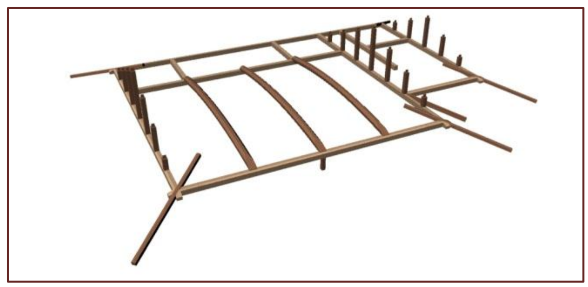


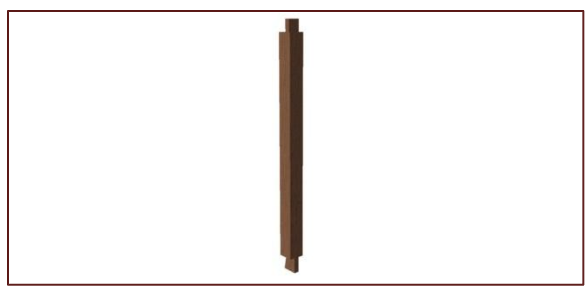


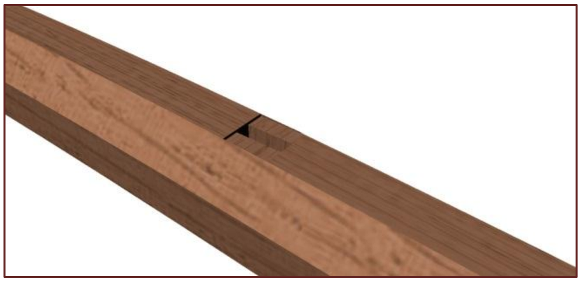


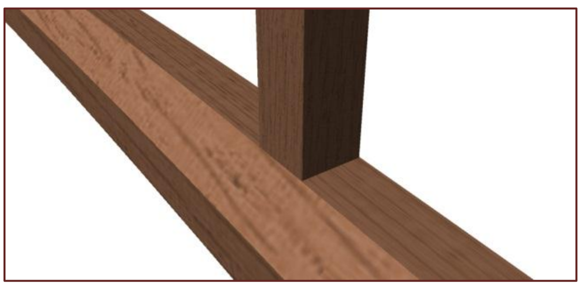


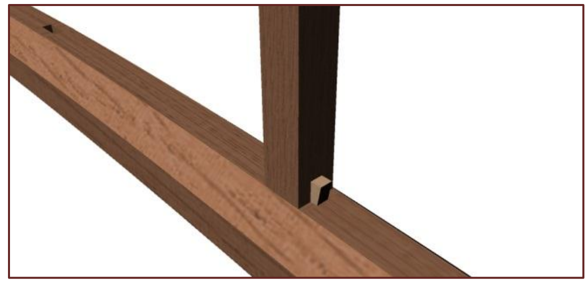






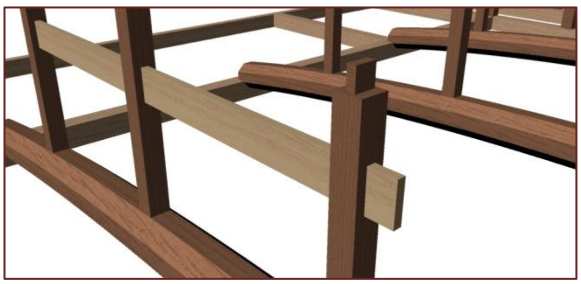
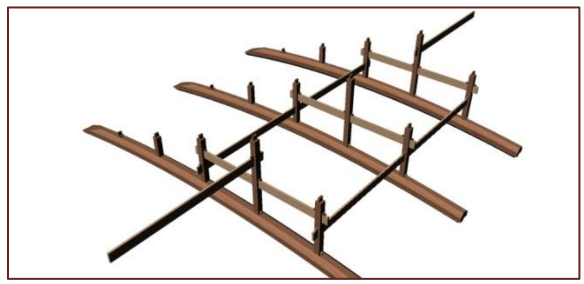
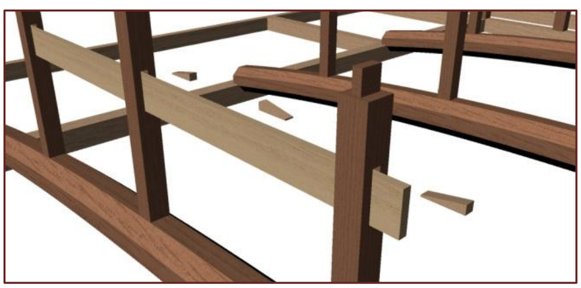
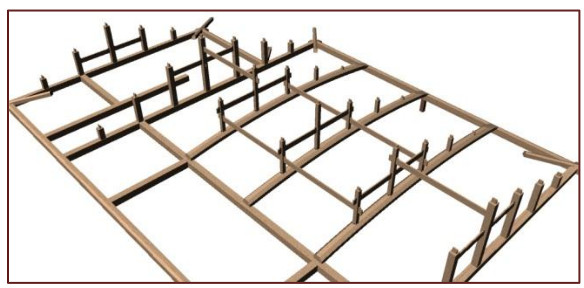


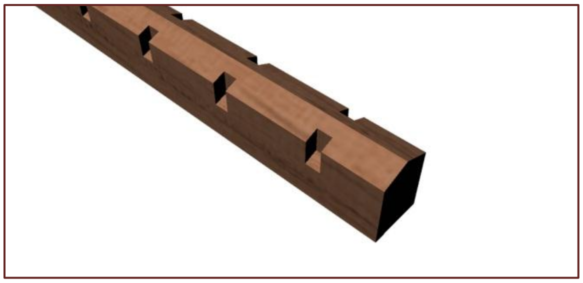


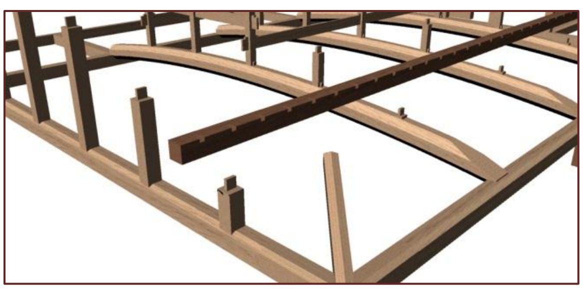


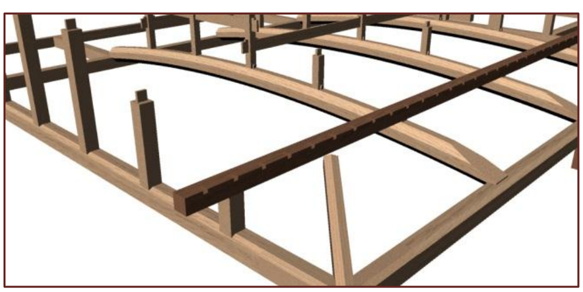


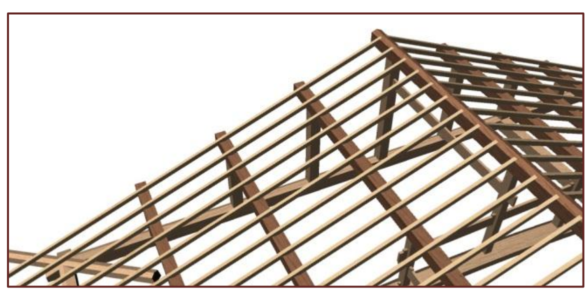


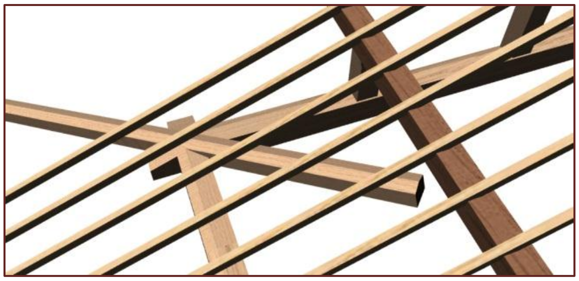
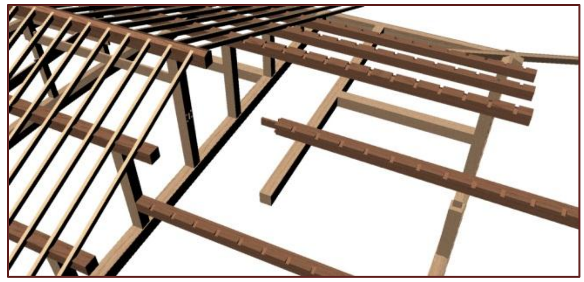





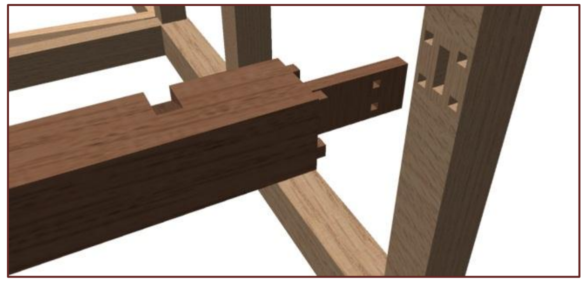
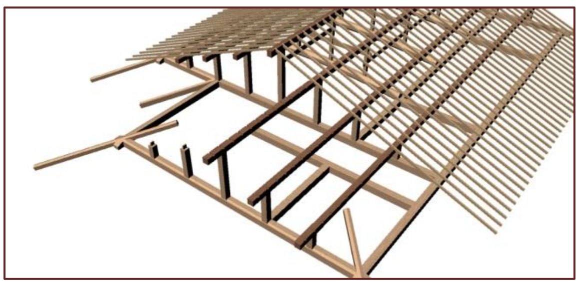
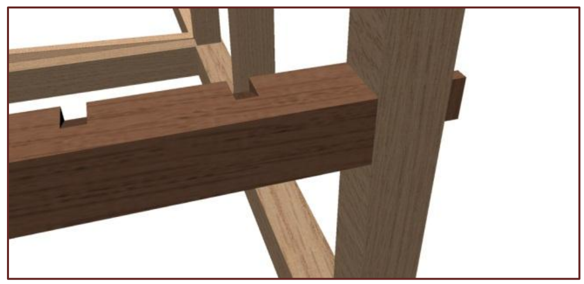
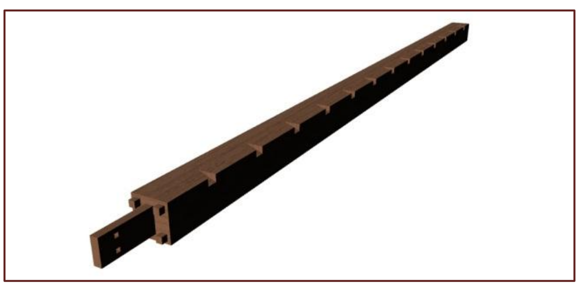


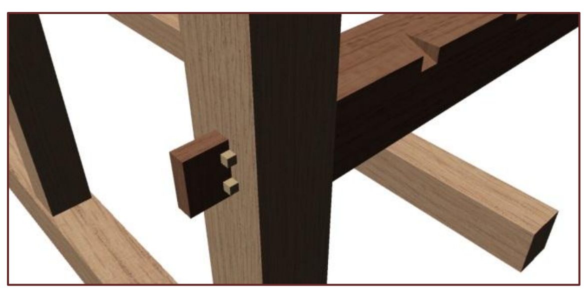




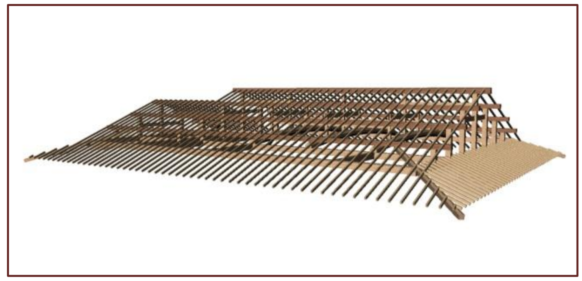
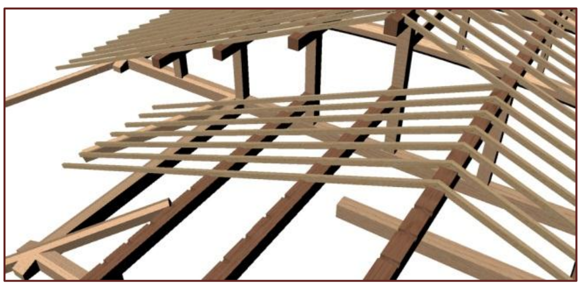


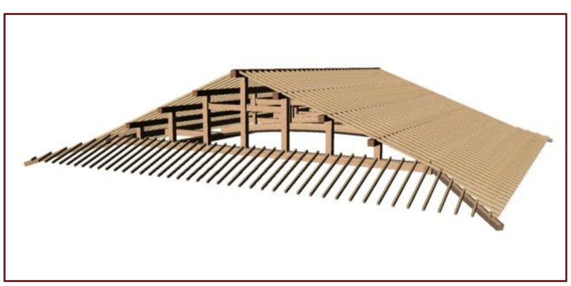





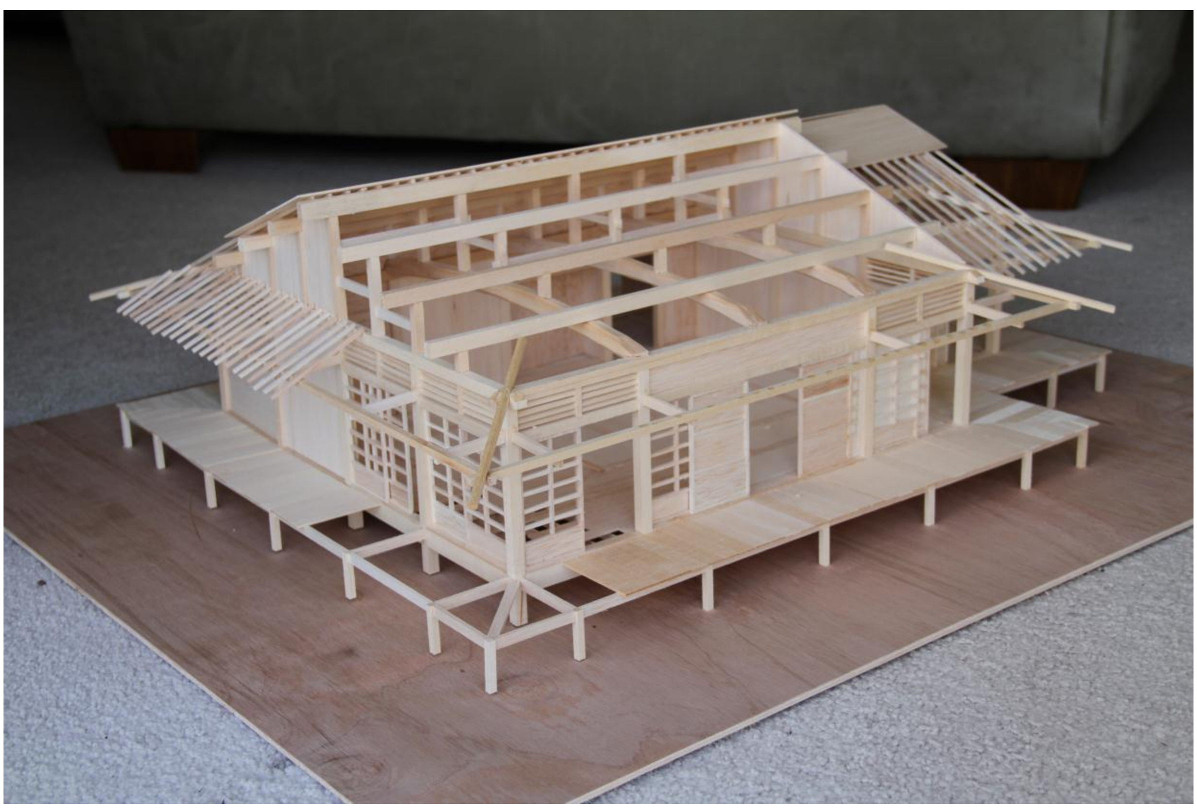


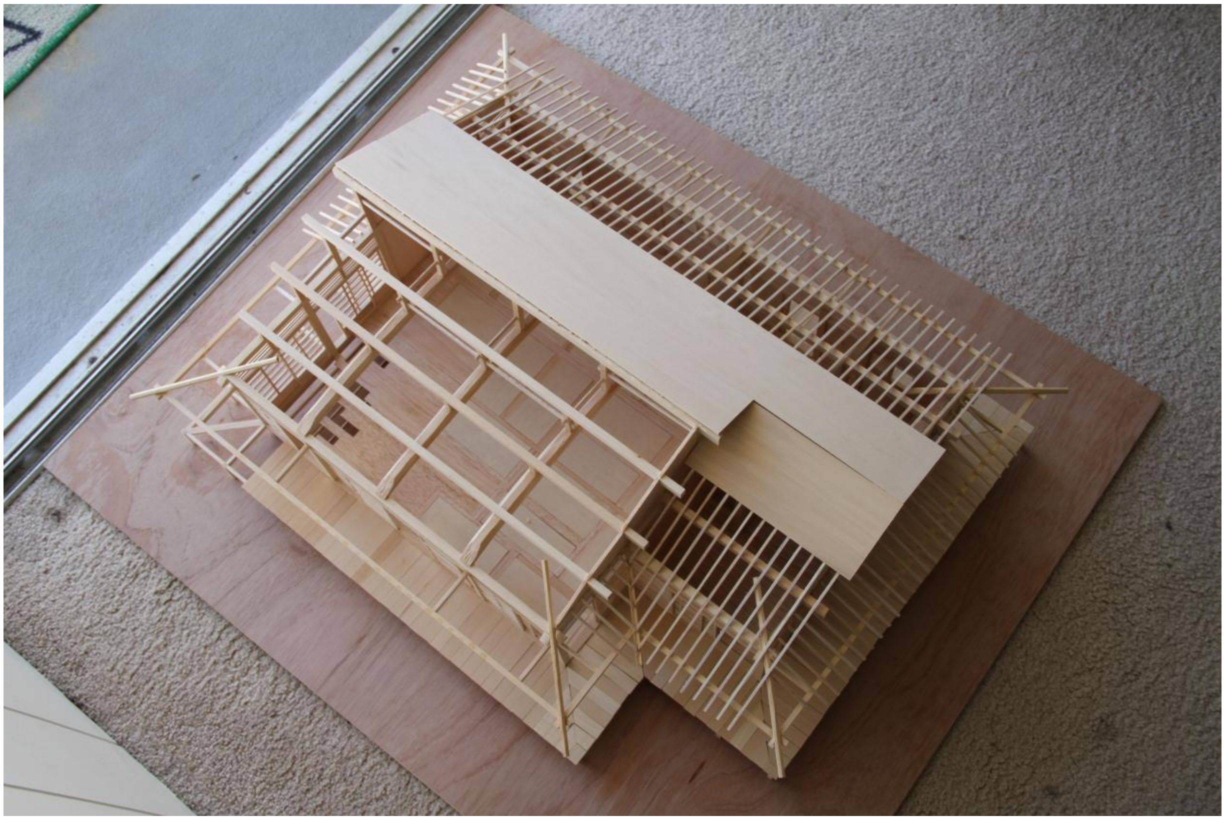




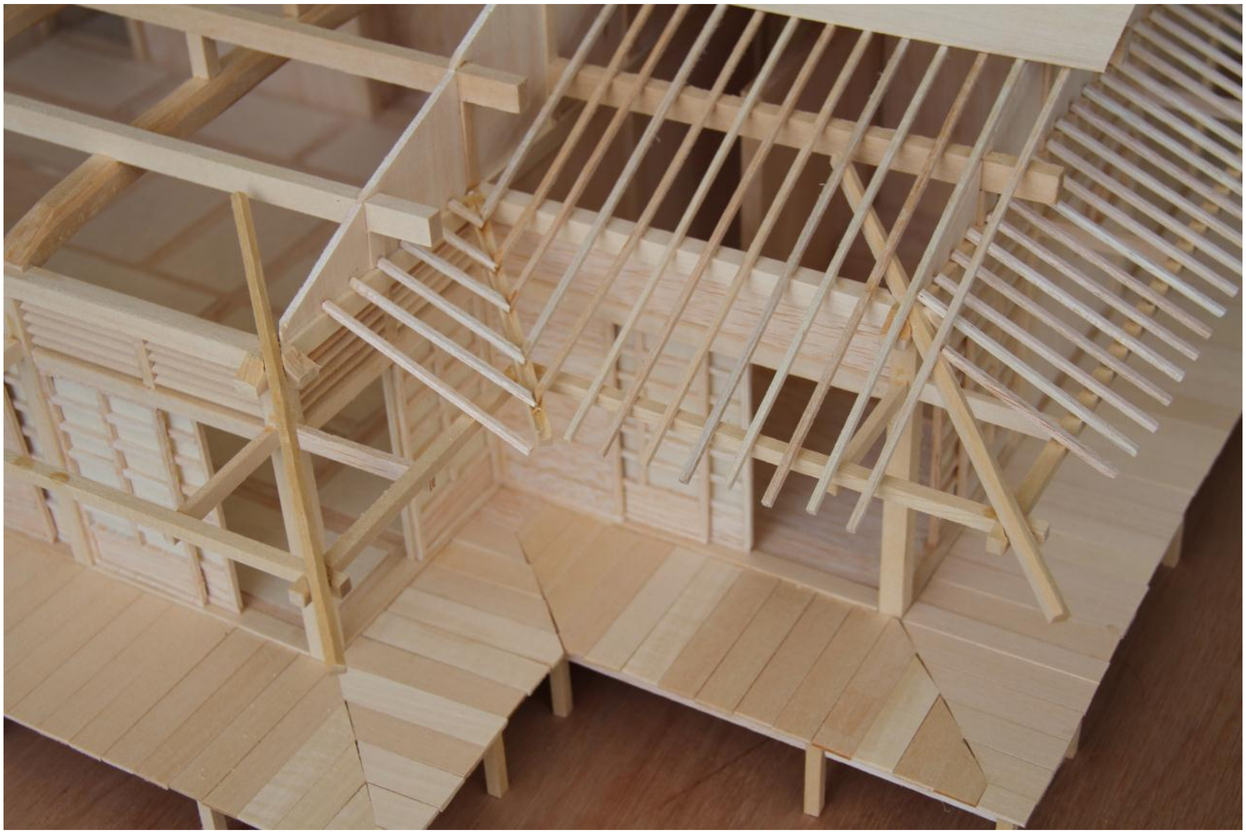


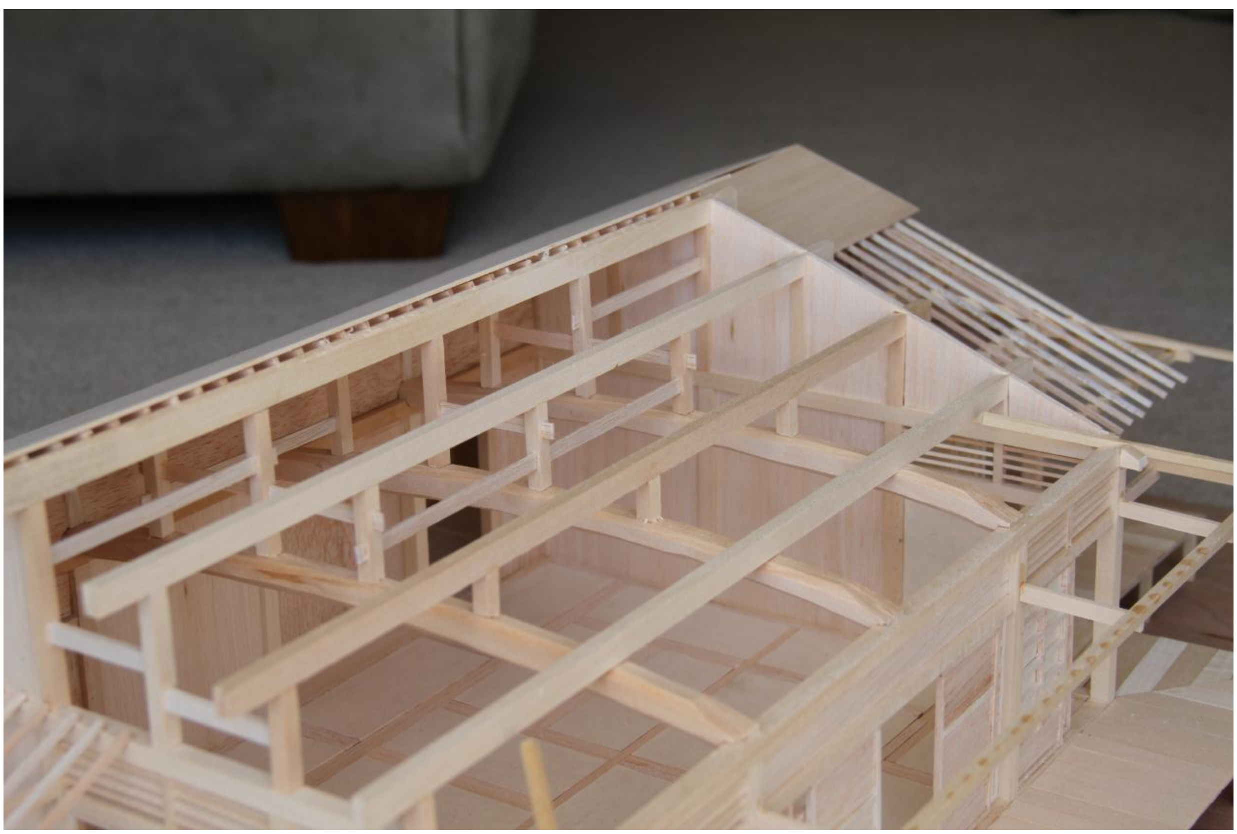



PART 9 – PHYSICAL MODEL









PART 10 – CONCLUSION

Traditional Japanese architecture spanned over 2000 years. Throughout its history a highly specialized timber frame methodology was developed. The method was developed by the Japanese Carpenters of the time. In the past, the Japanese carpenter played the role of both architect and builder. The Edo period marked the high point in Japanese residential architecture. The features of the Japanese house have had considerable influence to many modern day architects. However, most of the influence has been based on superficial design elements. This research attempts to look at traditional Japanese architecture from a different perspective. Although it considers the design elements of the Japanese house, the greater portion of the research focuses on the design and construction methodology devised by the Japanese Carpenter.

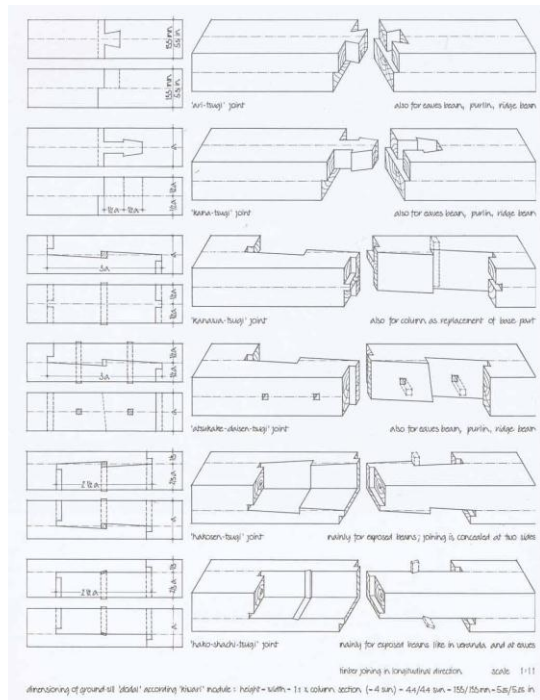
One might argue that the revival of traditional Japanese architecture has no value today, especially in Hawaii. Clearly the Japanese method of timber framing stemmed from a pre-industrial era, relying on pre-industrial construction methods to achieve their architectural needs. Although this idea may hold some truth, what is important to note here is not so much the objective value of transposing a clear copy of traditional Japanese architecture into Hawaii, as much as implementing reinterpretations of the architectural features, design, and construction methodologies into Hawaii that are relevant to present problems afflicting the built environment. The big idea is to learn from it and to borrow from traditional Japanese architecture what is applicable to Hawaii, such as its modular system of measure and construction, the application of a wood joinery method of construction, its flexible and multi-functional spatial layout, its raised pile structure, built-in furnishings, the use of the engawa (veranda), and the buildings architectural relationship between interior and exterior environments. In this effort, hopefully a more sensible and appropriate architecture can be developed for Hawaii.

Although wood is not a building material readily available in Hawaii for construction, due to its lack of forested resources, reclaimed lumber is becoming more at the disposition of local designers and builders as a viable alternative resource to wood-based design. As the lifecycles of older buildings reach their expiration date, more and more reclaimed lumber will become available. The use of this alternative wood resource can alleviate the exploitive pressures of construction from our limited natural forested habitats, decrease the construction cost of imported materials, and also introduce to design a whole new outlook into timber frame building typologies and aesthetic quality.

Reclaimed wood may not offer the structural strength that old growth wood provides. However it does have a place in contemporary design and construction. As seen from the research, reclaimed and salvaged wood are appropriate in many ways for design. A piece of lumber may look weathered from the surface. However, with proper milling, one may find that a workable piece of wood may be extracted for the construction of something new and exciting, a new building typology. This new typology is based on the current need to think bigger, but build smaller, more functionally flexible spaces that can be easily modified to cater the specific day to day needs of the client and users.

The trend or need to build smaller structures that offer multi-functional spaces is something which the Japanese have readily done throughout their building tradition. In Japan, the trend occurred because of the diminishing availability of large lumber, caused by overexploitation of forest resources. Today, this problem is still afflicting us. Although trees are a renewable natural resource, the rate in which we consume it is far too exploitive. It is of great importance that when considering timber framing we look into alternative wood resources. The diminishing availability of large timber in Japan pushed builders to alter their building methodology and to adopt new techniques to build with smaller timber. There are various joints developed by the Japanese that allow smaller pieces of wood to be joined to create larger spans. Although these joints do not afford the same structural strength as a solid piece of lumber might, it can still provide added value in a different building application. Below are a few images that provide different variation to specific joinery details.

This traditional Japanese joint is used to connect two pieces of wood to create a longer spanning board plank.



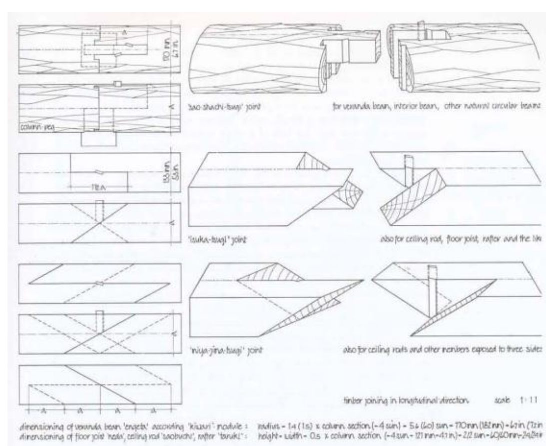


Figure 39-40: Connecting Horizontal and Vertical Structural Members

Source: Fig 39: Engel, 1989

Source: Fig 40: Engel, 1989

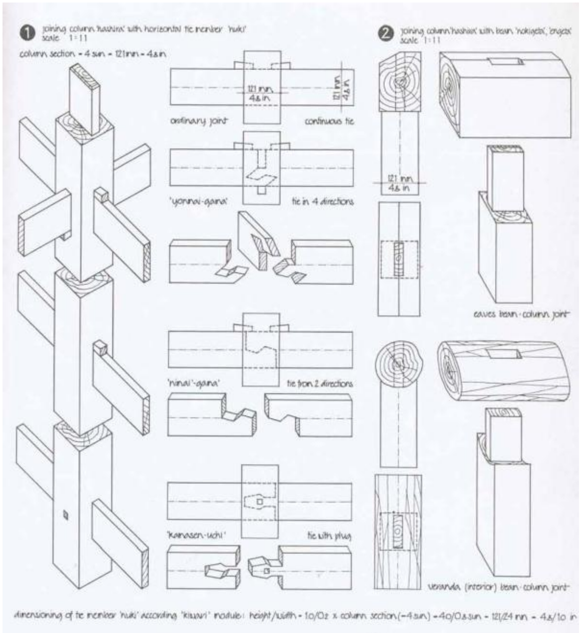


Figure 41: *Nuki*: Lateral Bracing
Source: Engel, 1989

The proposed pavilion takes into consideration traditional Japanese architectural design and construction methodology for a number of reasons. First, many of its design features are appropriate and complement the climate, environment, and the lifestyle of the local community. For example, raised on posts, the building creates minimum impact on the site. The use of a post and lintel system allows for large open bays where movable walls enable considerable passive climate control strategies in Hawaii's temperate warm climate. The engawa takes the function of the Lanai (or veranda, porch) a step further creating an intermediate space between the interior and the exterior.

The design of the pavilion may be very much in the Japanese style. However, this was done in order to gain a better understanding of the construction methodology of traditional Japanese residential architecture. Without taking these steps in learning, the research document could never be credited as a viable resource in Japanese pre-industrial timber framing design and construction.

Japanese design relied heavily on joinery for construction. This methodology is highly specialized, requiring years of learning and training by the apprentice under the guidance of a Master Carpenter. It takes about 15 years of training and hard work for a carpenter to be regarded as a good tradesman. This level of skilled labor has slowly diminished over the years, resulting in the decline of the traditional Japanese style of construction. Given this knowledge, it is difficult to fathom the use of Japanese joinery today. However, this is not to say that there is not a value in the methodology of building with joinery.

Technological advancements in design software (3D modeling, AutoCAD, and Revit) and machines that facilitate the fabrication process (CNC Machines) can help to reinvent, and in the same instance revive, the Japanese timber frame methodology. These design enhancing tools can help in facilitation the organization and production of wood joinery at a much greater speed than was once achieved. This research document is a testimony to this fact.

Just as the Japanese carpenters of old took pride in their craft, so must the designers and builders of today. To the Japanese, building was not just a job. It was a lifestyle rooted in their traditional value systems of everyday life, thought, and religious devotion. Here, Zen Buddhism played as important influential role.

In the *Book Zen Architecture: The Building Process as Practice*, the author, Paul Discoe states that "according to Zen teaching, everything that exists does so interdependently; everything that exists is a dependent co-arising."[39] The concept of co-arising is a fundamental part of Zen Buddhist teaching. The idea suggests a holistic view of the world where all things are intrinsically connected to one another, working together in a symbiotic relationship to successfully "co-arise," and co-exist. This notion is built into the value system of the Japanese carpenter

The idea of co-arising is not limited to human ideals of how nature functions. It also extends to elements of human creation and intervention, such as the built environment that has a profound effect on the way we live and interact with nature, and on nature itself. In dependent co-arising, the built environments we create must follow the guidelines of nature and the idea that everything created must exist in terms of relationships. Whether the relationship is positive or negative it will undoubtedly affect the system as a whole.

The Zen style of architecture attempts to nurture this idea of dependent co-arising by following a set of guidelines, or the principles of Zen design, in their design and construction methodology. The principles of Zen design are noted by Paul Discoe as having a flat site, the use of horizontal and vertical elements, specific room style that denote hierarchical order, a flexible open plan, roof-ism, use of relationships, and having focused energy.[40]

There is not a particular style to Zen Buddhist architecture, although some design features do remain constant throughout its various building forms, such as the ones mentioned above. In the Zen system of thought, these elements are to be treated only as reference points in establishing balance between humans and nature, the built environment with the natural environment, and not in verbatim.

There also exists in Zen Buddhism the idea that the truth lies beyond what the eye can see. When the untrained observer first looks at Japanese architecture, he or she views the building as being simplistic and subtle in design. However, what is overlooked by the observer is the fact that the building structure is a complex system of joints, hidden from the eye, which to be built, requires a level of technical skill, training, and practice that can only be described as methodical and in the Zen style of thought and in its building methodology. In Zen architecture, the final completed building is of importance, but only so far. What is of greater value is the process, the steps taken and involved, the care and thoughtful thinking used to in the creation of the building. This notion is the main contribution of this thesis, the idea of the "thesis as a process" of learning and designing.

Architects pride themselves in the "process" of design. Now they must find a way to include the process of construction into their design solutions to a project, since a great part of architecture is construction. This is especially true when considering sustainable architecture. In sustainable architecture a great many variables must be followed and the whole lifecycle of materials, the "cradle to cradle" idea presented by William McDonough, must be kept in focus and constant awareness in order to truly create a sustainable building. Traditional Japanese building methodology offers insight into this idea and that is why this thesis has been accomplished, to look into a historical past for present solutions to Hawaii's built environment.

[39] Discoe, 7
[40] Discoe, 21

BIBLIOGRAPHY

Ambrose, James and Tripeny, Patrick. *Simplified Design of Wood Structures*. Hoboken, New Jersey. Wiley & Sons, Inc., 2009.

Arsdale, Jay van. VIDEO: Japanese Handplanes: The Workings and Wonders of Kanna. A California Daiku Production, 2009.

Brown, Azby. *The Genius of Japanese Carpentry: The Secrets of the Craft*. New York, New York: Kodansha America, Inc., 1995.

Coaldrake, William H. *Architecture and Authority in Japan*. New York: Routledge, 1996.

Rao, Peggy L., Brackett, Len. *Building the Japanese House Today*. New York: Harry N. Abrams, Inc., 2005.

Discoe, Paul. *Zen Architecture: The building Process as Practice*. Layton, Utah: Gibbs Smith, 2008.

Engel, Heino. *The Japanese House: A Tradition for Contemporary Architecture*. Rutland, Vermont/Tokyo, Japan: Charles E. Tuttle Company Inc., 1964.

Engel, Heino. *Measure and Construction of the Japanese House*. North Clarenton, Vermont: Turtle Publishing Inc., 1985.

Hazleden, D. G. and Morris P. I. "*Designing for Durable Wood Construction: The 4 D's*." 8th International Conference on Durability of Building Materials and Components. May 30 – June 3, 1999. Vancouver, Canada.

Kishida, Hideto. *Japanese Architecture*. Japan. Board of Tourist Industry/Japanese Government Railways, 1936.

Kurokawa, Kisho. *Rediscovering Japanese Space*. New york, New York, and Tokyo, Japan: Weatherhill Inc., 1988.

McQuaid, Matilda. *Shigeru Ban*. New York: Phaidon Press Limited, 2003.

Unknown Author. Nihon Kenchikushi Zushiu. Tokyo, Japan: Nihon Kenchiku Gakkai, 1980.

Nishi, Kazuo, and Hozumi, Kazuo. *What is Japanese Architecture? A Survey of Traditional Japanese Architecture*. Tokyo, New York, London: Kodansha America, Inc., 1996.

Odate, Toshio. *Japanese Woodworking Tools: Their Tradition, Spirit, and Use*. Fresno, California: Linden Publishing Inc., 1998.

Sadler, A. L. *Japanese Architecture: A Short History*. North Clarenton, Vermont: Tuttle Publishing, 1963.

Sarvimaki, Magi. Lecture Notes: UHM, SoA, Arch 271: World Architecture and Urbanism A. Fall 2010.

Sato, Hideo, and Nakahara, Yasua. *The Complete Japanese Joinery*. Point Roberts, Washington, and Vancouver, British Columbia: Hartley and Marks Publishers Ltd., 1995.

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