J. W. Gottstein Memorial Trust Fund

The National Educational Trust of the Australian Forest Products Industries

GOTTSTEIN TRUST

The influence of traditional Japanese timber design and construction techniques on contemporary architecture and its relevance to modern timber construction.

By

Georgios Anagnostou

2017 GOTTSTEIN FELLOWSHIP REPORT

Sydney

Edited October 2018

1 JOSEPH WILLIAM GOTTSTEIN MEMORIAL TRUST FUND

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a **national educational Trust** for the benefit of Australia's forest products industries. The purpose of the fund is "to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."

Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

The Trust's major forms of activity are:

1. Fellowships and Awards - each year applications are invited from eligible candidates to submit a study programme in an area considered of benefit to the Australian forestry and forest industries.

2. Seminars - the information gained by Fellows is often best disseminated by seminars as well as through the written reports.

3. Wood Science Courses - at approximately two yearly intervals the Trust organises a week-long intensive course in wood science for executives and consultants in the Australian forest industries.

4. Study Tours - industry

The information contained in this report is published for the general information of industry. Although all reasonable Endeavor has been made to verify the accuracy of the material, no liability is accepted by the Author for any inaccuracy therein, nor by the Trustees of the Gottstein Memorial Trust Fund.

Further information may be obtained by writing to,

The Secretary, J.W. Gottstein Memorial Trust Fund,

PO Box 351 Macquarie ACT 2614, Australia.

gottsteinsecretary@gmail.com

2 Acknowledgements

The author would like to express his gratitude to the Gottstein Trust for the support it has provided to undertake the research trip to Japan which was essential for this project.

Special thanks go to:

Jackson Teece who have supported a previous research trip to central Europe and the participation at the World Timber Engineering Conference 2016, which has triggered and informed this particular project;

Adam Zgola, for his time and generous support in regards to his technical experience and Japanese language skills to help gain access to insights in traditional and contemporary Japanese carpentry and timber construction industry that otherwise, would have eluded the author;

Aya Utsumi from 'Aya Utsumi Architects Associates' and a member of 'Team Timberize', who was so kind to elaborate on some recent timber engineering projects and technologies as well as emerging trends in Japanese timber architecture and construction;

Yuki Ikeguchi and Marc Camille Moukarzel from 'Kengo Kuma Associates', Tokyo for the opportunity to meet and for their time to talk about the approach and inner workings of their practice and some of their local and international timber projects;

Mr. Nakahara for his time at the Mokuzai building (head office of the Japan timber wholesale association) and a private tour of the 'Timber Hall'.

3 About The Author

Figure 1 Georgios Anagnostou, Author

Georgios was founder of SKOPOStudio and co-founder of the design collaboration "funktionsraum" in Berlin, Germany. After completing a traditional carpenters' apprenticeship in Esslingen, Germany he worked internationally as a builder specializing in engineered timber construction. He established his career in architecture after graduating from The University of Applied Sciences in Berlin and located to Sydney in 2002.

He is an owner and director at Jackson Teece Architects and provides over 24 years of experience in architecture, design, planning and construction. His experience includes design and construction of timber engineered buildings, designs for residential, retail and commercial developments as well as healthcare and public projects. His experience in ESD projects includes sustainable masterplans, the delivery of 'green-star' certified commercial developments and low to zero energy houses in Australia and overseas.

Georgios is leading Jackson Teece's efforts in timber design and construction. His team has recently completed one of Australia's largest residential mass timber (CLT) projects in Circa Norwest, Sydney.

> *"I started my career with a very traditional carpentry apprenticeship in southern Germany and was a carpenter and builder before getting into timber engineering and ultimately graduating in architecture at The University of Applied Sciences, Berlin. Back than I would have never expected that Australia would become such an interesting place to work on cutting-edge timber engineered buildings.*
>
> *My specific interest in the subject of Japanese carpentry and timber construction stems from my time as a carpenter when I was extensively working with Japanese hand and power tools while attempting to master some of the intricate traditional connections. The opportunity to produce this report for the Gottstein Trust coincided with our (Jackson Teece) recent involvement with projects in Japan."*

4 TABLE OF CONTENTS

5 INTRODUCTION

The premise of this report is to connect the dots between contemporary timber architecture, current high-tech timber engineering and how traditional Japanese craftsmanship could be relevant to the development either.

We will start with a brief exploration of the rich history of traditional Japanese timber design and construction techniques and how these are deeply rooted in Japans cultural heritage and connection with its forests. An overview of traditional arts and craftsmanship and a summary of traditional design principles will form the basis of our understanding of the country's modern timber architecture and its influence internationally. But it is not only architectural design that has been influenced by traditional values and design aesthetics. It is also construction technologies and product design that has been informed by traditional techniques. The report will outline some specific areas of relevance and where certain traditional concepts have already found their modern application. Finally, a number of case studies will provide references and examples of adapted design and construction principles.

6 BACKGROUND

In order to understand and appreciate the connection between traditional craft, traditional and contemporary arts, design and architecture in Japan and how these influences have been relevant and continue to be relevant not only in its country of origin but worldwide, it is helpful to put things in context and understand some key aspects of Japans history, its cultural relationship between its forests, the use of timber and the crafts and technologies that have developed over the centuries. While this brief introduction does in no way try to be comprehensive, it attempts to make a connection between the country's history and the wealth of design innovation that has captured the attention and imagination of an international audience.

6.1 THE LAND OF FORESTS

Japan's climate is influenced mainly by its proximity to the Asian continent and two oceanic currents, the warm Kuroshio Current and the cold Oyashio, or Okhotsk Current. The country's humid, temperate monsoon climate provides excellent conditions for fast tree growth and allows for much faster re-forestation than for example in tropical rainforests.

i

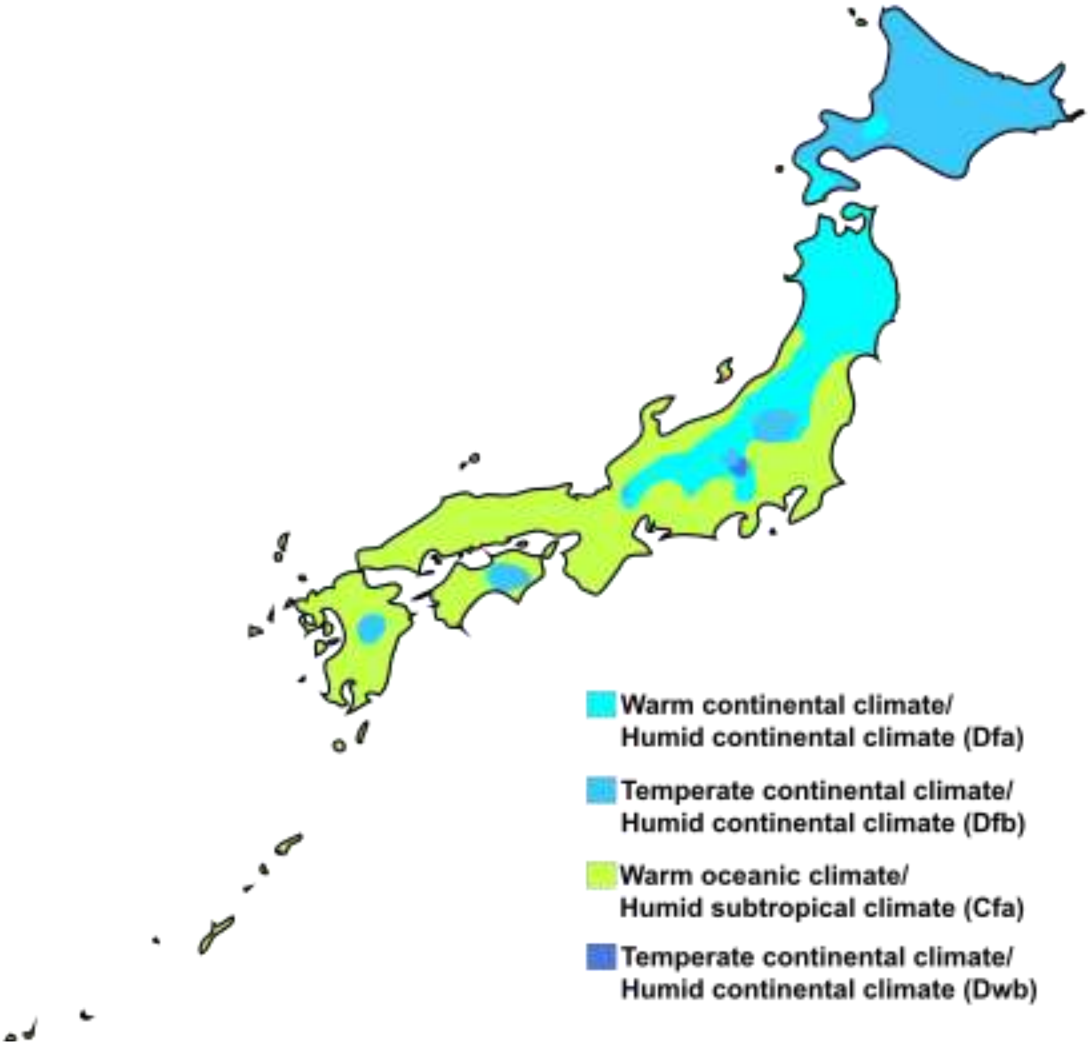


Figure 2. A Köppen climate classification map of Japan

THE ISLAND NATION OF JAPAN IS OFTEN REFERRED TO AS THE LAND OF FORESTS. BESIDES FINLAND AND SWEDEN JAPAN HAS ONE OF THE DENSEST FOREST COVERS AMONGST THE DEVELOPED COUNTRIES IN THE WORLD.

Before human intervention almost all of the country's volcanic archipelago was covered in forests. Initial major deforestation was due to the cultivation of rice by means of artificial irrigation, a technique introduced to Japan from Korea around 3000 years ago.

Figure 3. Rice Fields of SHIRAKAWA GO. Photo: GA

Later periods of major deforestation were related to the development of iron smelting technology and again as a result of the rebuilding efforts after WW2. Today still about 68.55% of the country's area is covered in forests, although the balance of virgin forests is tipped and commercial forestry faces serious challenges. Partially this is due to the fact that about 73% of Japan's topography consists of mountainous areas which makes forest cultivation and harvesting more difficult.

Japan's three distinct types of native forests are the coniferous spruce and fir forests of Hokkaido's northern and eastern regions; deciduous oak and beech forests, in the cooler regions of central Honshu and southern Hokkaido; and the broadleaf evergreen forests of western Honshu, Kyushu and Shikoku featuring chestnut, chinquapin and laurel.

Figure 4. INARI Shrine. Photo: GA

IN THE JAPANESE SHINTO RELIGION TREES HOLD RELIGIOUS SIGNIFICANTS. KAMIA OR MEGAMI ARE SPIRITS OF NATURE WORSHIPPED AS THE INTERCONNECTING ENERGY OF THE UNIVERSE MANIFESTED AS BEINGS, THE FORCES OF NATURE OR ELEMENTS OF LANDSCAPE SUCH AS MOUNTAINS, WATERWAYS, FORESTS OR TREES.

The oldest tree groves can often be found around temples and shrines and are protected. Such sacred groves were believed to be places where gods and spirits dwell and shrines and temples would be built in these locations. [ii]

Figure 5. KOTOHIRA Shrine. Photo: GA

Sometimes the protected groves around a shrine extend to entire forests behind a group of shrines and temples.

Figure 6. Broad leaf forest around the KOTOHIRA Shrine. Photo: GA

6.2 MANMADE FORESTS

While temperate broad leaf forests have declined considerably mainly lumber trees are cultivated. Amongst other cultivated species like hinoki, larch and cypress the main focus of commercial re-forestation is on “sugi”, the Japanese cedar. “Sugi” (Cryptomeria japonica) is considered the most economically important plantation tree in Japan and it is estimated that “sugi” constitute approximately 40 % of all plantation timbers and 20% of the entire manmade forest area in Japan (Forestry Agency, 2012).

Figure 7. Planted, 70 year old sugi forest in Niigata prefecture

DESPITE JAPAN'S LARGE TIMBER RESOURCES AND FORESTS, THE COUNTRY IMPORTS 80 PERCENT OF ITS TIMBER TO SATISFY MARKET DEMAND. THIS INCLUDES THE IMPORTATION OF UNCERTIFIED TIMBERS FROM COUNTRIES LIKE CHINA, RUSSIA AND INDONESIA IN TURN FUELLING DEFORESTATION OF TROPICAL RAINFORESTS IN THESE COUNTRIES.

Outdated and inefficient logging and transport techniques have made the local forest industry unable to compete with international competition. According to Adam Zgola [iii] the difficult lifestyle associated with traditional logging and forestry work has led to entire generations abandoning small villages in the mountainous region north west of lake Kanna in the south of Gunma Province.

In order to improve efficiencies and repair the industry the government has executed its forest and forestry industry revitalization plan in 2010. Industry bodies and academia, incl. institutions like Gifu

Academy of Forest, Science and Culture have looked to Central Europe and countries like Austria and Germany for solutions and ongoing collaboration.

Productivity has been improved. The daily transported volume of timber increasing to 11.2 cubic meters per worker. This is nearly four times the two or three cubic meters transported per worker before the village adopted the new method. Production costs dropped to 3,520 yen per cubic meter, less than a half of the previous cost of 8,000 yen to 10,000 yen. [Source: Yomiuri Shimbun, May 4, 2012]

"*The forest and forestry industry revitalization plan was compiled by the government in 2009. The plan aims to raise the nation's self-sufficiency rate of timber to 50 percent or more by 2020. The plan includes measures to train forestry technicians, reform forestry cooperatives and put national forests to practical use. National forests are expected to play the role of an engine in the revitalization of Japan's forestry industry. Putting national forests to practical use is considered easier than utilizing those owned by the private sector, which often lack clearly defined property lines and consensus among owners.*" [iv]

6.3 The High Art

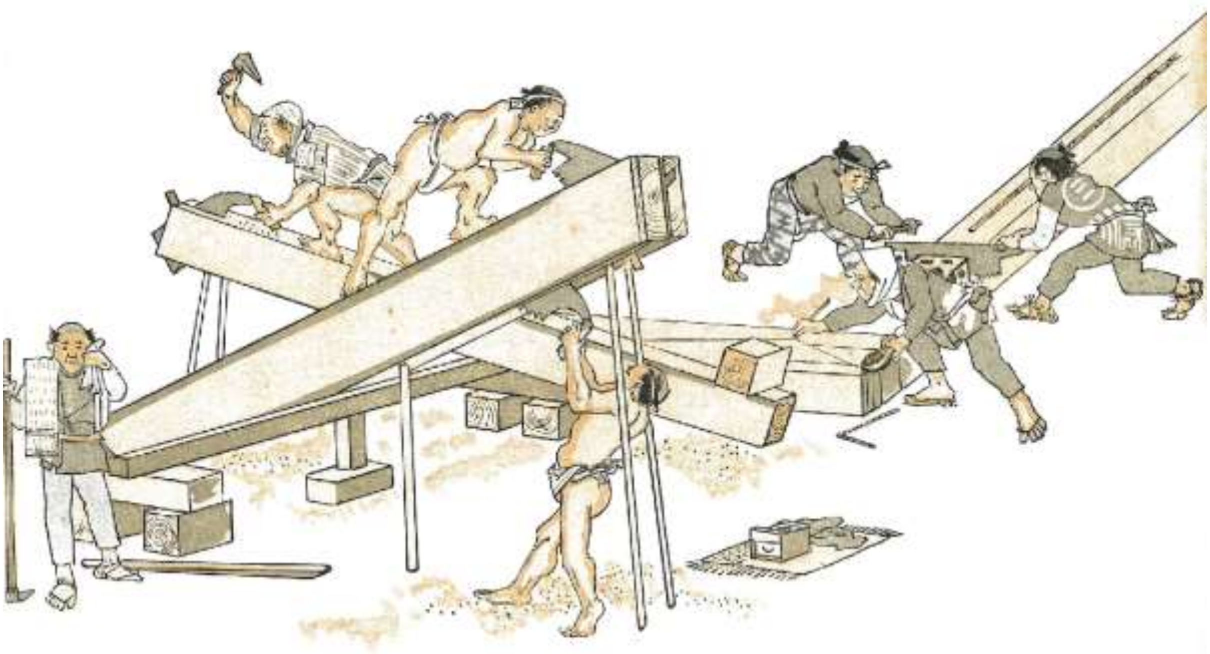


Figure 8 Traditional Carpenters Image: http://www.mokuzai-tonya.jp/

The appreciation of craftsmanship in japan is immediately apparent to the foreign visitor and can be witnessed in many aspects of Japan's everyday life. From highly prescriptive traditional ceremonies like the preparation of tea or the wrapping of gifts, to the more mundane acts of the preparation of food and serving of sake, the use of delicately crafted objects is involved. The skill and artistry once involved in producing the thin ceramic bowls, sheets of washi paper, the razor-sharp blades of folded carbon steel or finger jointed cedar boxes appears to extend to the way they are being used in everyday life. Thus, emphasizing the objects significance and highlighting societies appreciation of craftsmanship in general.

Figure 9 Sake served in a 'masu' (wooden box cup) Photo: GA

Symbolic values extend and connect seamlessly to the crafted object. The 'masu' catches the Sake spilling over when the glass is poured. Filling the glass to the brim and letting it overflow into the 'masu' symbolises the prosperity and generosity of the host.

Figure 10 KINTSUGI repair of a tea bowl Photo: https://www.urushi.info/kintsugi

Kintsugi **金継ぎ** or Kintsukuroi **金繕い** - a Japanese technique of repairing broken pottery with lacquer mixed with powdered gold, silver, or platinum is another example of the appreciation of the crafted object. As a philosophy, it treats breakage and repair as part of the history of an object, rather than something to disguise. [v]

Figure 11 Photo: https://i.pinimg.com/originals/6b/58/64/6b5864f253c35dcddf5f097e91e7a707.jpg

The above images demonstrate a n architectural application of the Kintsugi principle to a concrete floor.

AMONGST THE TRADITIONAL CRAFTS THE ART OF CARPENTRY IS ONE OF THE OLDEST AND MOST HIGHLY REGARDED. MASTER CARPENTERS HELD SIGNIFICANT SOCIAL STATUS (COMPARABLE TO THAT OF A BLACKSMITH).

This could be considered quite appropriate for a profession dealing with materials that are believed to have been inhabited by spirits (Kami, or Megami) and are of high importance in Shinto religion. The craft was also closely connected to the influences and changes of architectural styles imported from mainland China and later from the west, which introduced different woodworking techniques and structural systems.

Traditional Japanese carpentry can be divided in 4 distinct categories, Miyadaiku **宮大工** – the temple carpenter; Sukiya-daiku **数奇屋大工** – the tea-house carpenter; Sashimono-shi **指し物師** - the furniture maker, or joiner and Tateguya **建具屋** – specializing in the creation of room dividers, screens, doors and windows. The required knowledge of materials and understanding of proportion and geometry as well as the wealth of experience passed down from master craftsmen to apprentice over generations was usually well guarded (similar to western crafts like carpentry and especially stone masonry). The master carpenter's involvement begins with the selection of individual trees for felling according to their intended use and instructing methods of cutting and processing the lumber, long before the actual design and construction of the final object or building. The intricate knowledge of wood as a material, the qualities of different species, location and context in which individual trees have grown and resulting stresses within the trees, long and short-term behaviour relating to climate, season and moisture content informs all aspects of the craft.

THE FUNDAMENTAL UNDERSTANDING OF THE MATERIAL 'WOOD' FORMS THE VERY BASIS OF TRADITIONAL TECHNIQUES AND DESIGNS.

The understanding of material properties and the ability to predict its behaviour inform not only which species is used for what application, but also the design of joints, processing techniques (like the use of water and fire), the design of tools, the shape of individual objects or structural building members and the design of buildings.

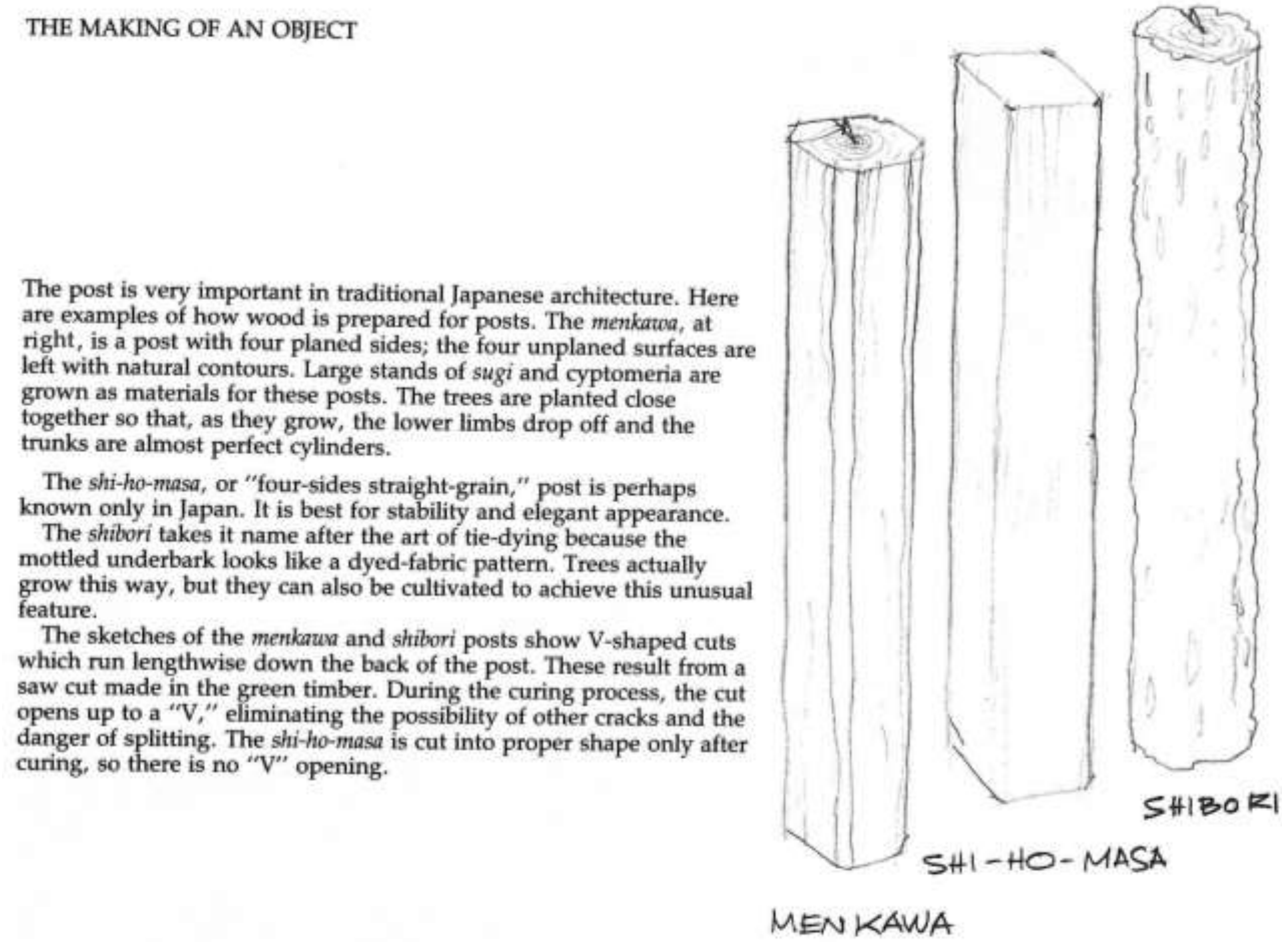
A further source of information on the craft and its history is the Takenaka Carpentry Tools Museum in Kobe, Japan. A place to experience, understand and possibly revive lost wisdom and aspects of traditional work methods and design.

6.3.1 The Art Of Working With The Grain - Material knowledge

The traditional use of materials is in great contrast to the modern approach of homogenising and standardising materials to arrive at a fully engineered product by means of deconstruction and reconstitution. Rather than seeking to eliminate the diverse and distinct characteristics and qualities of individual sections of timber, trees were either specifically selected or even grown and cultivated for a particular purpose and specific applications according to species, shape, visual attributes, resilience, etc.

FUTURE MOVEMENTS OF TIMBER SECTIONS ARE ANTICIPATED AND TAKEN INTO ACCOUNT IN THE DESIGN, DETAILING AND INSTALLATION.

All timber sections are selected for their individual attributes and installed accordingly. Each timber section has a direction, a top and bottom, an inside and outside, an up and down side. Siding boards are installed considering future cupping according to which side used to face towards the centre of the trunk and which faced outward. Straight trunks will become posts, curved sections will be used as a beam, utilising the curve as a camber, similar to a pre-stressed, engineered beam.



THE MAKING OF AN OBJECT

The post is very important in traditional Japanese architecture. Here are examples of how wood is prepared for posts. The *menkawa*, at right, is a post with four planed sides; the four unplaned surfaces are left with natural contours. Large stands of *sugi* and cyptomeria are grown as materials for these posts. The trees are planted close together so that, as they grow, the lower limbs drop off and the trunks are almost perfect cylinders.

The *shi-ho-masa*, or "four-sides straight-grain," post is perhaps known only in Japan. It is best for stability and elegant appearance.

The *shibori* takes it name after the art of tie-dying because the mottled underbark looks like a dyed-fabric pattern. Trees actually grow this way, but they can also be cultivated to achieve this unusual feature.

The sketches of the *menkawa* and *shibori* posts show V-shaped cuts which run lengthwise down the back of the post. These result from a saw cut made in the green timber. During the curing process, the cut opens up to a "V," eliminating the possibility of other cracks and the danger of splitting. The *shi-ho-masa* is cut into proper shape only after curing, so there is no "V" opening.

Figure 12 from 'The Soul of a Tree' by George Nakashima

The above figure describes an example of 'kerfing' (used in posts and beams alike). During the curing process the saw cut opens to a V- shape, eliminating the possibility of other, uncontrolled cracks on the visually exposed sides. The tree for the post is selected, processed and installed according to the predicted behaviour with the kerfed side hidden within or against structural elements.

Azekura is a log-cabin style construction method, typically used for the construction of storehouses. Shoso-In is an 8th century treasure repository at Todai-ji, in Nara.

Figure 13 Shoso-In

Un-chinked joints open in dry weather and ventilate the building. They close during humid periods and seal the building keeping the building dry.

Figure 14 Shoso-In corner detail

6.3.2 The Art Of Planing - KANNA

One of the most highly used items in any western joinery workshop would have to be sandpaper. Sanding timber to shape and finish work pieces or prepare surfaces for finishing (with oil, lacquer or paint) is so ingrained in the western timber craft and industry that one will hardly find a highly finished timber product that hasn't been subjected to the process at some stage. Yet, it is highly unlikely one will find a single scrap of sandpaper floating around in a traditional Japanese timber workshop.

"We use no sandpaper at all when crafting our furniture. Sandpaper rubs away the natural pattern of the wood, leaving behind a smoothness that is artificial and which obscures the tree's innate characteristics. In contrast to this, the KANNA cuts away successive layers of wood in a way that preserves the wood's natural appearance." [Tokunaga Furniture Studio] [vi]

THE KANNA 鉋 (JAPANESE HAND PLANE) PLAYS A CENTRAL ROLE WHEN IT COMES TO ACHIEVING A HIGHLY FINISHED SURFACE OF A WORK PIECE, OR THE DIMENSIONAL ACCURACY REQUIRED FOR THE EXECUTION OF THE NUMEROUS INTRICATE TRADITIONAL TIMBER JOINTS.

It is also a prime example for the highly specialised tools that have evolved around the processing of timber. At a planing competition during the annual Kezuroukai exhibition in Japan craftsmen attempt to slice the thinnest shaving of timber possible, where shavings of up to 3 microns are achieved.[vii]

Figure 15 Precision in tool preparation and execution are essential.

Figure 16 The carpenter aligns the blade and adjusts the cutting depth

Like the blades of the Nomi 鑿 (Japanese chisel) or even the KATANA 刀 (the long, single-edged sword used by Japanese samurai) the blade of the KANNA is forged of two different types of folded carbon steels, a softer metal for the hilt to absorb impact of the push or hammer stroke and a harder metal that allows to form a razor-sharp edge for slicing, cutting or prying (depending on the particular type of tool and its intended use).

Figure 17 Example of a wood shaving

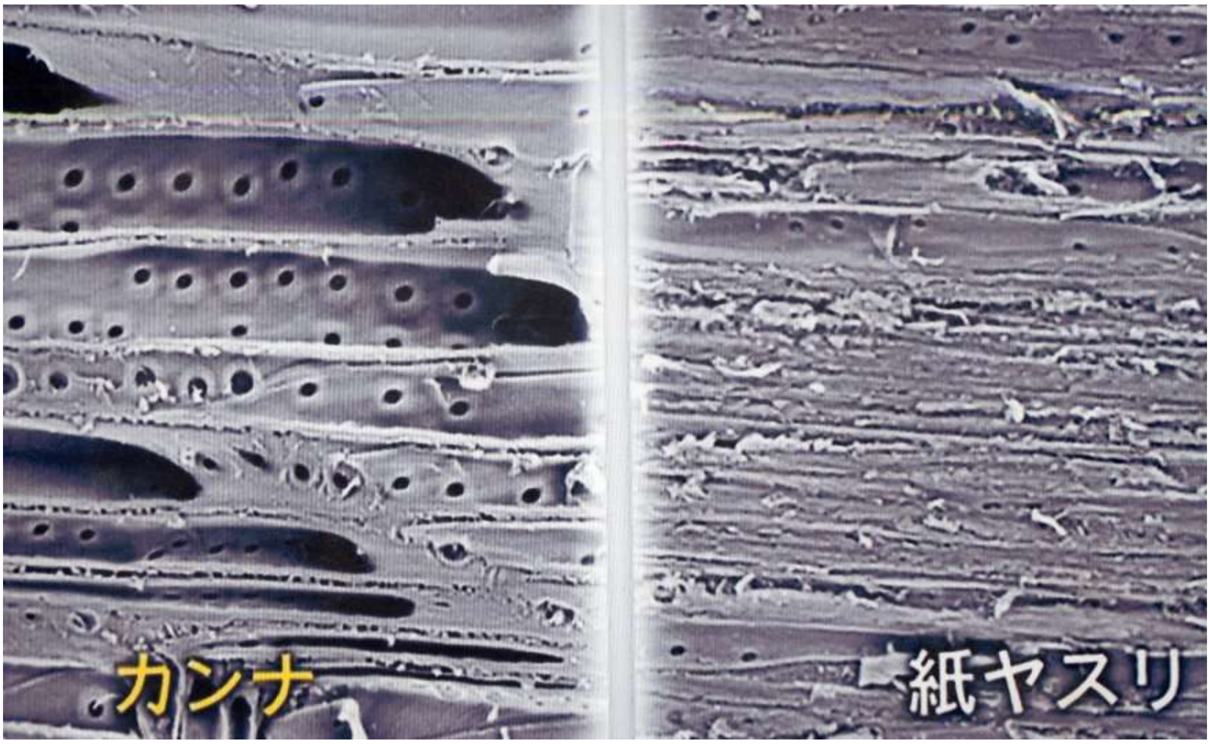


Figure 18 Planed surface (left) and sanded surface (right) Photo: Tokunaga Furniture Studio

Surface preparation by hand planning facilitates accuracy in framing connections (increased surface area). It is understood that the planed surface has distinct advantages over sanded or rough sawn surfaces in regards to water resistance and vapor transmission (cell structure on the surface remains intact, water droplets form). The process of sanding will tear the grains rather than cutting them and thereby destroying the timber's cell structure as can be observed under a microscope. Planing on the other hand slices through the cells, leaving their structural integrity intact. This affects the hydroscopic properties and the way water is absorbed on the timber surface.

Figure 19 Water absorption of planed vs sanded finish Photo: Unknown

The planed surface is presumably resisting moisture absorption more than the a sanded one by allowing the liquid to maintain surface tension at the contact area and to form droplets. This is obviously highly desirable when leaving timber untreated or when exposing untreated surfaces to the elements, as it is still common practice in Japanese timber construction. This behaviour would have to be considered however, if the surface was to be sealed or glued, since this may lead to lesser penetration of any applied sealer or glue and may affect adherence or bonding.

Another tool worth mentioning is the NOKOGIRI 鋸 (Japanese pull-saw) which stands out especially when directly compared to its western counterpart. The western handsaw typically cuts on the push-stroke. This can lead to buckling of the metal, potentially jamming the blade within the saw cut. The NOKOGIRI 鋸 cuts on the pull-stroke which straightens the blade while cutting allowing for much thinner saw blades to be used and providing more control when directing the blade - resulting in more accurate cuts.

6.3.3 The Art Of Working With Water – NAKAGAWA SHUJI (a cedar bucket)

While the use of water in connection with steaming and bending timber sections is quite established in joinery workshops it is less practiced in general carpentry and timber framing in the west.

An exemplary use of using water in the assembly of the traditional Japanese NAKAGAWA SHUJI, a cedar bucket used for carrying water and grains is described in Hugh Miller's study on Japanese Wood Craftsmanship:

"An ingenious use of water was found in the assembly method of Nakagawa Shuji's cedar buckets. Staves of wood are joined together to form the sides of the bucket, and the base is inserted at the end. These buckets are used to carry water and rice, and so must be watertight. A base tacked onto the bottom would leak and so it must be jointed into the construction in a tight ftting groove. However, if you attempt to insert a bucket base sized to ft perfectly into a groove inside a pre-assembled bucket, the base will foul on the inside faces of the bucket before it can get into that groove. The way of achieving this seemingly impossible bucket-and-base assembly is to utilise woods ability to expand when moisture is introduced. A hammer is used to compress the fibres all around the edge of the base. This makes the base slightly smaller than its natural size, and so allows it to be positioned into the groove in the bucket sides. The base of the bucket is then soaked in warm water. This plumps up the compressed fibres, expanding them into the groove in the bucket side. When dried, the wood will remain in its expanded state, creating a sealed base in the bucket whether wet or dry."

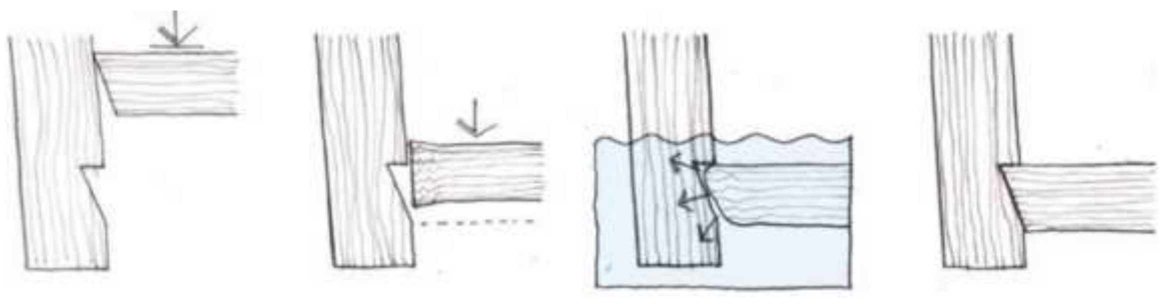


Figure 20 Sketch out of Hugh Miller's JAPANESE WOOD CRAFTSMANSHIP

viii

Other uses of water or steam include methods of finishing difficult surface areas and sections of timber, where the grain has grown in different directions around branches or knots. In order to get a perfect finish such areas are temporarily subjected to water to raise moisture content, soften the fibres and cause localised swelling. The subject areas are then hand planed with a KANNA 鉋 (plane) or finished with a NOMI 鑿 (chisel). Once the area has dried out and the swelling has subsided a flush surface will be achieved.

The method most relevant to the assembly of tight timber framing joints is the one least known and practiced in western carpentry.

INDIVIDUAL FRAMING MEMBERS ARE KEPT AT DIFFERENT MOISTURE CONTENTS PRIOR TO BEING ASSEMBLED. THIS RESULTS IN A SELF-TIGHTENING JOINT AS THE INDIVIDUAL MEMBERS DRY OUT AFTER ASSEMBLY.

In the case of the typical Japanese lock joints it is the square pegs that are kept at a lower moisture content than the main members and/or utilize species that react differently to moisture. Other techniques involve the timing of cutting the joint - either well in advance or shortly prior to assembly. Once the pieces have equalized the pegs have swollen relative to the joint members and tighten the joint.

Figure 21 Lock Joint Phot: http://itook.co/japanese-furniture-plans/

6.3.4 The Art Of Working With Fire - SHOU SUGI BAN (Charred Cedar)

Shou Sugi Ban 焼杉板, also known as Yakisugi 焼杉 is a traditional Japanese method of preserving exposed timber elements. The process of charring is said to protect wood against fire, rain, rot, and insects. When the wood is burned it changes both the cellular structure and thermodynamic conductivity of the timber. The softer, more reactive, cellulose compounds vaporize, while the harder lignin takes a lot longer to burn. Resulting in the lignin requiring a lot higher heat and exposure to flame for it to ignite again. The technique forms a carbon layer on the surface of the timber which provides an insulating barrier that retards further degradation resulting in a pre-charred product.

The aesthetic quality of the charred timber application for facades enjoys growing popularity in contemporary architecture in Japan and the West alike.

Figure 22 Shou Sugi Ban 焼杉板

Figure 23 Bar in KYOTO, Detail Photo: GA

Figure 24 Bar in KYOTO Photo: GA

Aside from charring, smoked timber can also be found in many old buildings for external as well as internal applications. Yoshidake Okoshi is a privately owned and operated heritage timber framed building with a traditionally thatched roof. Some of the government-imposed heritage conditions, which can be very onerous for significant heritage buildings, include that the open fireplace is continued to be operated in order to keep the exposed timber roof structure and thatching treated with smoke against insects, fungi or moisture damage.

Figure 25 Yoshidake Okoshi Photo: GA

Figure 26 The mistress of Yoshidake Okoshi with the author and Adam Zgola around the open fireplace Photo: GA

6.3.5 The Art Of Joining

The joining of individual timber members has been the most fundamental principle of construction for millennia. Whether the pieces were stacked on top of each other, tied together or spliced and joined with mortice and tenon, scarf or lap joints, doweled or nailed, bolted or glued - or any combination of the above. Today the sophistication and accuracy of traditional timber joints is probably the most outstanding and recognised aspect of Japanese carpentry which has elevated the craft to a true form of art. To cover the entire spectrum and complexity of traditional timber joints is beyond the scope of this report. However, the following paragraph aims to give a brief summary of key aspects.

JOINTS USED IN THE CONSTRUCTION OF BUILDINGS OR BRIDGES ARE PRIMARILY DESIGNED TO FORM SOFT MOMENT CONNECTIONS WITHIN THE STRUCTURAL FRAME. THIS IS ALSO TRUE FOR MANY JOINTS USED IN TRADITIONAL JOINERY.

The complexity of the various joint types aim to:

- Maximise the surface area between the connected members
- Mitigate and/or utilise the effects of timber movement (swelling shrinking due to changing moisture content)
- Create homogeneous connections without the use of steel connectors
- Facilitate workflow during the assembly sequence
- Allow disassembly for repair or relocation of structures

Figure 27 Timber Gates at KANAZAWA Castle; restored (left), original (right) Photo: GA

Figure 28 Timber Gates at KANAZAWA Castle; Detail, planed finish Photo: GA

One of the factors often associated with the development of the complexity of traditional Japanese timber joints is Japan's geographic location which historically is prone to earthquakes. According to Adam Zgola, this may have been a potential factor especially for temple architecture (influenced by styles from the Asian mainland/continent). However, significant destructive seismic events would have occurred over considerable timespans and would have been too few and far between to provide enough empiric data to solely inform the entire repertoire of Japanese framing connections, particularly when looking at the designs for teahouses and residential buildings. The consideration of the long and short-term behaviour of the individual timber sections and their predicted movements (like splitting, warping or twisting) would have played a more significant role, says Adam.

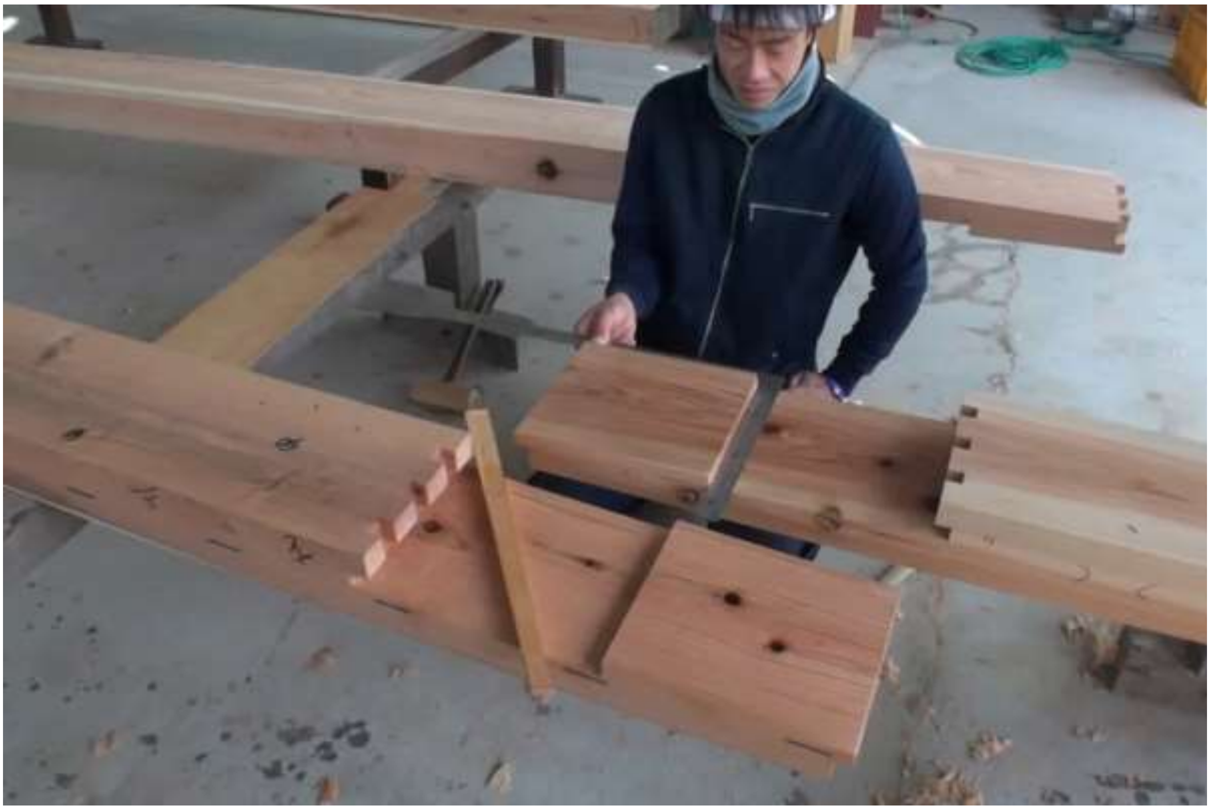


Figure 29 KANAWATSUGI joint prior to assembly Video: https://youtu.be/W1pvUlQgYtk

Figure 30 KANAWATSUGI joint during assembly Video: https://youtu.be/W1pvUlQgYtk

ix

Figure 31 Marked framing members in Zgola's workshop Photo: GA

Figure 32 Marked framing members in Zgola's workshop. Photo: GA

Individual timber sections are carefully selected and assigned to form specific framing members according to their structural attributes (shape, grain structure, trunk section, etc).

DEPENDING ON THE FUNCTION WITHIN THE STRUCTURAL FRAME MULTIPLE SUITES OF JOINTS ARE AVAILABLE TO FORM SPECIFIC CONNECTIONS. BUT THE FINAL SELECTION OF THE JOINT DESIGN WILL BE GOVERNED BY BOTH, THE FUNCTION OF THE MEMBERS WITHIN THE FRAME AND THE INDIVIDUAL CHARACTERISTICS OF THE PIECE OF TIMBER.

As the natural shape of the timber sections is integrated within the frame design the timber section's natural shape is largely preserved. Beams for example would only be shaped or squares off on the sides and where they are joined to other members but leaving as much of the grains within the structurally loadbearing zone uncut and intact. Thus, utilizing the natural camber of a curved member.

Figure 33 Hand-fabricated frame for a single residence, ready for assembly. Photo: GA

The development of the specialized tools required to produce the complex connections with sufficient precision went hand in hand with the development of the design for framing and furniture joints. As traditional joints are still used in contemporary Japanese timber construction modern power tools are used to produce them. Tools that are specifically designed to allow the execution of very sophisticated joints – tools that would stand out in any western carpenter's or joiner's workshop.

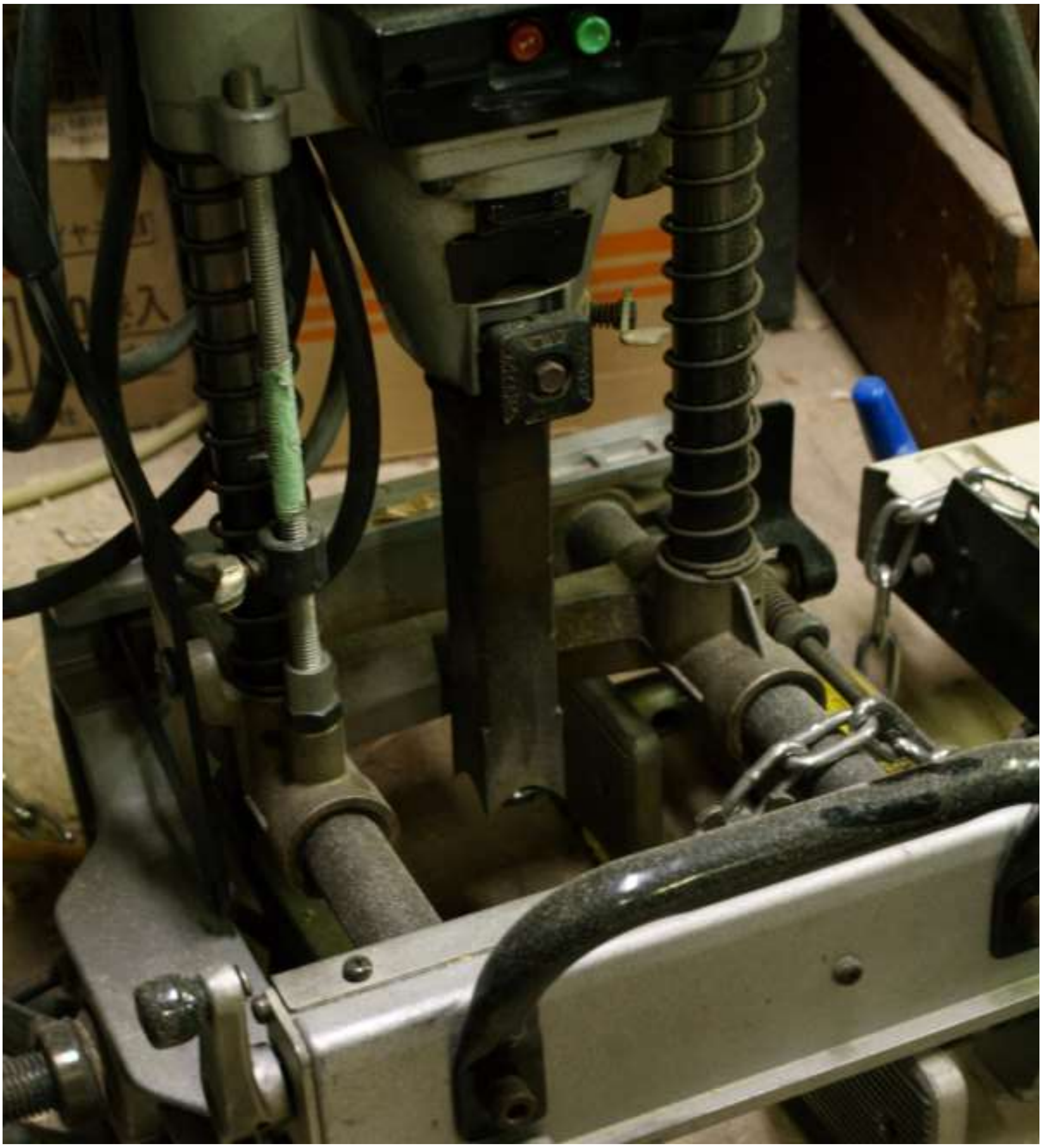


Figure 34 Clamp-on drill press with drill bit for square holes. Photo: GA

Figure 35 MAKITA Groove Cutter Video: https://www.youtube.com/watch?v=PsFXR-3QbN8

Figure 36 MAKITA 2516n Timber router Video: https://www.youtube.com/watch?v=ABmOYOsbytE

Figure 37 MAKITA 5000s Tenon cutter Video: https://www.youtube.com/watch?v=ANCmMOuB-Vw

6.4 TIMBER FRAMES AND STRUCTURAL SYSTEMS

6.4.1 Design and Proportion

From ancient Greek temples and Roman plazas to Le Corbusier's 'Modulor' architectural design was based on methods to construe ideal proportions.

IN JAPAN THIS EXPLORATION OF THE PERFECT MEASURE AND THE SEARCH FOR THE PERFECT ORDER IS KNOWN AS KIWARI 木割, LITERALLY "DIVIDING WOOD".

The principle evolved from a concept of merely establishing the proportions of structural members into Kiwari-Jutsu, a formalized system of prescribed design techniques. Of the various Kiwari Systems that have been formalised and written down since before the Kamakura period (1185 – 1336) the best known is probably the five volumes of Shoumei 匠明 from1608. The system is scalable and relates members sectional sizes to span, height and rhythm of posts, walls and openings, as well as room heights to plan proportions.

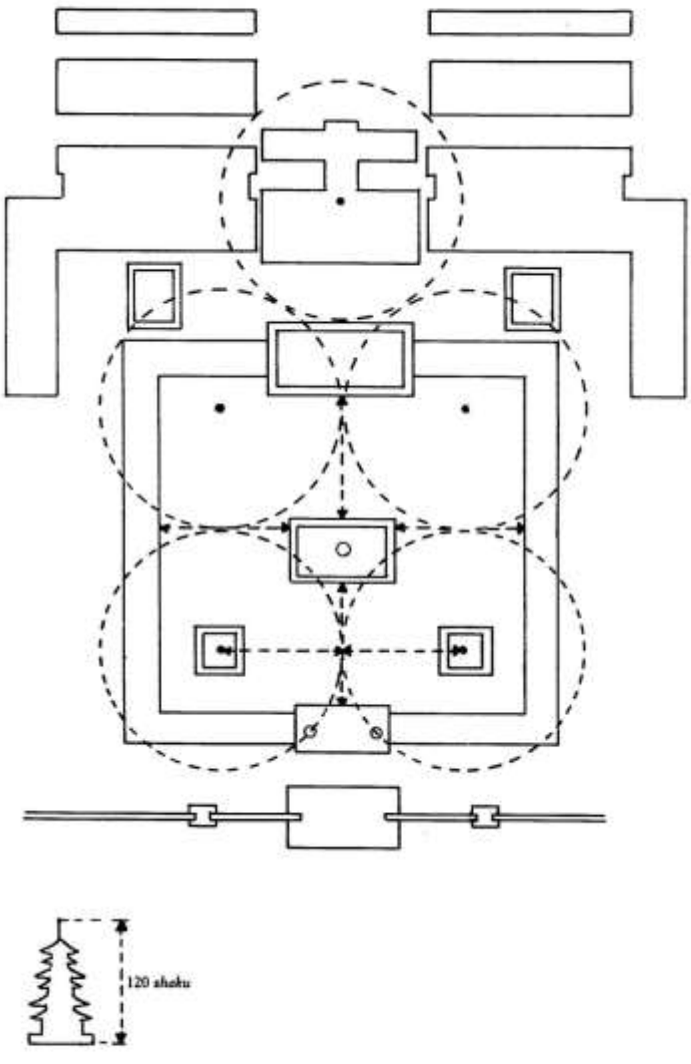


Figure 38 Proportional diagram of the Yakushi-ji temple complex. [Brown, 1989]

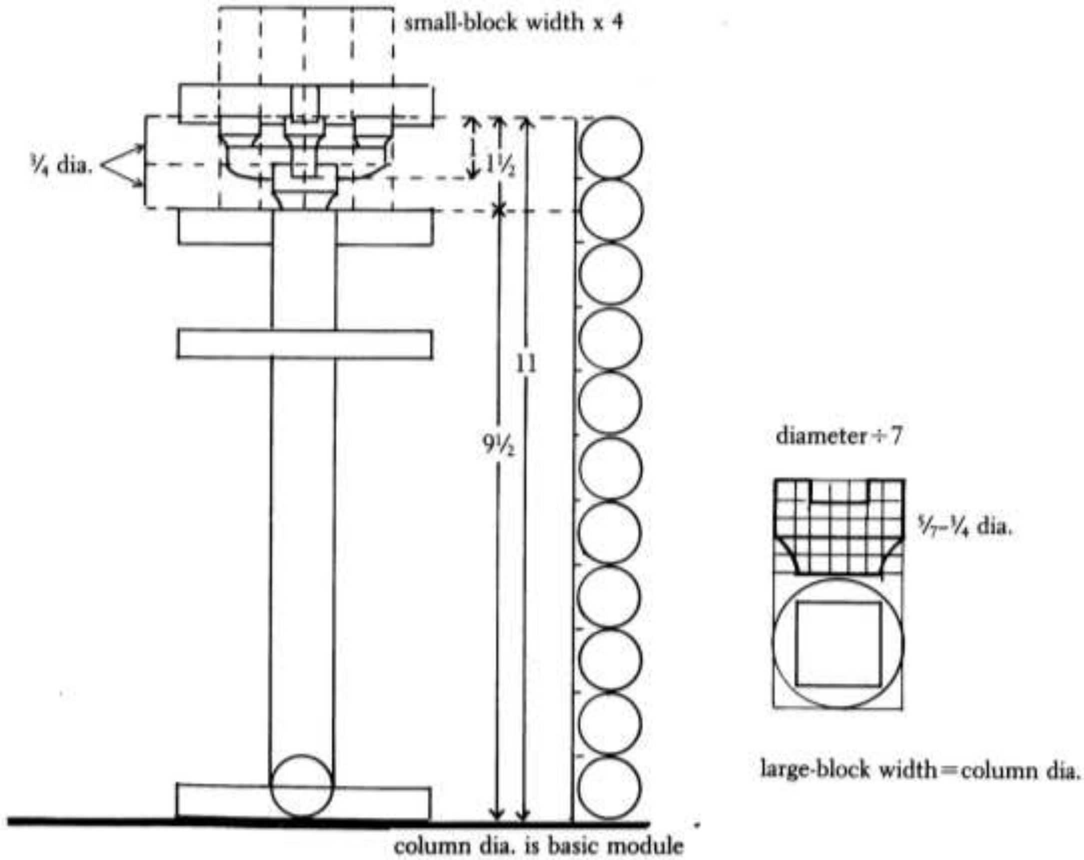


Figure 39 Example of the kiwari method. Proportion of column diameter and altitude. [Brown, 1989]

"AS A RESULT OF THE ADOPTION OF THIS PROPORTIONING SYSTEM, ARCHITECTURAL CONSTRUCTION BECAME A COMPREHENSIVE, UNIFIED, RATIONALLY ORGANIZED INDUSTRY, CONTROLLING EVERYTHING DOWN TO THE SIZES OF WOODEN MEMBERS AVAILABLE IN THE LUMBER MARKET." [x]

Another important system which was an integral part of traditional carpenter training in Japan is kiku (**規矩**). It describes of the traditional roof forms with their curved main roof planes and upsweeping overhangs and eaves and the complex geometry resulting for the individual structural members and junkions. Kiku was established as established as a geometrical and mathematical concept by the second half of the 18th century.

"Also read sumigane **墨矩**; kikujutsu **規矩術**; tsubokane **壷矩**.

- Also called yatsunaka **八中**, honnaka **本中** or umanorinaka **馬乗中**. Plans drafted to the actual size of various parts of a structure. These parts may include: the bracket complex *tokyou **斗きょう**, including the joinery of bearing blocks *masu **斗**, and bracket arms *hijiki **肘木**, the details of roof structure; rafter *taruki **垂木**, placement; cross section drawings *danmen-zu **断面図**, etc. The technique advanced remarkably from the 17c onward. The word kiku junjou **規矩準縄** sums up the method: ki **規** is measure, ku or kane **矩** is a carpenter's square or ruler; hence, kiku.; jun **準** means in proportion to and jou **縄** means a marking line. The use of this system as the basis of construction resulted in highly developed and precise techniques, and the development of the modular system called *kiwari **木割**.
- Kiku is also used as a synonym for *kiwari **木割**." [JAANUS] [xi]

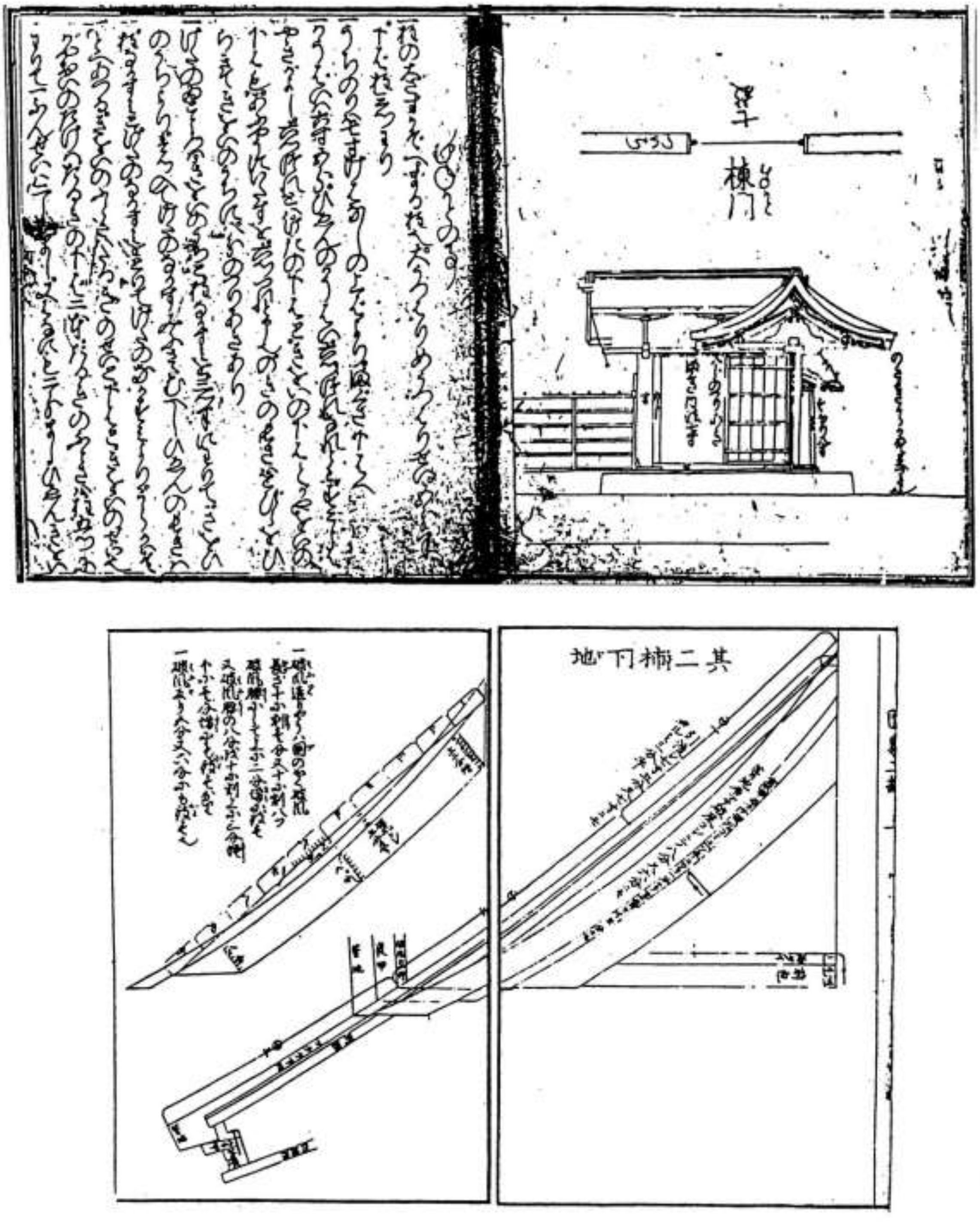


Figure 40 KIKU, Guidelines for determining the roof gable arch at the entrance of the Samurai residence. [Coldrake, 1990]

A this point the tatami principles should also be mentioned since their exploration was a very early and fairly systematic attempt to establish a modular grid system. Although it never really constituted a real modular system for design or construction purposes.

WHILE THE TATAMI, OR 'JO' IS CLOSELY RELATED TO STRUCTURAL GRIDS, PROPORTIONS AND STANDARD ROOM SIZES, IT HAS NEVER FUNCTIONED AS A TRUE UNIFYING MODULE FOR EITHER CONSTRUCTION OR BUILDING DESIGN.

Figure 41 Tatami Room in the Nakano Yoshimori Residence, Shirakawa-Go. Photo: GA

The different tatami systems deal with the fundamental problem of integrating the dimension of the structural members into a uniform structural grid reconciling the centre to centre dimension with the dimensions of clear openings.

Comparison of the kyo-ma method (1 ken = 6.5 shaku; only one standard mat with varying column grid) and the inaka-ma method (1 ken = 6 shaku; various mat sizes derived from the fixed centre to centre column grid).

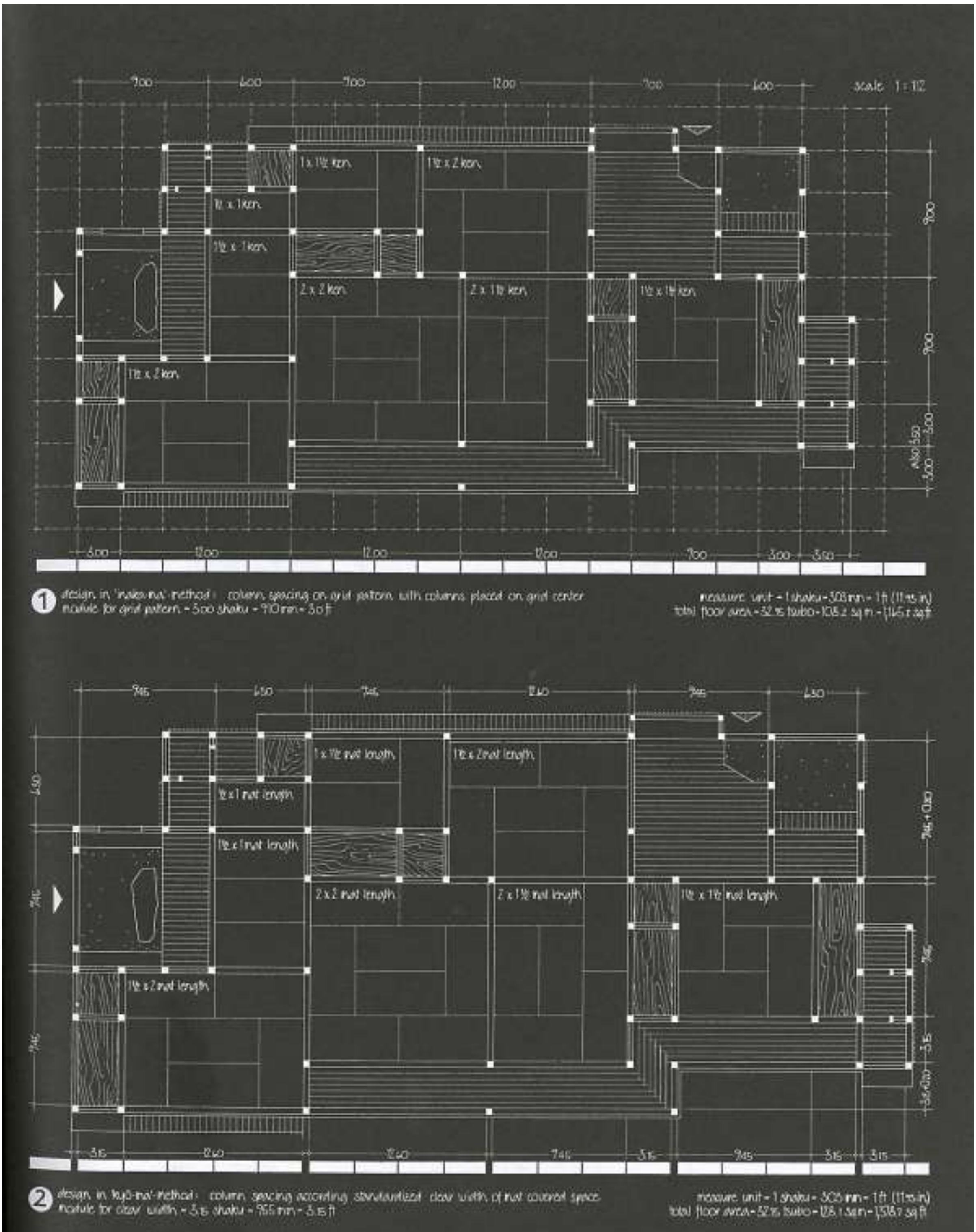


FIGURE 12: A comparison of the *kyō-ma* and *inaka-ma* methods of design.

Figure 42 Comparison of design methods [Measure and Construction of the Japanese House, Heino Engel]

6.4.2 Domestic Framing Methods

The traditional Semi-Rigid Frame was predominantly used for two storey houses. It comprises of a post and beam system with ductile joints that transfer lateral loads. Generally, no diagonal stiffeners are used. The posts are continuous with the beams joined at ground, first and roof level (similar to the 'balloon framing' principle). The post – tie beam joints are designed for assembly and disassembly and provide strong ductile restoring forces in seismic events. Frames have been prefabricated off site for onsite assembly.

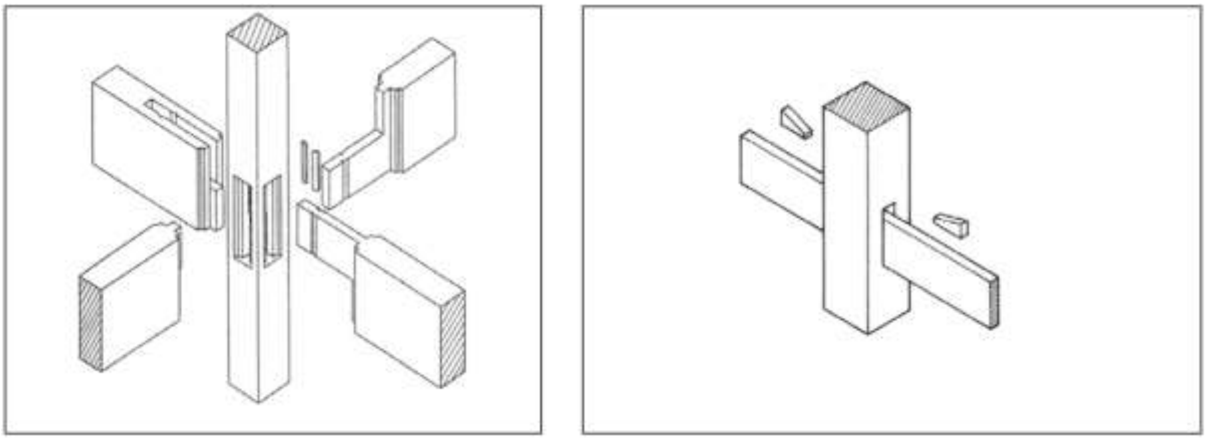


Figure 43 Traditional Post and Beam connection (left). Traditional Column - Girth joint (right). [Mokuzou Kenchiki Kenkyu Forum, Encyclopedia of wood architecture, Gakugei Shuppan, Kyoto, 1995].

Each post rests on individual stone footings with footing designs varying for different load and ground conditions.

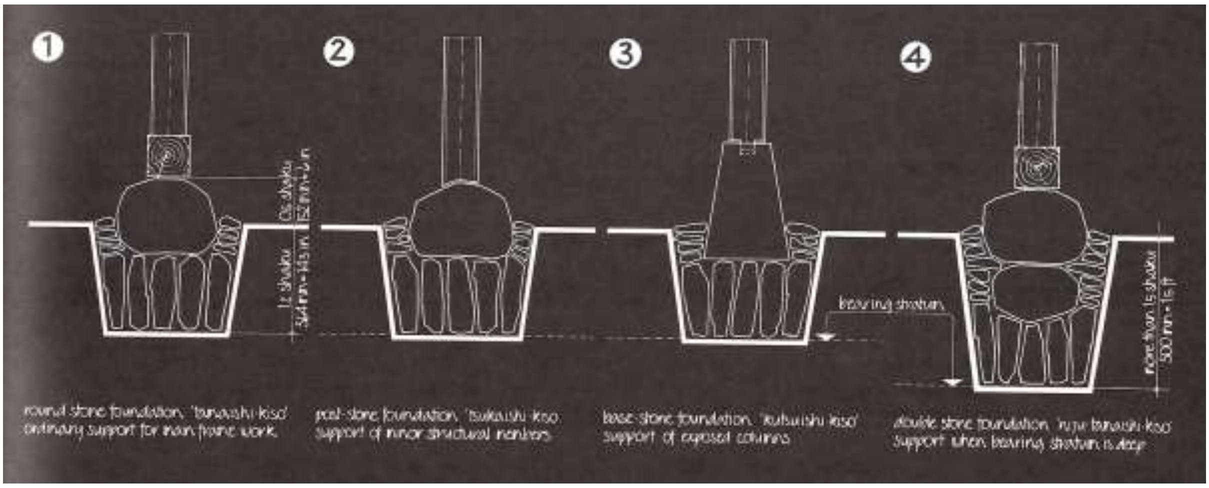


Figure 44 Footing Design [Measure and Construction of the Japanese House, Heino Engel]

Figure 45 Post detail, Shirakawa-Go. Photo: GA

The above detail shows how, rather than being fixed or doweled to the footing the, bottom detail of the post is precisely scribed and shaped to the natural form of the stone. This allows the frame to rock and move on the footing.

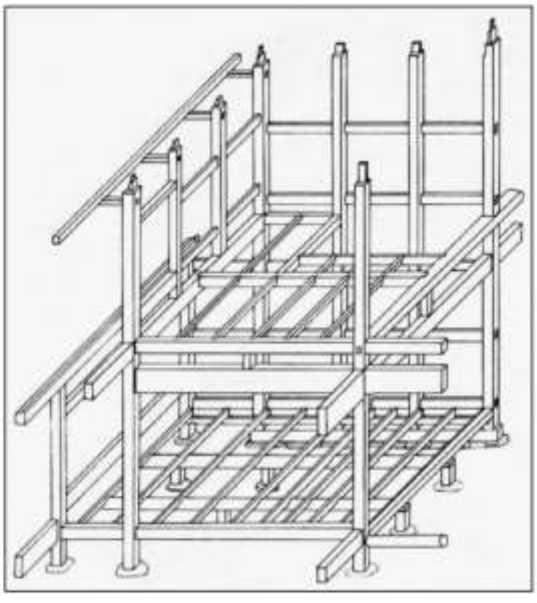


Figure 46 Framing system of Takagi House in Nara (left); Kita House in Ishakawa (right), both early 19th century. [H. Tanahashi & Y. Suzuki Ritsumeikan University, Japan; Embedment Mechanism and Formulation of Major types of traditional wooden joints in Japan]

There are exceptions that can be found for traditional framing in some buildings that utilize diagonal stiffening elements within the framing system or inserted as wall elements. The above example shows the interior of Café Sarasa, a former bath-house with extensive tiled areas to internal areas. The tiling required a stiffer substrate to avoid cracking. This is an instance where diagonal stiffeners were used in combination with traditional framing methods.

Figure 47 Cafe Sarasa 澡堂咖啡館 in Nishijin, Kjoto – former bath-house. Photo: GA

Figure 48 Yamashita Harurou Residence, Gassho-Style house in Shirakawa-Go. Photo: GA

Figure 49 Yamashita Harurou Residence, Gassho-Style house in Shirakawa-Go. Photo: GA

The above examples are typical farmhouse in the area around the villages of Gokayama, Shirakawa-Go, Suganuma and Ainokura. They were homes to large families spanning several generations. While they may look very similar to each other the houses of each village have distinct differences. For example, the roof pitches of Suganama and Ainokura Village are saif to be slightly steeper due to heavier snow fall in this area. The main feature of the above Gassho-Style houses is their A-Frame roof structure and the thatching technique.

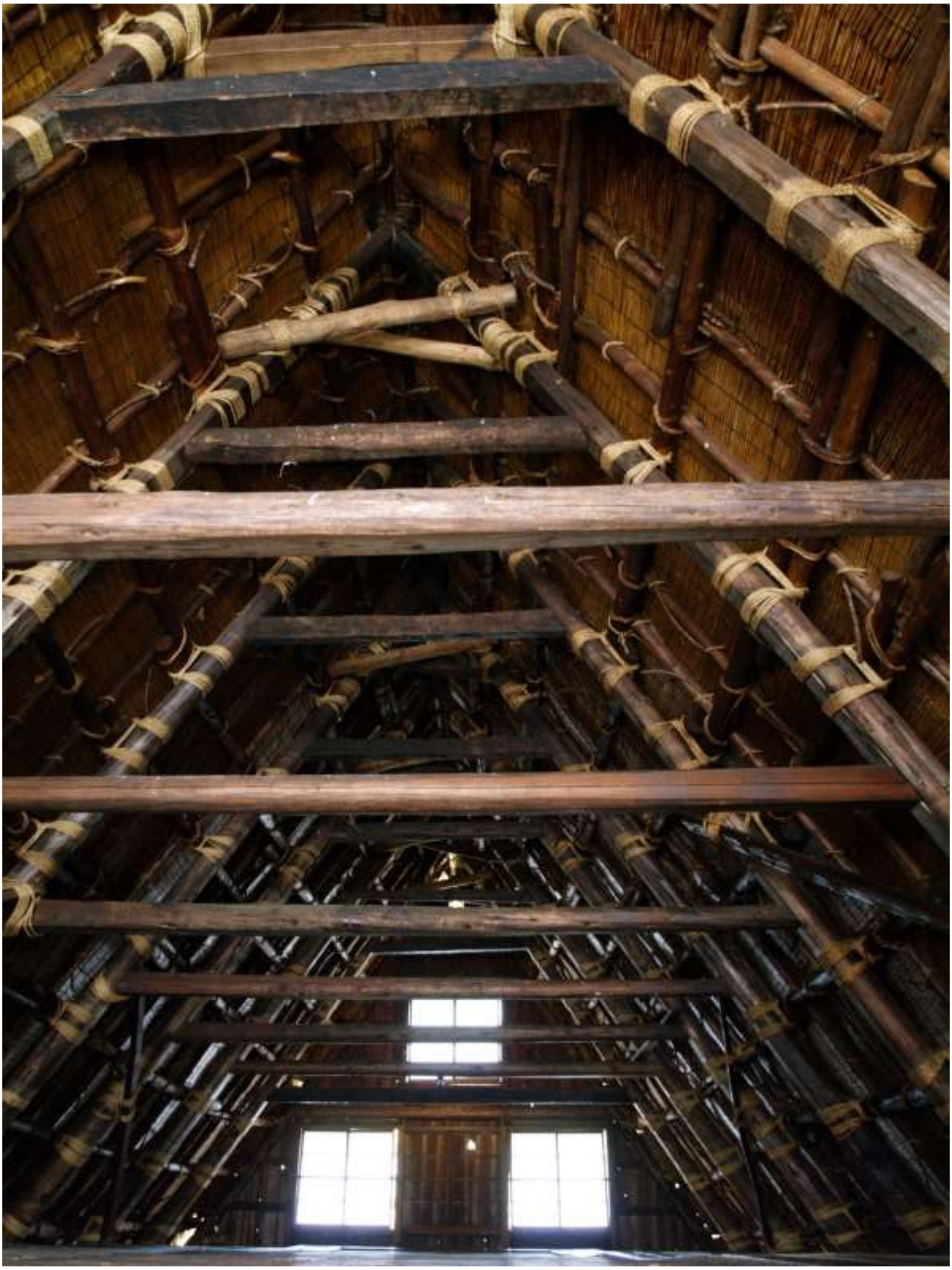


Figure 50 Gasso House Roof in Shirakawa-Go Photo: GA

Conventional Japanese Framing from 1950 onwards saw the introduction of diagonal stiffeners / sheer walls and metal fasteners, together with other construction methods brought from the west.

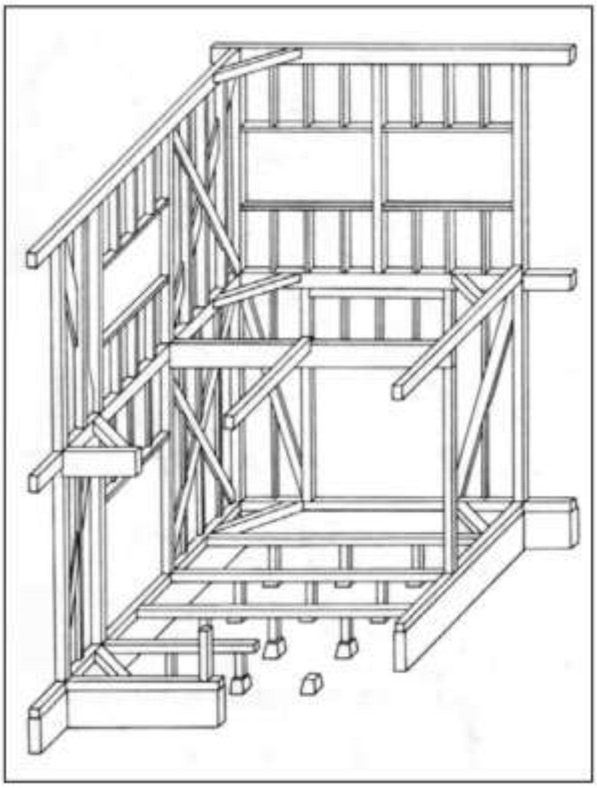



Figure 51 Conventional framing system (post 1950)

Traditional post and beam connections were modified in order to integrate engineered metal fasteners and connectors which replaced timber pegs and lock joints. As the fabrication of pre-cut framing members became increasingly automised joint details were adapted to suit machining processes and tooling.

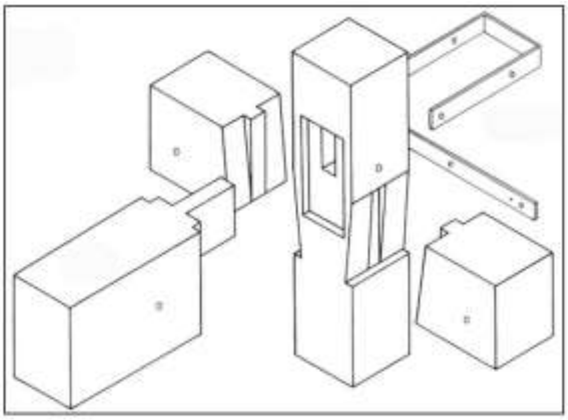



Figure 52 Conventional Post and Beam connection [Mokuzou Kenchiki Kenkyu Forum, Encyclopedia of wood architecture, Gakugei Shuppan, Kyoto, 1995]. (left) Pre-cut joint [Wolfgang Winter] (right)

7 INFLUENCE ON CONTEMPORARY ARCHITECTURE

The one aspect of modern Japan that has always fascinated me the most is how the culture appears to embrace and drive cutting-edge technologies and ultra-modern social and design concepts while remaining deeply rooted in its age-old history and rich tradition. It should come as no surprise that this distinct relationship between innovation and tradition, tradition and adaptation, continues to manifests itself in all aspects of Japanese culture - from cuisine to couture, from movies to mangas, from pop-art to pop-music, from product design to building design and to Architecture.

7.1 TRADITION AND ADAPTATION

The ways in which tradition integrates with contemporary design or informs technical solutions can be very diverse. While references to traditional principles are often obvious and emphasised, they may also be subtler or sometimes even completely unintentional. And when it comes to timber architecture the influences of Japanese design are particularly interesting due to the country's special relationship to the material.

One contemporary Japanese architect who specifically focuses on the reinterpretation and adaptation of traditional Japanese building design to 21st century architecture is Kengo Kuma.

Figure 53 Kengo Kuma

> *"I didn't have a job in Tokyo for 10 years. I was designing small buildings in the countryside. I worked with a craftsman and studied how to use natural materials in those 10 years. From this experience, I learned the great aspects of Japanese traditional architecture. I started to design traditional Japanese architecture and foreign people took notice of the design." [Kengo Kuma]*

In his written work he explains his focus on the connection to place and how materiality, light and transparency connect spaces and frames nature. It is the dematerialisation – the lightness of structure and its interaction with light that results in the desired transparency. The concept of shōji (障子), the sliding door, or window frame covered with washi paper (和紙), embodies this idea of continuity of space, flow and transparency.

“(the proliferation of concrete buildings) destroys Japanese culture and the Japanese mentality. The price is loss of our own identity. If wood can become the main material again, we can recover the mentality of Japan. This is my dream." [Kengo Kuma] [xii]

Kengo Kuma’s close relationship with and intricate understanding of traditional craftsmanship is evident in his architectural details. Many of his numerous timber structures emphasise, or feature traditional design principles and construction details (e.g. Yusuhara Kinbashi Museum, the GC Prostho Museum Research Centre or the Sunny Hills Cake Shop). Adaptive design techniques include the up-scaling of member sizes and connection details as well as repeating, arraying and extrapolating details creating an abstraction of the traditional structural concept. The reference to traditional connection details and expression of the structural system is often used to make symbolic or historic references to the immediate context or convey philosophical concepts.

Shigeru Ban’s approach is also noticeably rooted in traditional Japanese principles and values, although the connection may not be as immediate and obvious.

Figure 54 Shigeru Ban

“I travel a lot. Japanese culture is very ancient and very strong. That's why most people who commission work from Japanese architects expect them to create works that have an element of exoticism, the kind typical of Japanese culture. I don't do that.” [Shigeru Ban]

The influences of western schools of architecture and his years studying under Hejduk in the US have resulted in a much tighter fusion of western and eastern design techniques applied in his work. Many of his projects are international and not located in Japan. He is renowned for his ingenious use of paper as a structural material, used in relief projects for shelters in countries like Rwanda, or Nepal and pushing the boundaries of building regulations in other countries (Japanese Pavilion, EXPO 2000 in Hanover, Germany, or The Cardboard Church in Christchurch, NZ).

“The material (individual element/component) does not have to be strong in order to form a strong structure.” [Shigeru Ban]

His work generally focuses on the exploration of form and geometry itself, the lightness of structure and continuation and flow between spaces rather than the expression of structure and connection details. Although in the case of the Tamedia building in Zurich, Switzerland, the large expressed timer connection details of the expressed frame are central to the overall design.

Besides how tradition and history have influenced Japans star architects, the importance and reference to traditional timber construction is abundantly obvious in modern Japanese architecture. Two outstanding projects by Nikken Sekkei, described in the case study section of this report, are 'The Tokyo Sky Tree' (Tokyo telecommunications tower) and 'Mokuzai Kaikan' (Tokyo timber wholesale headquarters). These two projects are significant as they are demonstrating the relevance of traditional influences in very different ways. The Sky Tree utilises an ancient design principle of temple design which informed the highly innovative structural design concept of the telecommunication tower to address movement and load behaviour of the tower in a seismic event. Whereas 'Mokuzai Kaikan' makes a conscious symbolic statement, attempting to influence and boost consumer behaviour and boost the timber industry.

Figure 55 Tomohiko Yamanashi Executive Officer, Principal-in-Charge, Nikken Sekkei

> *"The purpose of this project was to display the various possibilities of wood in the hope of reviving its popularity as an urban construction material." [Nikken Sekkei]*

The design makes an appeal to Japanese society to remember and revive Japans relationship with timber as a building material in a city context. It was mainly due to strict building codes and fire regulations that the use of timber within densely populated areas of the country has declined. But it the project also makes a statement regarding the use of small-scale standardised timber sections (as available off-the-shelf in a hardware store) and assembling them to a complex and bespoke design. At the 17th Asian Congress of Architects, in Hong Kong Yamanashi talks about the role Information and Communication Technology (ICT) plays in the replacement of mass production by mass customisation in the 21st century.

> *"In the 20th century, architects tried to hold onto this ideal of mass production. But architecture was originally about producing things one-by-one – it should be unique." [Tonohiko Yamanashi]* [xiii]

7.2 INFLUENCE AND MANIFESTATION

THERE ARE SOME DISTINCT PATTERNS RECOGNISABLE IN HOW TRADITIONAL TIMBER DESIGN AND CONSTRUCTION MANIFESTS ITSELF IN MODERN ARCHITECTURE.

One is the historic use of timber all over Japan and the relationship to the material 'wood' and forests itself. This includes its expression and treatment of finishes. Another reoccurring theme is the physical up-scaling of design details that have been adapted from common joinery details or even toys, like the Japanese Puzzle-Box. The principle of assembling a large number of smaller members into larger structures (mitigating immediate catastrophic failure due to a single element) is also noticeable in many projects. It presumably stems from historic building designs which were constrained by the maximum dimensions of lumber that could be turned into structural members. This principle is now resurrected through designs that incorporate greater numbers of smaller size lower-grade timber sections into larger members. The last concept I would like to mention here is reciprocal structural systems, which to some extent have also played a role in traditional Japanese building design. Their contemporary application however faces considerable complications due to the inherent issues with disproportionate collapse and lack of structural robustness.

7.2.1 Material Expression

Timber facades have been used traditionally in Japan, or Central Europe and are a common sight on old and new buildings in the countryside as well as in the cities. The desire to use timber materials externally and the architectural to express structural timber has been growing internationally for some time now and this trend has experienced a further boost with the increased structural use of timber in 'Tall Timber Buildings'. While there is an enormous potential for more off-the-shelf products to utilise the natural qualities of various timber species, selection of specific cuts and sections (e.g. considering bark-side and growing direction) as well as different finishing techniques (e.g. improving planing/slicing techniques), one traditional method stands out.

Figure 56 Charred timber profile by ECO TIMBER, Richmond Photo: https://ecotimbergroup.com.au/wp-content/uploads/2017/06/charred_1937.jpg

The traditional technique of smoking, or charring of timber has enjoyed a spectacular renaissance and a huge number of different charred timber products have emerged on the market. To a great extent this is certainly due to its stunning visual qualities and Architects and designers have embraced this particular aesthetic. More products become available that address the visual aspect of exposed aging timber, like pre- weathered, smoked or charred cladding products.

Figure 57 Cedar Cladding, Tokyo Photo: GA

Exposed timber ages irregularly (patchy colour, rain marks) before it turns grey. While this is a familiar sight for people in Japan or Switzerland, such discolouration would possibly trigger an insurance claim here in Australia. The fact that a buildings external aesthetic may be compromised for years before the uniform aged look is achieved has deterred many designers from specifying natural timber finishes for facades. With the above-mentioned products this issue is addressed. As previously discussed the charring of timber not only prevents discolouration, but also provides increased resilience against mould, insects and fire.

In the case of St Kilda's 'Stokekouse' the use of the charred material is not only an aesthetic choice, but also makes reference to a not so fortunate event in its history. The original Stokekouse was destroyed in a severe fire in June 2014 - nobody was injured.

Figure 58 Stokehouse, St Kilda Photo: https://images.adsttc.com/media/images/5982/f8d3/b22e/38c5/7900/0099/slideshow/20170536_JG_0464rgb.jpg?1501755596

Figure 59 Fire at the original Stokehouse Photo: https://cdn.newsapi.com.au/image/v1/32d76e2a6193d1db2030d03005032b75?width=1024

7.2.2 Size Matters

Chidori (千鳥) is the Japanese word for "a thousand birds". Amongst other objects and characters in Japanese kulture it has lent its name to a traditional children's toy, manufactured in the small town of Hida Takayama. It is said that only the special skills of the local craftsmen could produce the accuracy required for the intricate joints. The puzzle toy consists of wood sticks with a 12mm square section and individual interlocking joints.

Figure 60 'Chidori' Detail Photo: https://i.pinimg.com/originals/0f/5f/1e/0f5f1e5116012f205316e424c3af020e.jpg

This toy was inspiration for several building designs and a furniture range by Kengo Kuma. The joint system has been transferred literally to two larger scales – to the scale of furniture and to building scale.

Figure 61 Assembly of the 'Chidori' joint Photo: https://slowerthanslow.files.wordpress.com/2014/12/chidori-joint-3.jpg

Note the twisting required to lock the joint shown in the far-right image.

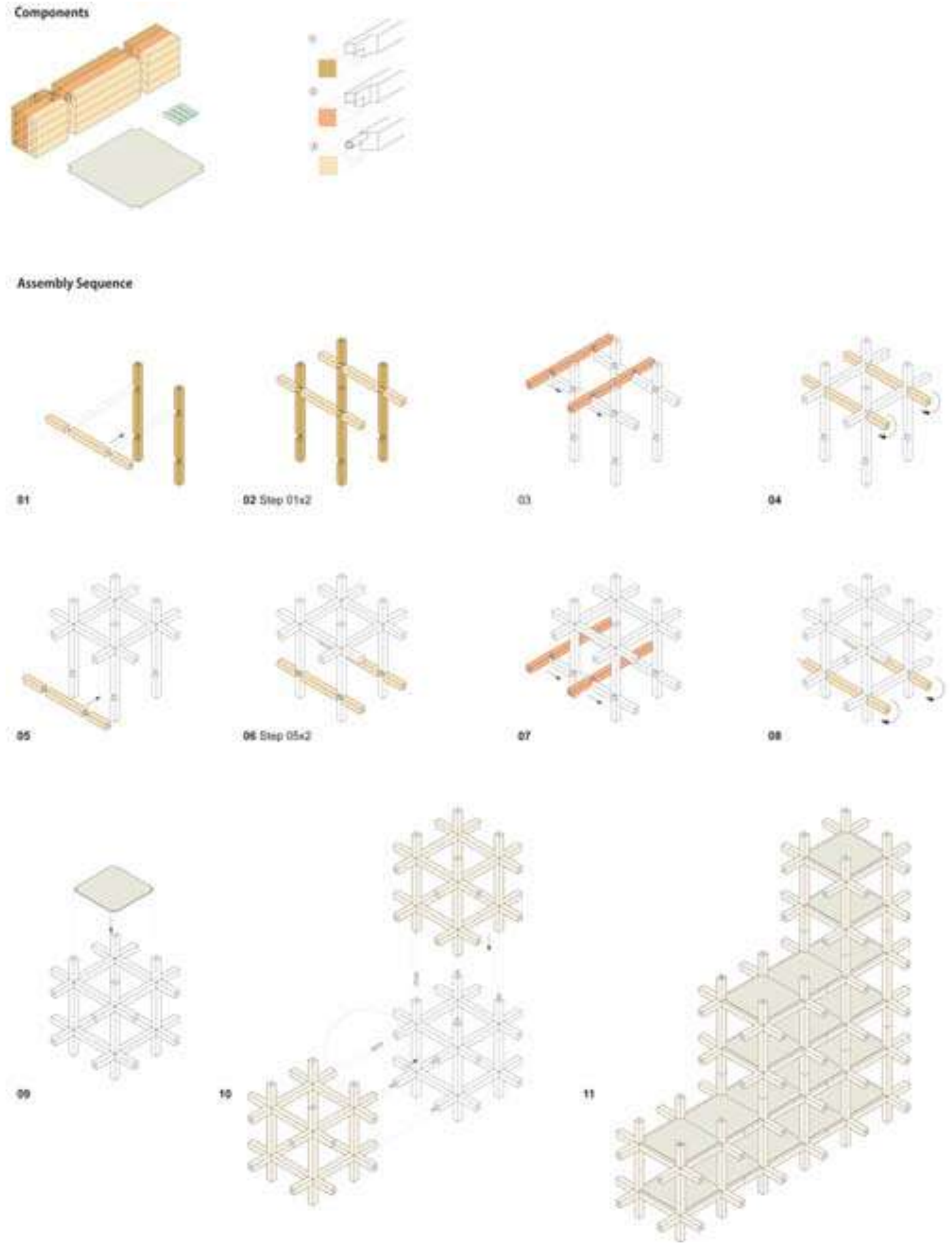


Figure 62 'Chidori Furniture System' Image: https://www.detail-online.com/fileadmin/blog/uploads/2011/11/components.jpg

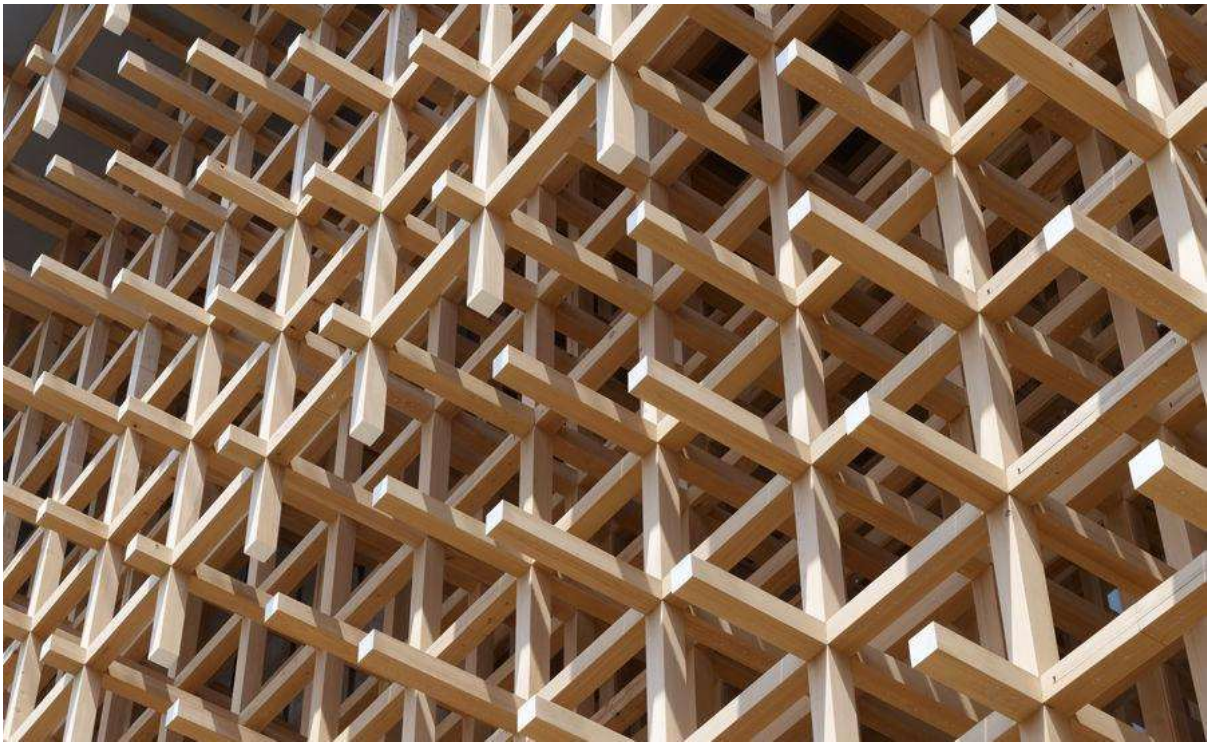


Figure 63 GC Prostho facade Photo: https://www.woodworkingnetwork.com/sites/woodworking/files/styles/large_landscape_desktop/public/Kengo-Kuma-Wood-Building3.jpg?itok=Jk-m9SvL

For the GC Prostho - Museum Research Centre project the ‘chidori’ sections were adapted to different sizes. The member sections for the building frames are 60mm×60mm×200cm or 60mm×60mm×400cm, to form a grid of 50cm by 50cm. The structural principle is based on the interlocking of a large number of small members with a high level of redundancy. Lateral forces are transferred through moment connections in the numerous soft joints, similar to projects like the Sunny Hills Cake Shop or the Yusuhara Kinbashi Museum.

7.2.3 More Is More

Similar structural principles applied to the previously mentioned examples by Kango Kuma also apply to other recent building designs, like the Mokuzai Kaikan by Nikken Sekkei, where the main beams spanning over the great timber hall are assembled with a multitude of small standard timber sections that interlock by means of a modern version of e wedged tabled splice joint, or the freeform grid shell of the Swatch HQ in Biel by Shigeru Ban.

Aside from such highly complex and prestigious projects the principle of assembling a large number of smaller members into larger structures (mitigating immediate catastrophic collapse due to the failure of a single element) may also find its way into more everyday applications. The following example shows the result of a research project carried out by T. Shiratori et al at the Swiss Federal Institute of Technology, Laboratory of Timber Structure directed by Prof. Natterer. T. Shiratori, interested in the function of the traditional beam intersection with multiple columns, proposed a solid wall structure stiffened only by girths.

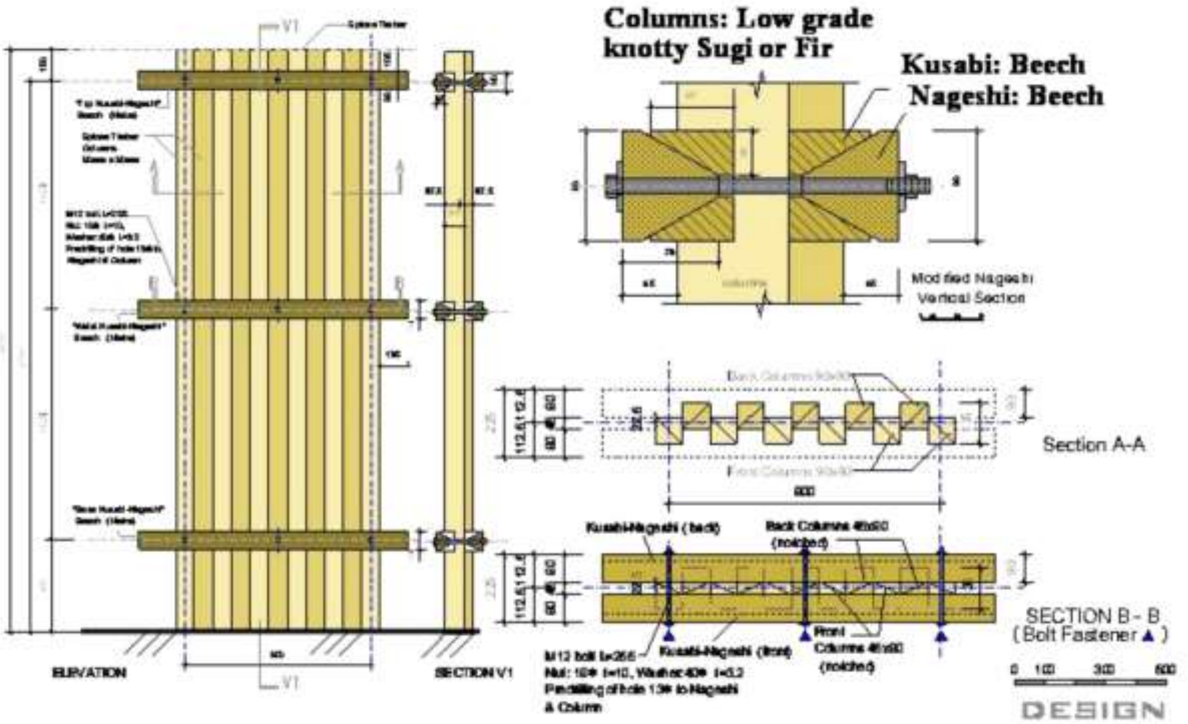


Figure 64 Kusabi-Nageshi Joint System [T. Shiratori]

The wall plane is composed of columns in a staggered arrangement. This wall is banded by the girths from both sides with the help of bolts. Since every girth consists of three pieces of hardwood with triangular cross-sections, the initial slip can be eliminated by being fastened by bolts. Even if the girths are damaged or loosened, re-tightening the bolts can eliminate again the play between the girths and columns. Experimental results demonstrated successfully the expected performance for practical applications.

Figure 65 Shearing Test setup (left). Detail od staggered column - girths (right). Photo: T. Shiratori

xiv

7.2.4 Reciprocity In Structural Systems

The predominant traditional framing method in Japan was the post and beam construction. However, examples of reciprocal frame roof structures to roundhouses in China and Japan date back to the 12th century and are also known as 'the mandala roof'.

> *"A reciprocal frame (RF) is a self-supported three-dimensional structure made up of three or more sloping rods, which form a closed circuit, namely an RF-unit. Large RF-structures built as complex grillages of one or a few similar RF-units have an intrinsic beauty derived from their inherent self-similar and highly symmetric patterns."* [xv]

Figure 66 Frame model by Nathan Melenbrink, Samo Pedersen and Shibu Raman Photo: https://www.mark-magazine.com/media/files/285994

The aesthetic quality of its geometry makes it extremely interesting for architects and designers as the Reciprocal Frame model by Nathan Melenbrink, Samo Pedersen and Shibu Raman demonstrates. It also poses equally extreme challenges for structural design solutions and applications in regards to detailing and structural robustness, since the failure of a single member could lead to progressive collapse. Braking up larger systems into smaller RF-Units is only one possible way to address this. Interlocking two RF-systems that work in opposite directions and provide redundancy is another concept that is being investigated. Such systems generate a large number of variations for connection details.

When it comes to completed projects, Kazuhiro Ishii is the Japanese architect with probably the most significant portfolio of reciprocal frame designs.

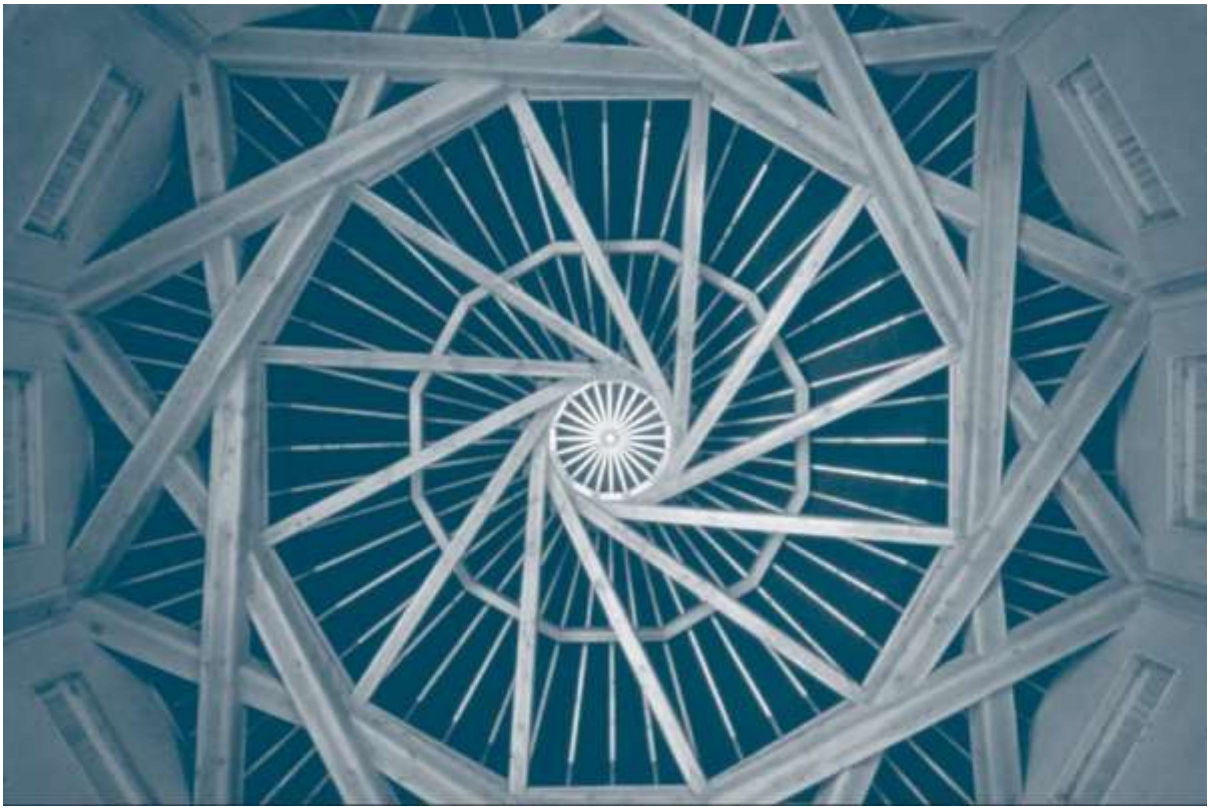


Figure 67 Seiwa Exhibition Hall by Kazuhiro Ishii Photo: https://www.architectural-review.com/pictures/980x653fitpad[31]/6/9/7/1269697_1.jpg

Figure 68 Roof installation of Seiwa Exhibition Hall Photo: https://i.pinimg.com/originals/2f/70/d9/2f70d9d9e5f0651a8b5e6372c9a3b629.jpg

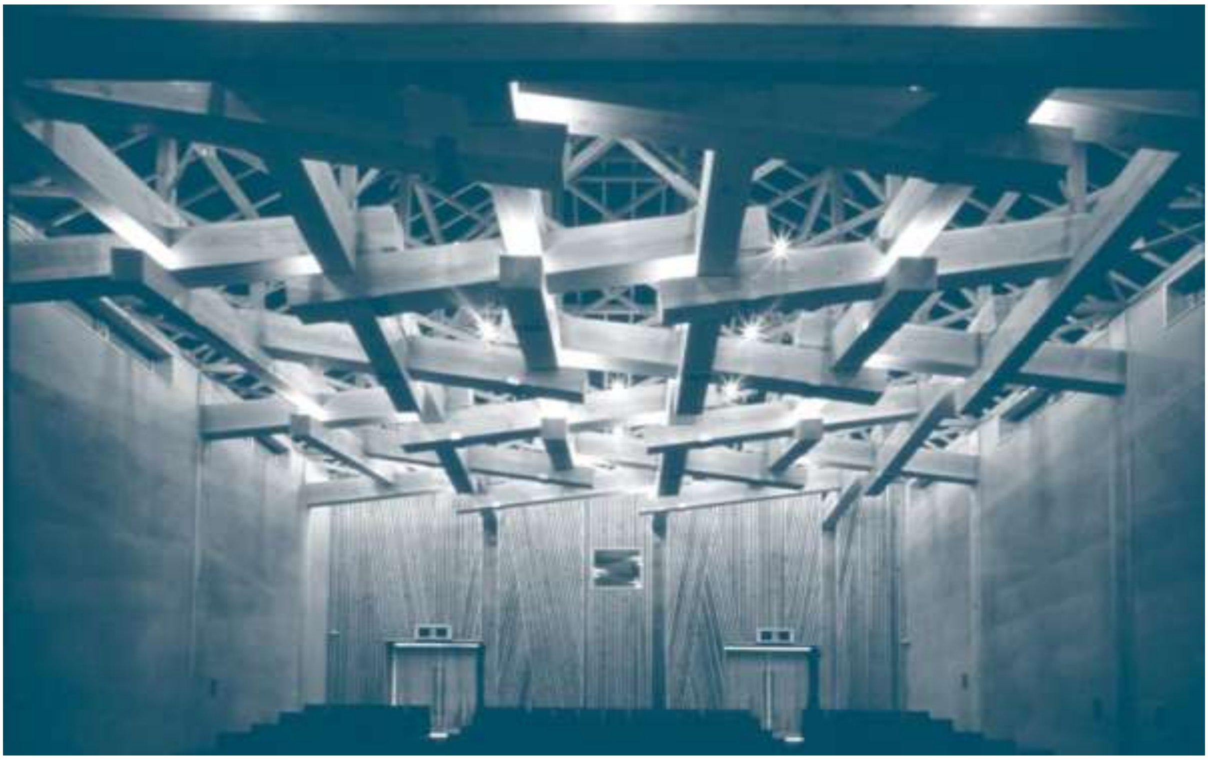


Figure 69 Kazuhiro Ishii's Bunraku Theatre Photo: https://www.architectural-review.com/pictures/980x653fitpad[31]/7/0/0/1269700_2.jpg

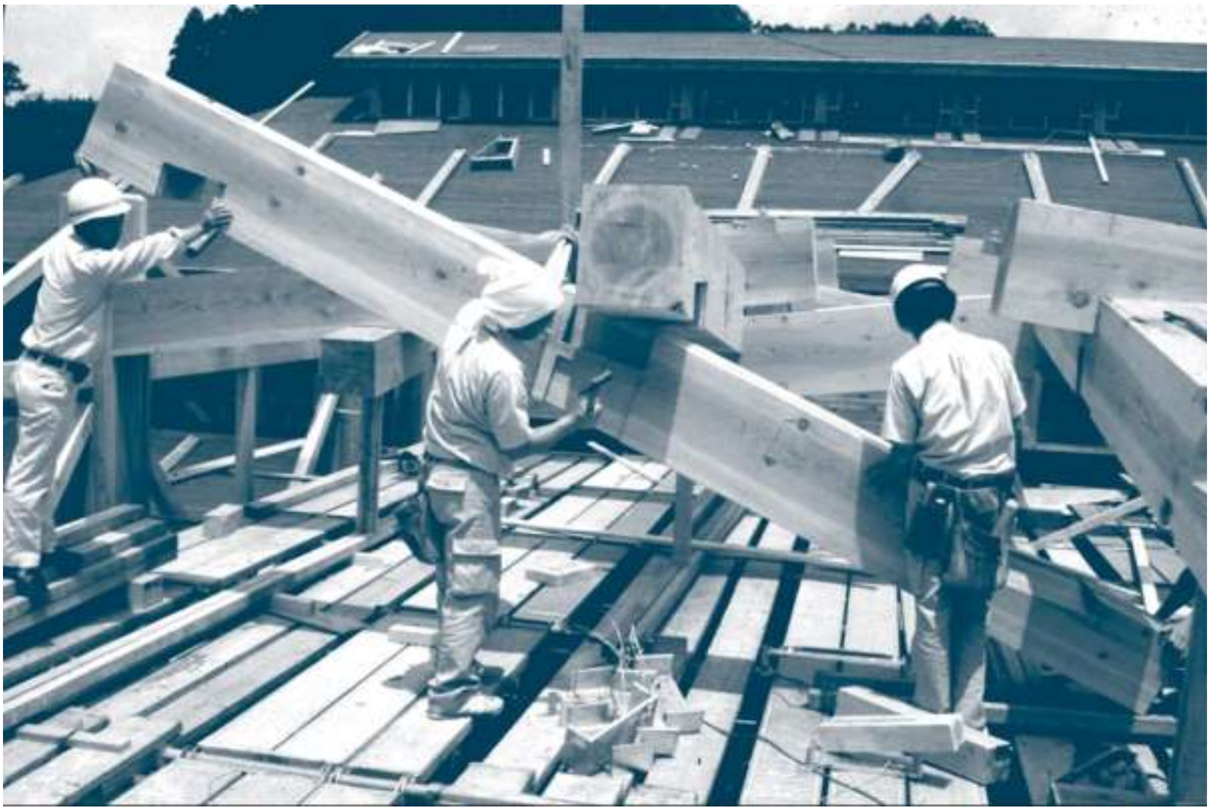


Figure 70 Installation of the reciprocal frame structure of the exhibition hall roof in Kazuhiro Ishii's Bunraku Theatre complex Photo: https://www.architectural-review.com/pictures/980x653fitpad[31]/7/0/3/1269703_2.jpg

8 TIMBER APPLICATION IN CUTTING EDGE TECHNOLOGIES

Traditional Japanese carpentry and construction techniques have certainly had a significant influence on contemporary design and architecture. But beyond the aesthetic and style aspects of the designs for buildings, furniture and other products these ancient techniques appear to have potential to inform new and future construction techniques and detailing at a much more technical level. And with the introduction of computational design tools, CNC and robotic fabrication, that is more akin to what we have known from the automobile industry, new opportunities have emerged.

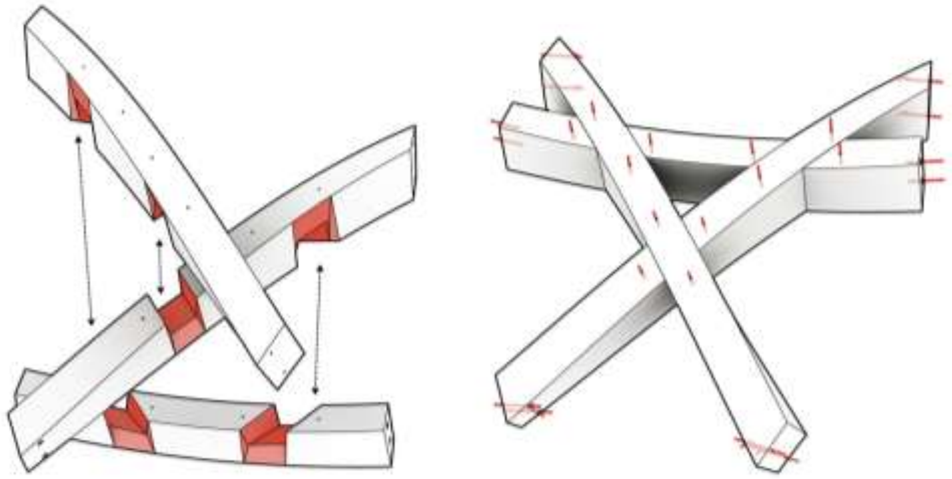


Figure 71 Detail of the Cambridge Mosque by Marks Barfield Architects and Blumer Lehmann Image: http://www.d2p.ch/fileadmin/images/projektbilder/d2p_cambridgemosque_4.jpg

Figure 72 Figure 72 Roof component of the Cambridge Mosque by Marks Barfield Architects and Blumer Lehmann Photo: https://i2-prod.cambridge-news.co.uk/incoming/article14033374.ece/ALTERNATES/s1200/Mosque-1.jpg

Figure 73 Swatch HQ in Biel by Shigeru Ban Photo: http://www.interactiongreen.com/wp-content/uploads/2017/11/Watch-Company-HG-Shigeru-Ban-4.jpg

Figure 74 Swatch HQ in Biel by Shigeru Ban Photo: http://www.interactiongreen.com/wp-content/uploads/2017/11/Watch-Company-HQ-Shigeru-Ban-7.jpg

8.1 Reverse Engineering

Before any application of traditional techniques in a modern engineered context, techniques which have developed over centuries based on empiric data and a principle of 'trial and error', it is essential to understand the mechanics behind these old structural systems. In order to do this, it is necessary to validate the empiric data and recreate the joints in structural models. Extensive research and investigation is being undertaken in relation to conservation of Japanese heritage items and especially in relation to damage due to seismic activity. This involves very specialized typologies of timber frame structures like temple or shrine architecture, vernacular residential buildings, tea-houses, and castle architecture or bridges.

The below example illustrates details and mechanisms of the Yatoi joint, including a test setup and dimensions of the joint as well as its the deformation and failure mechanism.

Figure 75 Traditional Post and Beam detail

THE MAJOR SEISMIC RESISTING ELEMENTS OF THE TRADITIONAL WOODEN BUILDINGS ARE RESTORING FORCES OF COLUMN ROCKING, ROTATIONAL RESISTANCES OF COLUMN-TIE BEAM JOINTS AND SHEAR RESISTANCES OF MUD/WOOD WALLS. AMONG THEM, THE COLUMN-TIE BEAM JOINTS SHOW THE MOST DUCTILE RESTORING FORCE CHARACTERISTICS DUE TO EMBEDMENT AND FRICTION

[H. Tanahashi & Y. Suzuki Ritsumeikan University, Japan]

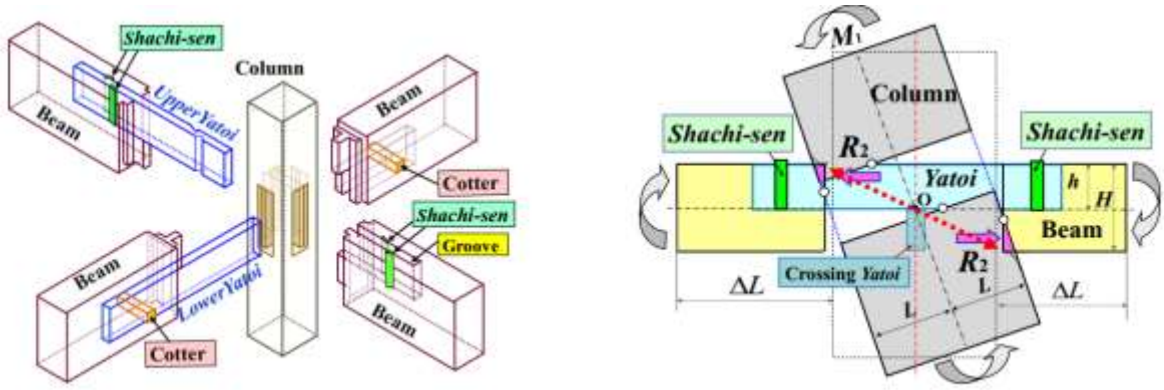


Figure 76 [H. Tanahashi & Y. Suzuki Ritsumeikan University, Japan; Embedment Mechanism and Formulation of Major types of traditional wooden joints in Japan]

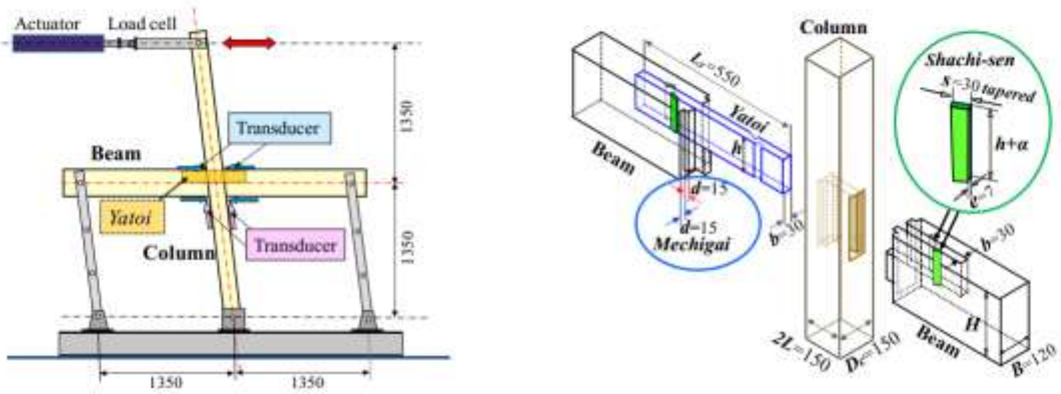


Figure 77 [H. Tanahashi & Y. Suzuki Ritsumeikan University, Japan; Embedment Mechanism and Formulation of Major types of traditional wooden joints in Japan]

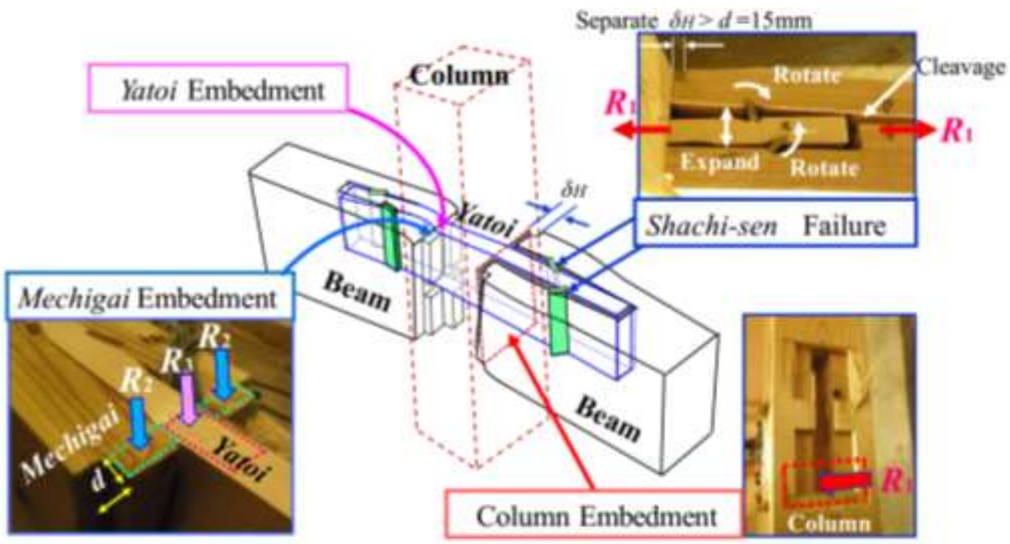


Figure 78 [H. Tanahashi & Y. Suzuki Ritsumeikan University, Japan; Embedment Mechanism and Formulation of Major types of traditional wooden joints in Japan]

xvi

Such detailed experiments and their test results, while not directly transferable to modern engineered systems, give valuable insights to the behaviour and limits of these pure timber to timber connections.

8.2 LESS IS MORE –THE REDUCTION OF STEEL FASTENERS IN TIMBER CONNECTIONS

This report is looking at the relevance of traditional Japanese timber design to modern timber construction and engineering. And one of the most outstanding characteristics of these traditional timber connections is the absents of steel connectors. It is not suggested that it would be feasible or even possible at this stage to produce structural connections for every application that do not rely on any steel connectors or glue. But there may be valid reasons to aim to minimise the amount of steel used in connections or where possible eliminate them altogether. Since modern industrialisation timber construction has increasingly relied upon metal fasteners, nails, nail-plates, steel bolts and brackets, screws and glue. Mass production of standardised fasteners and connectors, whether for joinery or building construction, is dominating the market and has developed on a much greater scale than technologies for automated and semi-automated pre-cutting of structural timber members for frame prefabrication or assembly on site, like in Japan or central Europe. The benefits of a homogenous – ‘pure’ timber to timber connection may not be entirely obvious at first glance. So, let’s have a closer look at possible advantages of reducing steel fasteners within connections.

8.2.1 Difference In Thermal Conductivity

When inserting a steel plate and bolts into a slotted timber section two materials are brought into contact that have very different physical properties. The steel plate conducts temperature (heat or cold) much better than timber. In certain instances, this could create prolonged condensation at a critical junction within a structural connection. However, this possibility is very remote. And even if significant condensation was to occur over a prolonged period of time and potentially cause discoloration, the amount of water would unlikely be enough to cause any structural damage. In the case of conduction of heat during a fire the consequences could be more significant. Generally steel connectors are embedded within the timber section to protect the steel from fire and achieve the required fire rating for the structural member.

Figure 79 Fire resistance of Beam to Column connections [Pedro Palma, ETH Zurich]. Photo: GA

The image above shows a number of test specimens being part of a study on Fire resistance of Beam to Column connections conducted by Pedro Palma at the ETH Zurich. This example shows how charring is increased in the area of the steel plate connection and around individual screws. While gaps in a pure timber connection joint would potentially still lead to increased charring this can be expected to be mainly superficial and heat would not be carried deep into the connection via the more conductive metal fasteners.

8.2.2 Homogeneity Of Connections

Steel connectors like nails, screws and bolts behave and move differently to the timber that surrounds them after they have been installed. Bolted connections often have to be retightened sometime after initial installation to compensate for movement of the timber members. Obviously, this is not possible with nailed or screwed connections. Timber to timber connections can be designed to self-tighten by considering the predicted swelling end shrinking of the individual members and components of the joint or lock-joint. Steel is generally also much harder than the timbers it connects. Doweled connections rely on friction for which a precise fit is required. Movement and/or vibration or extreme stresses within the connection can ultimately lead to elongations of holes in the timber sections, resulting in a reduction of contact area and a looser fit between steel and timber components.

Figure 80 Beam connection doweled slot-in-plate Photo: https://reynoldstom.files.wordpress.com/2013/01/jointmovements.png

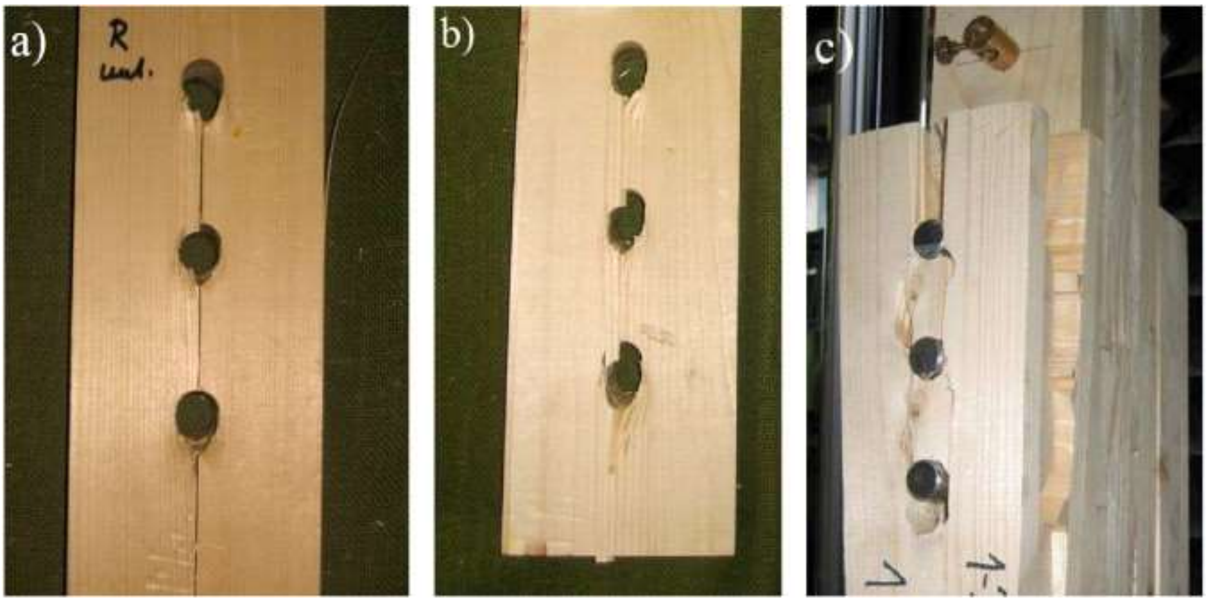


Figure 81 https://ars.els-cdn.com/content/image/1-s2.0-S0141029611000654-gr14.jpg

This is relevant especially since many contemporary timber connections (e.g. doweled slot-in-plates) are designed so the main structural loads are transferred via the steel connector rather than directly from timber section to timber section. "The timber is orthotropic, viscoelastic and the circular shape of the connector creates stress concentrations" on a very small contact surface area.[xvii]

8.2.3 Taking Things Apart

Another important aspect of the traditional Japanese timber connection, mentioned previously in the report, is how their design addressed installation, assembly and disassembly of frames and structures. Repeated assembly and disassembly of structures and/or their individual components connected with metal fasteners shows that it is more likely that the softer timber members are being deformed or damaged over time than the metal fasteners. This may lead to looser connections or the need to replace main members. It would be more desirable to replace, or adjust the smaller connectors, or reduce ware and tare during the process. This issue applies mainly to screwed or nailed connections, but can also be seen in bolted connections that have been specifically designed for reassembly. The traditional timber to timber connections mitigate the damage to the main timber members by directing the load paths directly through the main members and using the wedges or dowels only to lock the connection into place. The timber wedges themselves were easily replaced or reshaped to adapt to any deformation of the main member and reinstate the original precision of the fit when reinstalled. Creating such precise timber connections is something we are more accustomed to in the fabrication of fine joinery since the tooling technology at this smaller scale has been available and continuously been developed for a long time.

One resent example for a move away from metal fasteners and towards timber connections is IKEA's "Story of the Wedge Dowel".

Figure 82 IKEA's 'Wedge Dowel' Photo: http://ikea.today/wp-content/uploads/2016/07/IKEA_today_wedge_dowel_wood_hero-e1467925410468-1200x568.png

Figure 83 IKEA's 'Wedge Dowel' Photo: http://ikea.today/wp-content/uploads/2016/07/IKEA_today_knutmariannehagberg_detail_1.jpg

Figure 84 IKEA's 'Wedge Dowel' Photo: http://www.decomag.co.uk/sites/default/files/styles/page_image/public/images/articles/P%20desk%20underside%20ikea%20snap.jpg?itok=g8K7qj3e

The leg is inserted into the table top at the wider end of the wedge-shaped and ribbed mortise and pushed towards the narrow end until a tight fit is achieved. An elongation of the mortise provides room for tightening and adjustment of the connection by pushing the tenon further towards the narrow end. The plastic clip merely holds the leg in place and secures its position. The base principle of the table leg connection design is that all main forces are transferred through the main members (i.e. the table top and the leg) and not through the clip. Previous connection details often relied entirely on the load transfer through the metal connectors, screws or brackets. The new design aims mainly at simplifying the assembly and disassembly process. But this should also result in a reduction of wear and tear on the individual parts during assembly and disassembly, therefore improving durability of the product.[xviii]

8.2.4 Post and Beam Connections

We already have talked about how design principle likely associated with smaller scale objects, like the example of the 'cidori' puzzle-box game have been physically upscaled to the size of buildings and applied to architectural designs like Kengo Kuma's 'GC Prostho - Museum Research Centre', or the 'Sunny Hill – Cake Shop'. At a larger scale this level of precision is now achievable through CNC technology. But even with more conventional tooling methods pure timber connections have been applied continuously in modern frame construction in Japan and Central Europe. These details are now being rediscovered in an engineering context and become subject of more research.

The below image shows some semi-automatically machined framing connections applied to LVL members for residential frames. The connections offer a great benefit during installation on site, making it easier to position and join the members before installing metal fasteners to enable load transfer and complete the structural connection.

Figure 85 Joist connections at the Wood & Plywood Museum Photo: GA

Much more elegant than the older metal connector plates and brackets that would have been used to complete the above framing details is the modern ROTHOBLAAS metal joist connector. The connector consists of a male component that is screwed flush into the side of the beam and a female component which is routed into the end section of the joist and screwed into the end-grain (two different type of screws are required). The installation of the brackets would typically occur off-site. Installation on site is fast, precise and does not require additional fixings to be installed on-site. A pure timber alternative to this detail was tested at the ETH, Zurich.

Figure 86 Rothoblaas Joist connector at the WCTE 2016 in Vienna (left) and a timber connection tested at the ETH, Zurich (right) Photo: GA

This detail requires both members (beam and joist) to be routed, but eliminates the need for screwing and the metal connector altogether. The male and female element is shaped as a tapered dovetail joint making it easier to insert the joint into the beam while self-tightening the connection as it is being assembled.

8.2.5 Post And Plate Connections

Post and plate connections are not yet widely used in modern timber construction. The system of Post and Plate versus Post and Beam connects the post directly to the structural floor slab rather via a beam or truss that carries the floor. The latest timber buildings utilising CLT as main structural elements show a trend to move away from the extensive use of loadbearing CLT walls towards a mix of timber stud or panel walls and CLT lift and stair cores walls and floors, post and beam structures with CLT or cassette floors, or more recently, post and plate systems. The main challenge for the connection detail is the load transfer from the small area of the column section to the structural CLT slab without the post punching through the slab.

The ROTHOBLAAS spider-connector is screwed into the top and bottom of each post (into the end-grain), transferring vertical loads directly through the posts taking the slab out of the load path. Thus, avoiding compression of the CLT in the weaker direction of the timber 90 degrees to the grain. The slab is hung from the connector fixed with fully threaded screws. The spider connector is located on the top of the slab since the fire-proofing of the steel components relies on the screed topping of the slab.

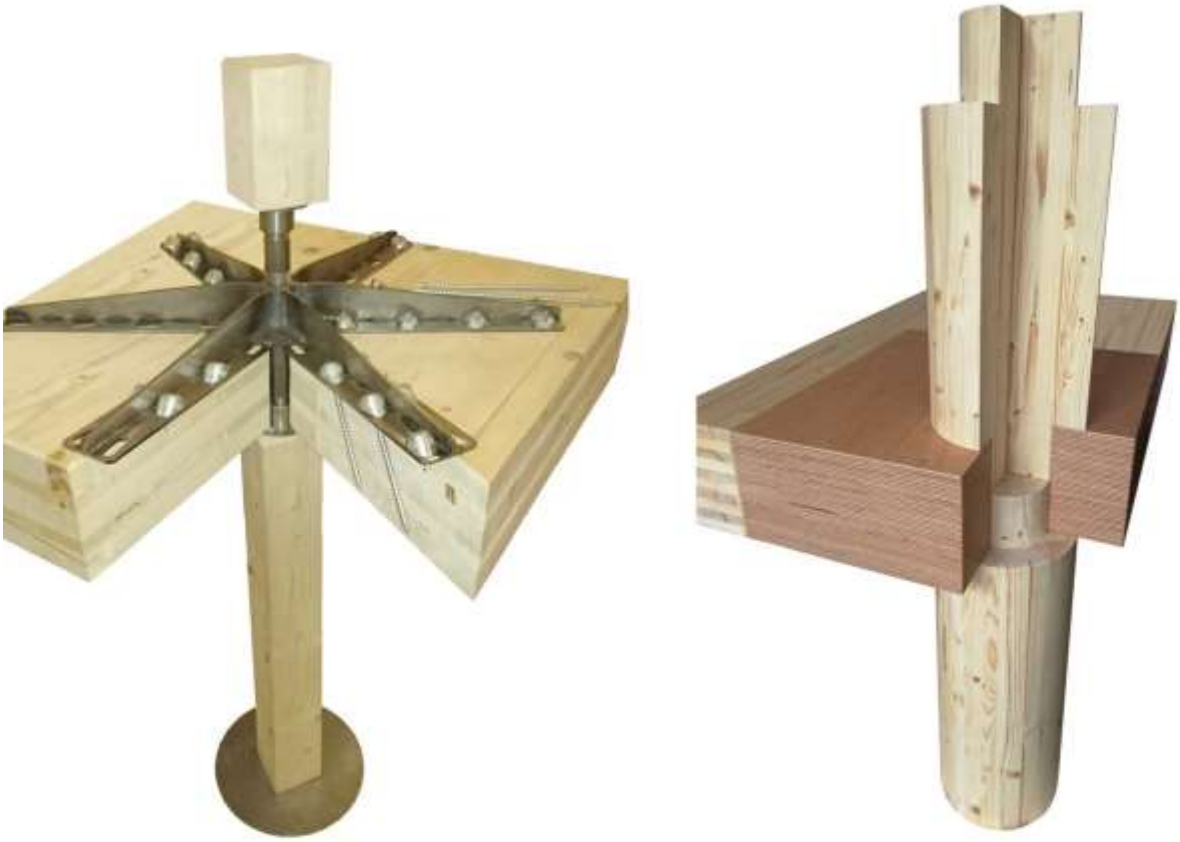


Figure 87 Post to CLT slab connection by ROTHOBLAAS screw-fixed (left) and by TS3 with glued-in beach reinforcement (right) at the WCTE 2016 in Vienna. Photo: GA

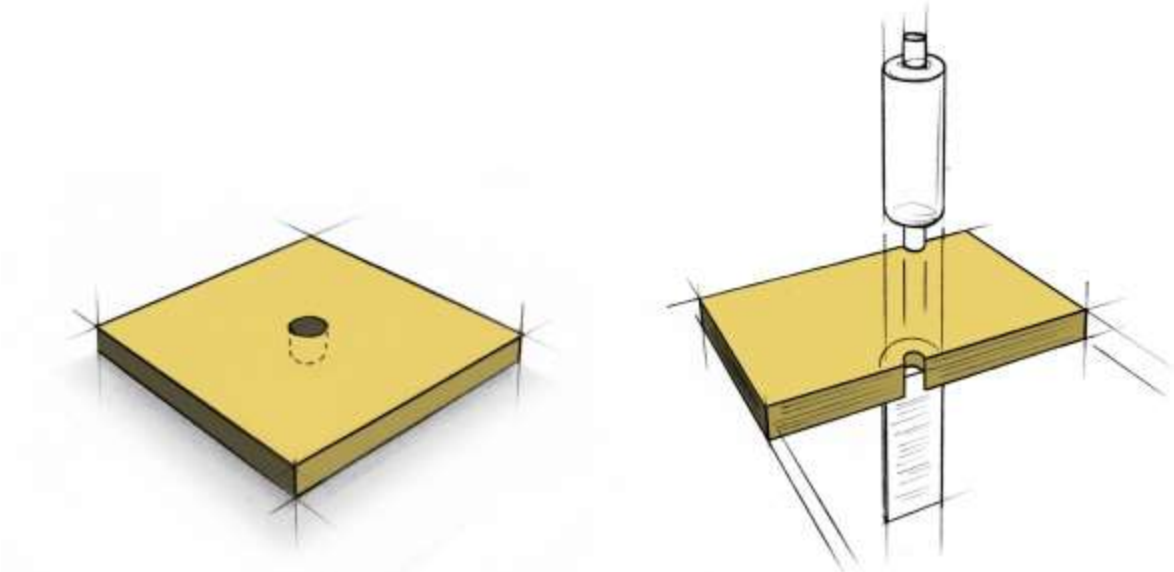


Figure 88 TS3 post and plate system Image: https://www.ts3.biz/media/img/TS3-Technologien/weblication/wThumbnails/Stuetzenkoepfe-0bde9c06fa72cc4g2d36f80bfc49fe42.jpg

The alternative connection detail by [TS3]() eliminates all metal components and achieves the load transfer from post to slab via a section of glued-in, laminated beach reinforcement. The principle of direct load transfer from post to post without involving the slab is the same as for the steel connection. No additional fire-proofing of metal connectors is required. However, the critical part regarding fire here is the glued connection. Further studies could be directed towards a specific timber detail to insert the beach reinforcement section to the CLT slab, in order to either increase surface area for gluing or to possibly eliminate the need for glue entirely.

8.2.6 Plate to Plate Connection

Sometimes, with the introduction of new construction technologies, like that of Cross Laminated Timber (CLT), old techniques are being rediscovered, or may become again relevant in unexpected ways.

Here is one example where the ancient technique of using water during the installation process of timber members has been revived. The underside of CLT panels may remain uncovered in order to expose a visual grade timber surface as an architectural feature ceiling. When the slab is designed for composite action with the concrete topping the wet concrete can poor through the slab joints during poring and stain the exposed underside of the panels. This is avoided by watering the CLT panels before the concrete pore to cause swelling of the timber which closes the panel joints.

The timber bowtie inlay, or chigiri (ちぎり) is a traditional technique to reinforce wide timber boards. The tie is inserted with the grain direction 90 degrees to the grain of the board, at specific locations (e.g. at knots or areas of internal stress) to avoid future cracking or splitting of the board.

Figure 89 Chigiri Photo: https://i.ytimg.com/vi/X7q2wgeDbdM/maxresdefault.jpg

Figure 90 X-fix C-type System, by SCHILCHER Photo: GA

A modern version of this technique has found an application in the installation of CLT floor and wall panels (specific application for visually exposed CLT panels). In this adaptation the tie has been split lengthwise into a two-part tenon and the mortise is split over the two CLT boards to be joined.

Figure 91 Installation of the X-fix C-type system Phot: http://www.x-fix.at/wp-content/uploads/2016/08/xfix_haus_weichsler_hasslacher023.jpg

The diagonal cut of the tie facilitates tightening of the panel joint during installation. According to the Austrian manufacturer SCHILCHER

> *"x-fix is … a timber to timber coupling system for easy and fast joining of cross laminated timber Elements in wall – wall Connections or ceiling joints. … a double dovetail shaped connector for CLT panels made from plywood without any metal. … time saving on the building site, with just a hammer for the self-tightening X-fix coupling System and the CLT Panels are clamped together 100 % accurate and form-locking. … the future in CLT building minimizing CLT waste and speeding up onsite installation."* [xix]

The x-fix L-type version for wall panels is based on the same principle as the floor coupling system.

Figure 92 x-fix L-type system Photo: http://www.x-fix.at/wp-content/uploads/2016/08/X-fix-L-eingebaut-hasslacher.jpg

Lastly, let us have a look at an example of a large scale version of a dovetailed timber box joint - the extension of the Théâtre de Vidy. The project has been realised through a collaboration of Blumer Lehmann and Laboratoire IBOIS at ETH Lausanne.

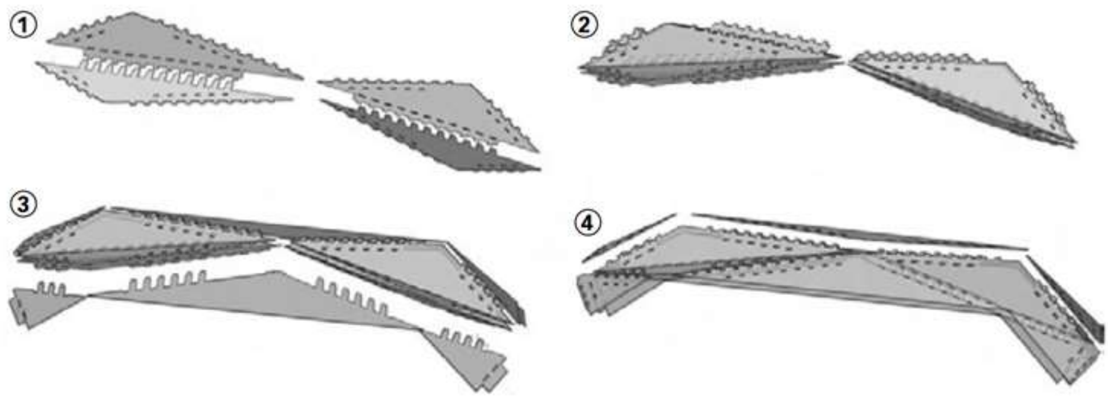


Figure 93 Timber Pavilion of the Vidy Theatre, Lausanne, system diagram Image: https://www.espazium.ch/uploads/592fffba7bb61.jpg

> *"The joinery method used for the individual wood panels is not new, but was thoroughly researched and further developed with modern methods. The clever wood-wood mortise and tenon joint comprising five-layer laminated spruce panels is similar to the traditional dovetail method, and renders glue and screws largely superfluous. The innovation is that the joints are algorithmically planned and cut using CNC technology. One might also call it 'engineering to build' – a joinery technology that we regard as very promising for the future." [Blumer Lehmann]* [xx]

The design is referred to as an origami structure – the Japanese design influence is quite literal. Literal is also the physical upscaling of a conventional joinery detail. While the complexity of the folded structure is impressive and poses challenges to the digital design and fabrication process, it is the scale and the absents of metal fasteners or glue which makes the details stand out. As previously discussed we are seeing an example where a traditional detail has been researched in a new structural context and has been adapted to cater for new design solutions and architectural expression.

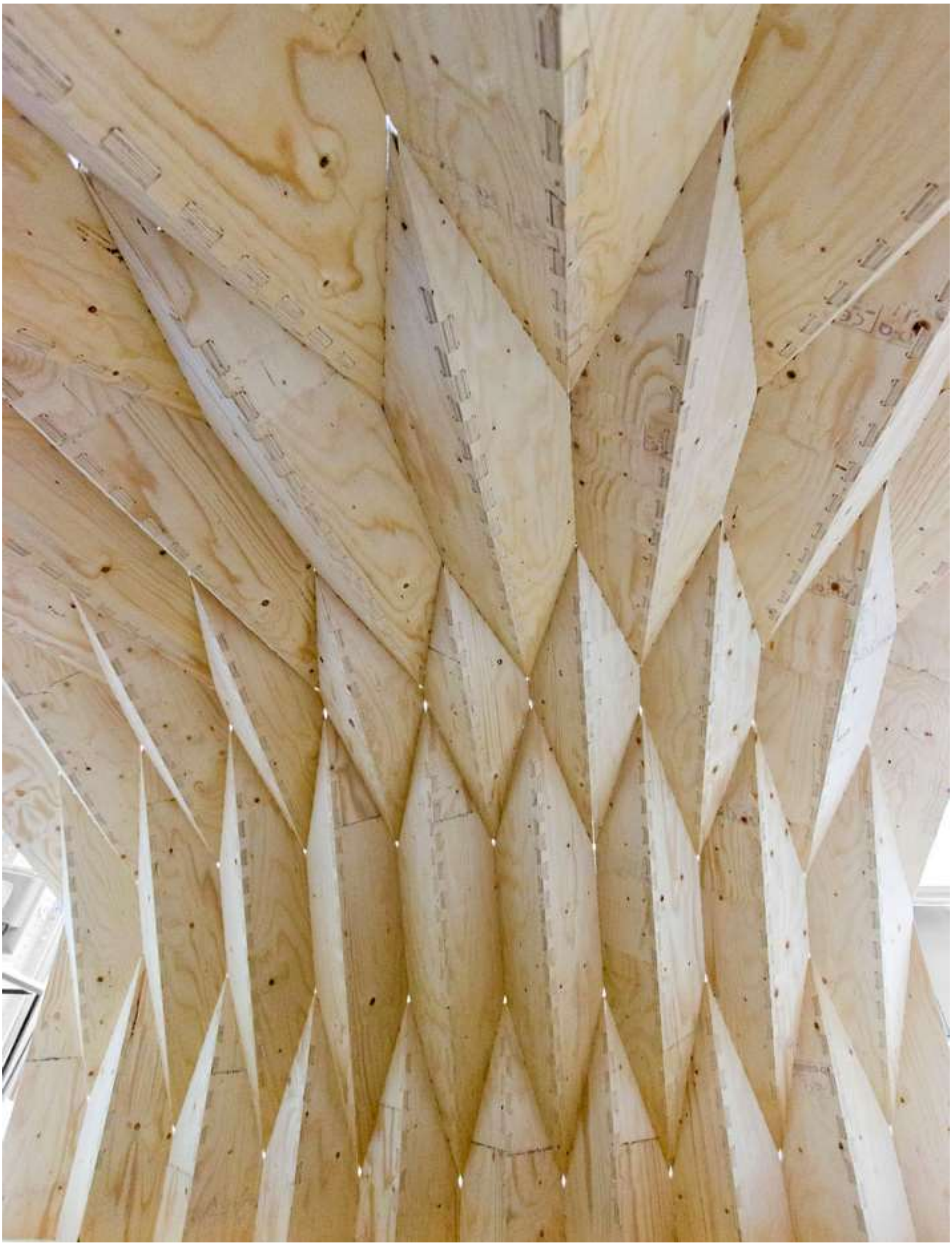


Figure 94 Timber Pavilion of the Vidy Theatre, Lausanne Photo: http://www.robeller.net/img/gallery/shell01sp.jpg

Figure 95 Connection detail Photo: https://ibois.epfl.ch/files/content/sites/ibois2/files/05_Projects/Vidy/Vidy3_copyright_Ilka_Kramer.jpg

9 CONCLUSION

Like any construction method timber structures has its constraints, but it also presents enormous potential. Prefabrication, digital design and manufacturing of timber elements allows very sophisticated designs to be realised (manufactured and installed) that would be cost prohibitive with other materials. The environmental and sustainability benefits are overwhelming and it is astounding how fast the Australian marked has embraced the development of tall timber buildings. It is through such a development in markets, that innovations in technology and new products become possible, necessary - and therefore inevitable. The sources of inspiration for such innovation often lies in concepts that are not entirely new - sometimes ancient, practices that have fallen out of fashion or have been entirely forgotten. The greatest potential for progress may lay in the rediscovery of such old concepts through the latest advances in technology. We currently witness an unprecedented renaissance in timber construction, made possible through modern computer and fabrication technologies. It seems obvious that, with the rediscovery of the material comes also the rediscovery of the techniques that have been used before the construction industry has fallen out of love with timber. New prefabrication technology and increased CNC precision makes designs and construction details feasible which would have never been thinkable before.

The report has shown that a continuous and strong influence of traditional Japanese design principles is evident on contemporary architecture and design in Japan and internationally. Traditional techniques for the treatment of timber and construction detailing have already found application in modern timber products and there is currently further potential to inform architectural and construction products. Further research is expected to result in a further increase of applications throughout the industry.

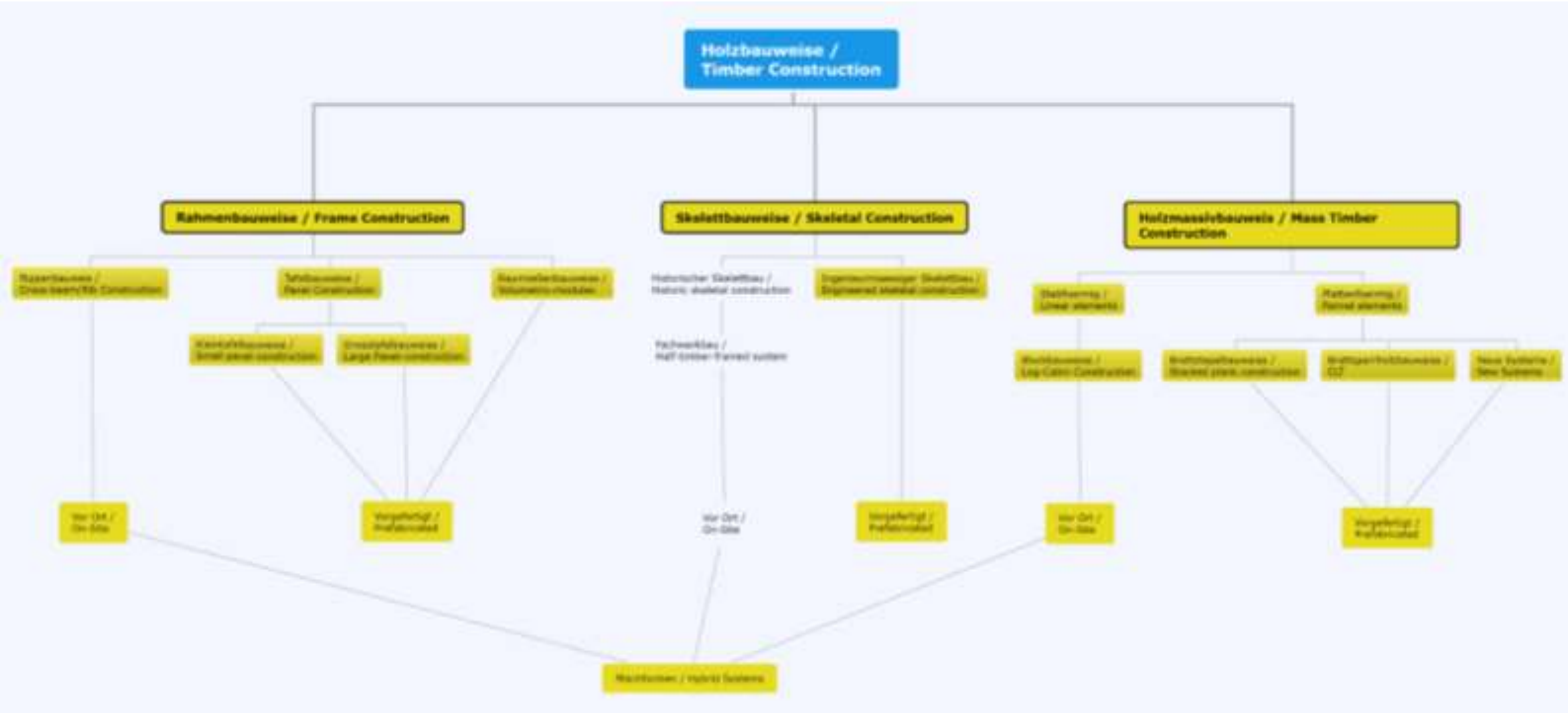


Figure 96 Diagram of potential application for timber construction typologies Diagram and translation: GA

9.1 Case Studies

9.1.1 Tokyo SkyTree – Telecommunication Tower

Architect: Nikken Sekkei

Date of construction: 2012

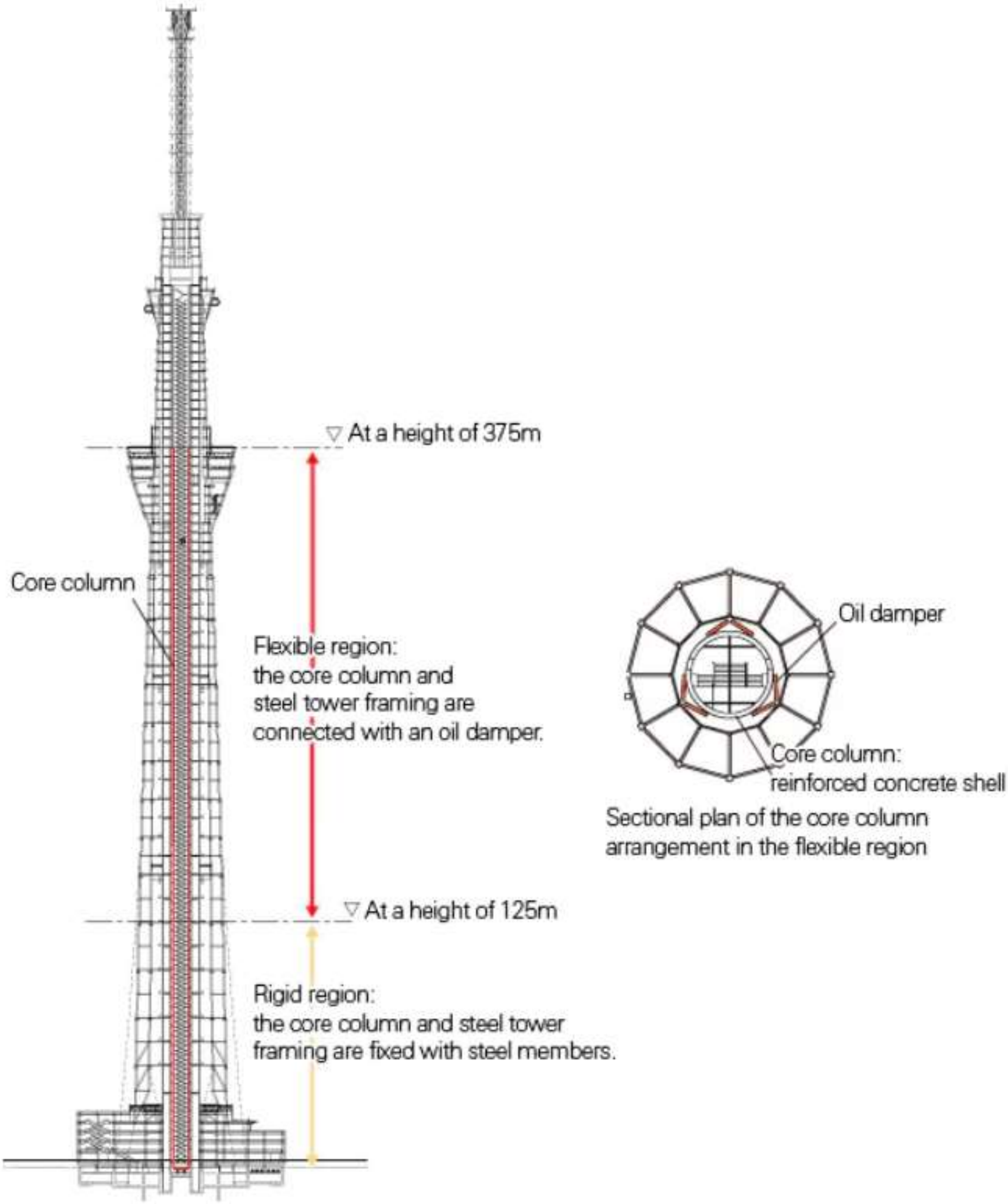
Location: Tokyo, Japan

Building type: Television transmitter

Design: 634m tall

Structure: Steel truss, centre column connected with oil dampers

With the design of Tokyo Sky Tree television transmitter and observation tower Nikken Sekkei took inspiration from the traditional five-story Japanese pagoda (example. Horyu-ji Pagoda built j. 609) and it's central dampening column (shimbashira seishin, or centre column vibration control).



The central column (or shimbashira) does not physically support any of the pagoda's stories but instead acts as a counterweight about which the rest of the building's structure can vibrate.

Nikken Sekkei applied this principle as the 'shimbashira seishin' (center column vibration control) with the core column and surrounding steel frame connected by a flexible oil damper. [xxi]

The temple that lent inspiration to the structural concept of the Tokyo Sky Tree is the Horyu Ji Temple.

Architect: N/A

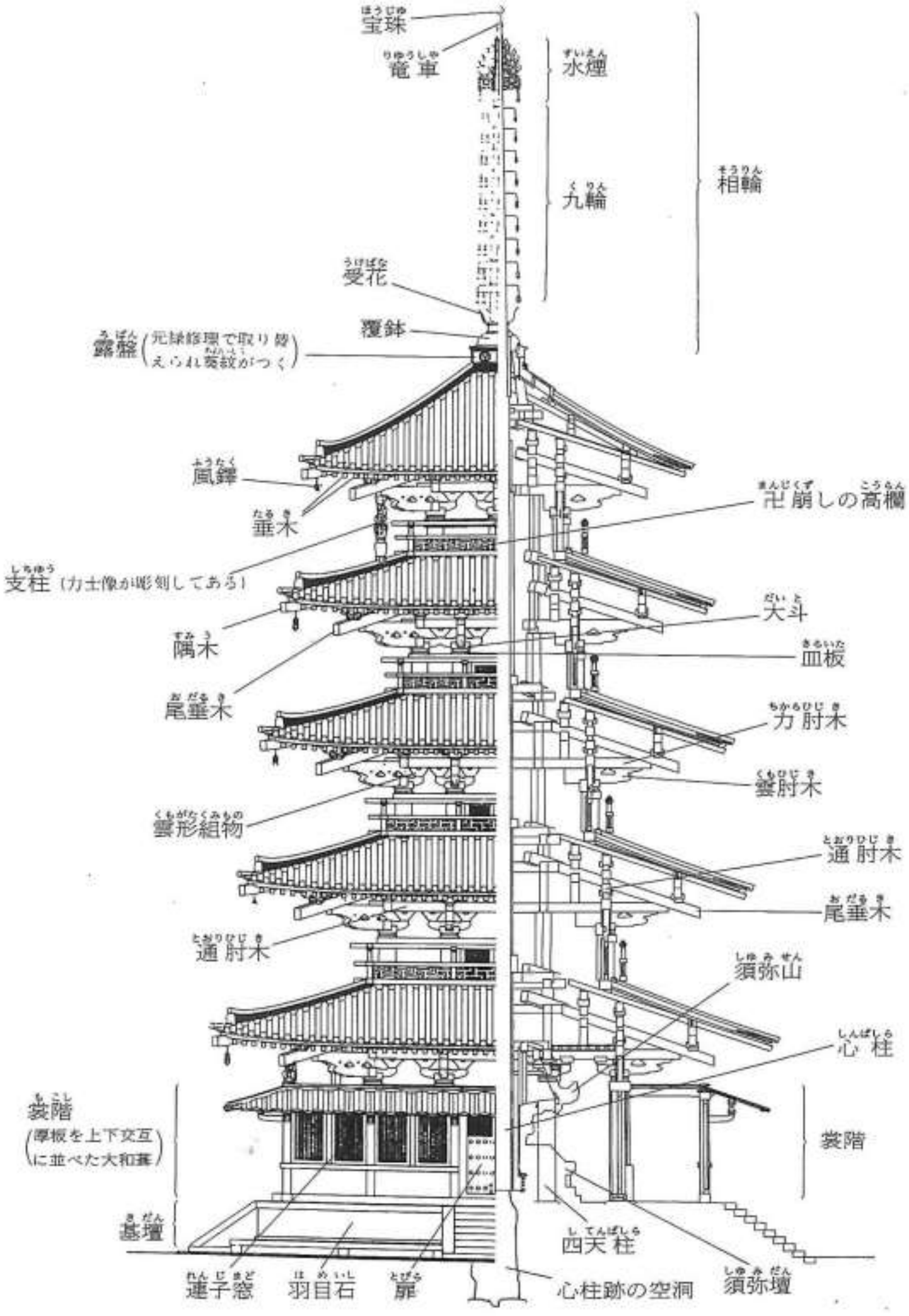
Date of construction: app. 603 - 1603

Location: Nara, Japan

Building type: Temple

Design: 5 Storey pagoda (32.25 Metres / 122 Feet)

Structure: Central wooden pillar; timber; Japanese carpentry



宝珠
竜車
水煙
九輪
相輪
受花
覆鉢
露盤（元禄修理で取り替えられ菊紋がつく）
風鐸
垂木
卍崩しの高欄
支柱（力士像が彫刻してある）
大斗
隅木
皿板
尾垂木
力肘木
雲肘木
雲形組物
通肘木
尾垂木
通肘木
須弥山
心柱
裳階（厚板を上下交互に並べた大和葺）
裳階
基壇
四天柱
連子窓
羽目石
扉
心柱跡の空洞
須弥壇

9.1.2 Yusuhara Kinbashi Museum - Gallery Above The Clouds

By Kengo Kuma & Associates

Kochi prefecture Takaoka gun Yusuhara cho Tarokawa 3799-3

2010.09

Exhibition hall

445.79 m 2

“The 446 m2 (4,800 ft2) gallery and bridge connect the Kumo No Ue (Above the Clouds) Hotel – a former visitor’s center, also designed by Kuma – and the resort’s hot spring baths. Bathers travel across the bridge, supported by a structural system inspired by hanebashi bridges from the Edo period. Instead of using nails and bolts, this ancient system uses a proliferation of square interlocking timber beams that gradually decrease in length as they transfer load downward into the supports.” [xxii]

‘The Tokyō’ (斗 栱) (also called kumimono (組物) or masugumi (斗組))[xxiii] is a system of blocks and brackets also called "masonry of wood".

Figure 97 Yusuhara Kinbashi Museum. Photo: GA

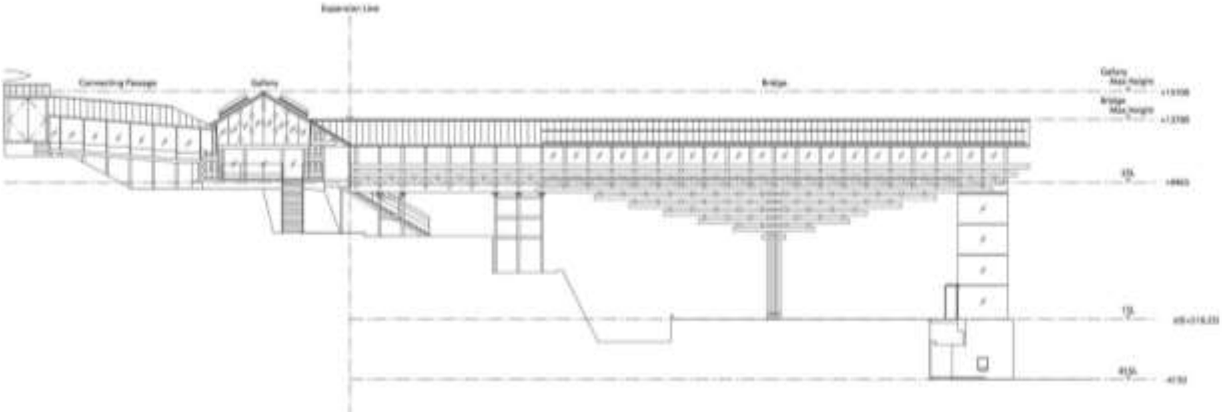
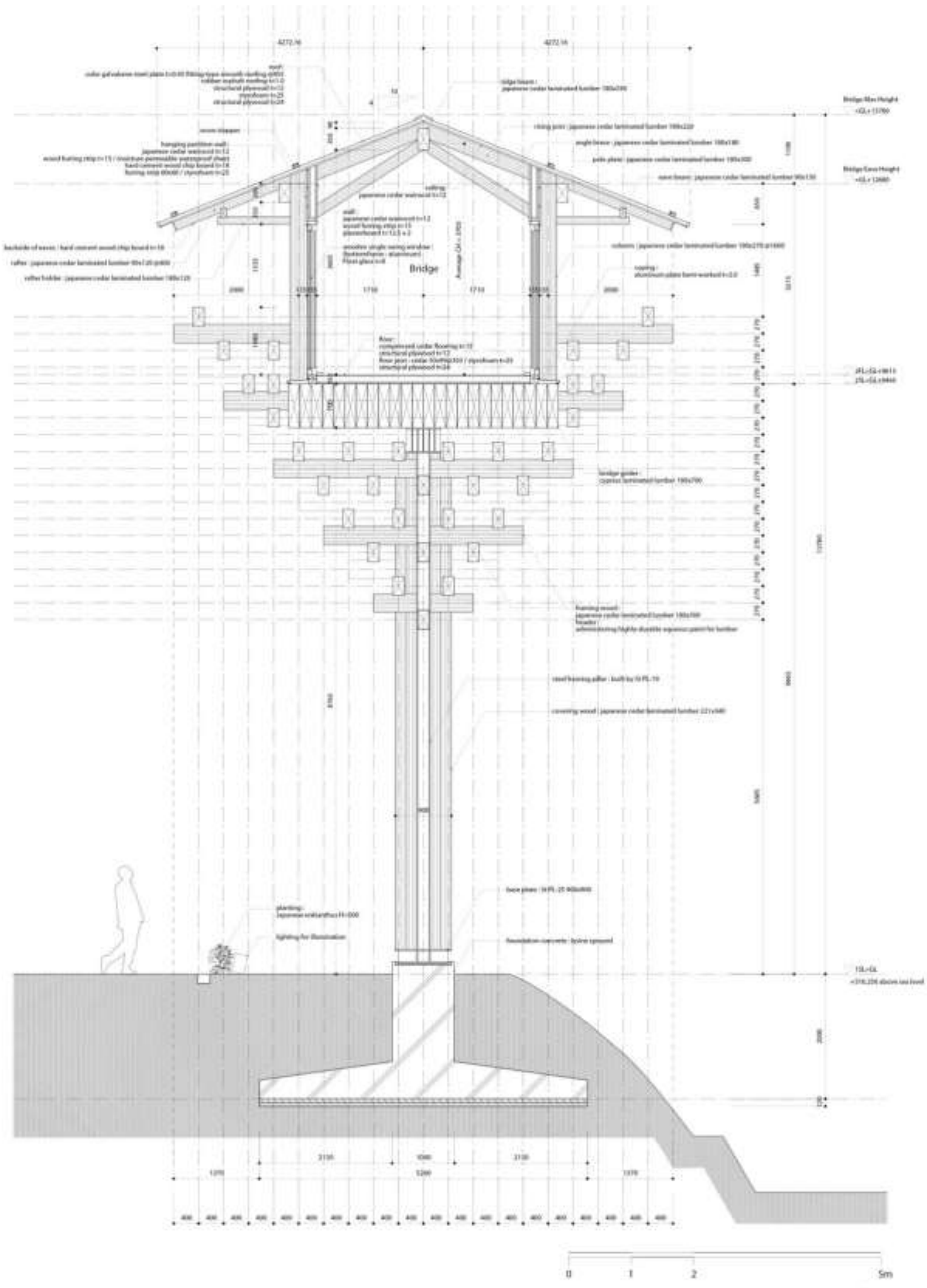


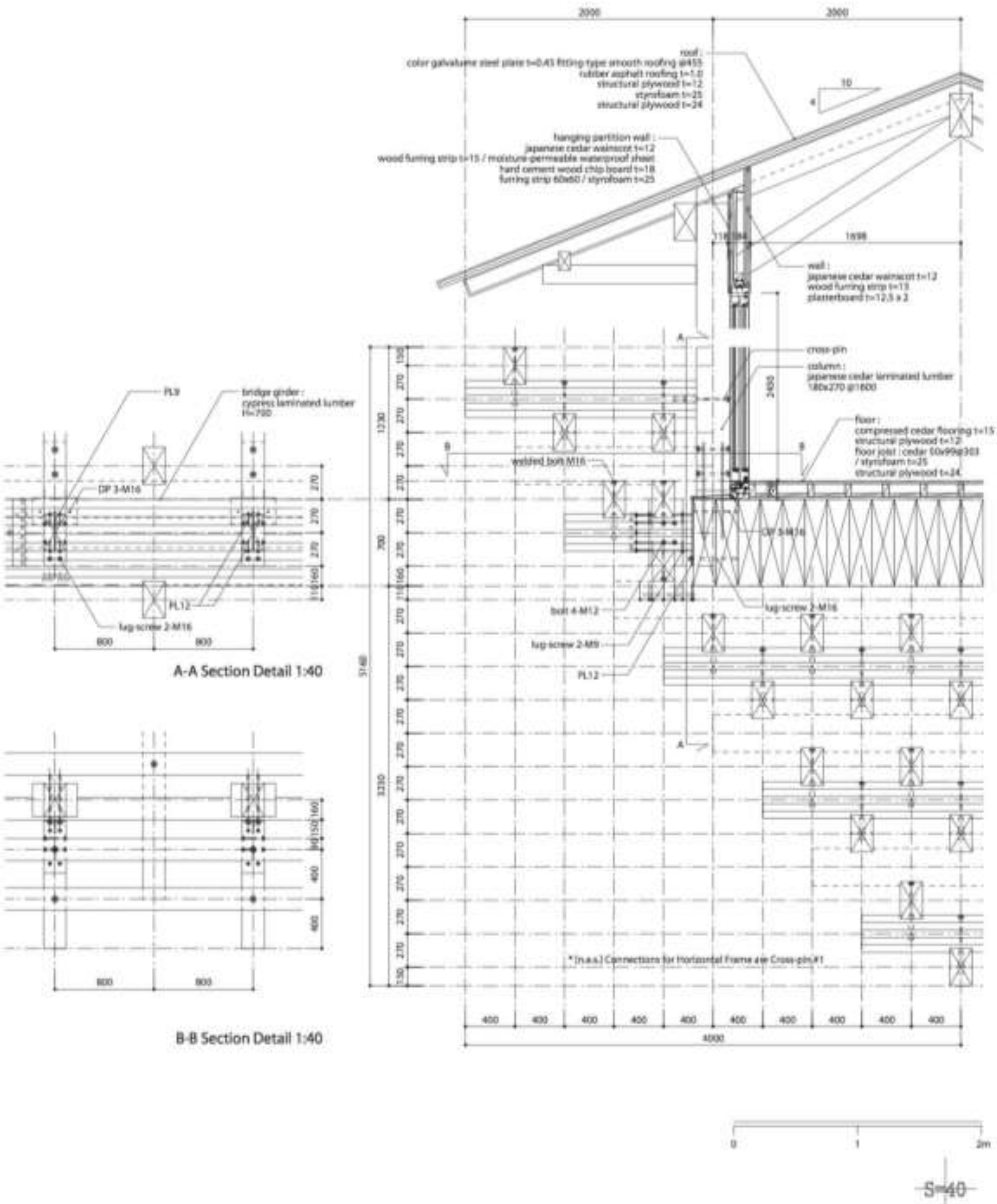
Figure 98 Yusuhara Kinbashi Museum interior. Photo: GA

Figure 99 Yusuhara Kinbashi Museum. Photo: GA

Figure 100 Yusuhara Kinbashi Museum stacking detail. Photo: GA



Bridge East-West Section Detail 1:80(A4)



Bridge Wood-Framing Detail 1:40(A4)

xxiv

9.1.3 Yusuhara-Cho - General Government Building

By Kengo Kuma & Associates

Kochi Prefecture Takaoka-gun Yusuhara-cho Yusuhara 1444-1

2006.10

General government building

2,970.79 m 2

Figure 101 YUSUHARA-CHO. Photo: GA

Figure 102 YUSUHARA-CHO column detail. Photo: GA

Kochi Prefecture Yusuhara Town was a forestry town, but in recent years it has been aggressively developing new environmental policies that focus on the environment, such as wind power generation and biomass power generation using cedar chips. We planned the "tree town hall" with complex functions as the base of the exchange in this town. As a response to weather conditions with many rain and snow, we made a semi-outdoor plaza that encloses facilities such as banks, agricultural cooperatives and commerce and industry. This open space is a large folding door for the hangar, separated from the outside, being open for more than half of the year and also helping to reduce running costs of air conditioning. A moving stage is set up in this square, and it functions as a space for the performance "festival" transmitted to this town and the festival. A double tiller beam structure using cedar laminated wood was made possible with a large span of 18 meters, and the structure was visualized as much as possible. A photovoltaic panel was installed on the rooftop and a cool tube was installed in the basement.

9.1.4 Sunny Hills – Cake Shop at Minami-Aoyama

By Kengo Kuma & Associates

Omotesando

Dec. 2013

Retail store

297 m 2

Project description by Kengo Kuma & Associates

This shop, specialised in selling pineapple cake (popular sweet in Taiwan), is in the shape of a bamboo basket. It is built on a joint system called "Jiigoku-Gumi" (Hell Joint), traditional method used in Japanese wooden architecture (often observed in Shoji: vertical and cross pieces in the same width are entwined in each other to form a muntin grid). Normally the two pieces intersect in two dimensions, but here they are combined in 30 degrees in 3 dimensions (or in cubic), which came into a structure like a cloud. With this idea, the section size of each wood piece was reduced to as thin as 60mm×60mm. As the building is located in middle of the residential area in Aoyama, we wanted to give some soft and subtle atmosphere to it, which is completely different from a concrete box. We expect that the street and the architecture could be in good chemistry. [Kengo Kuma & Associates] [xxv]

Figure 103 Sunny Hills Cake Shop entry. Photo: GA

Figure 104 "Hell Set" joint detail. Photo: GA

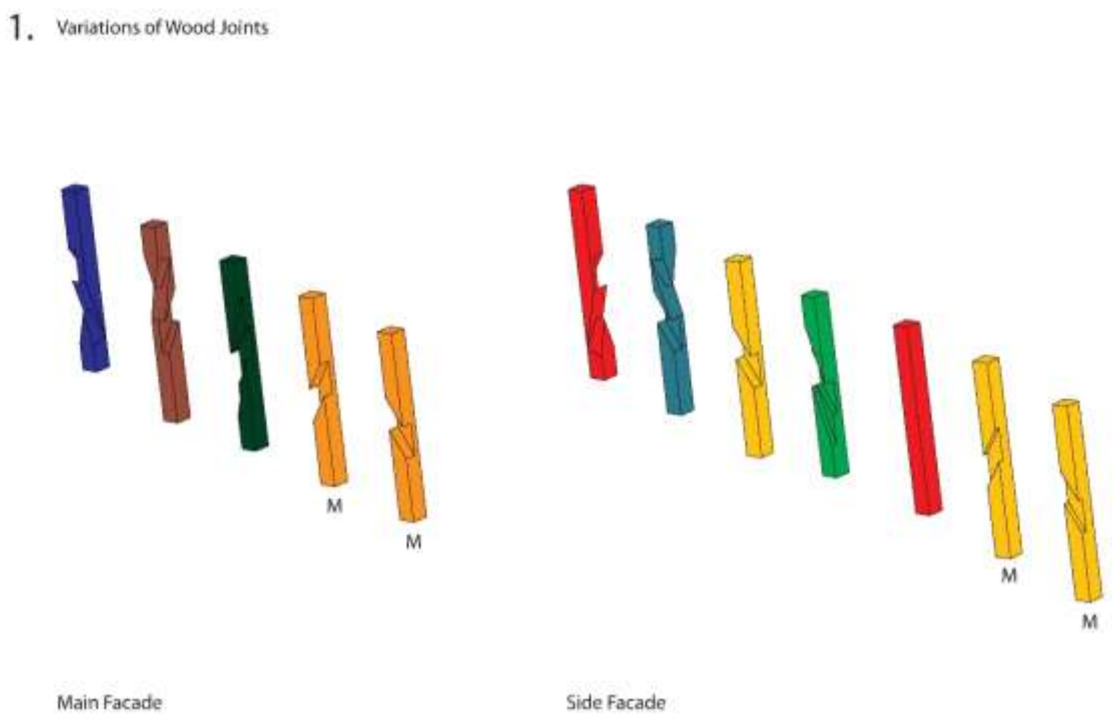


Figure 105 "Hell Set" diagram, curtesy of Kengo Kuma & Associates

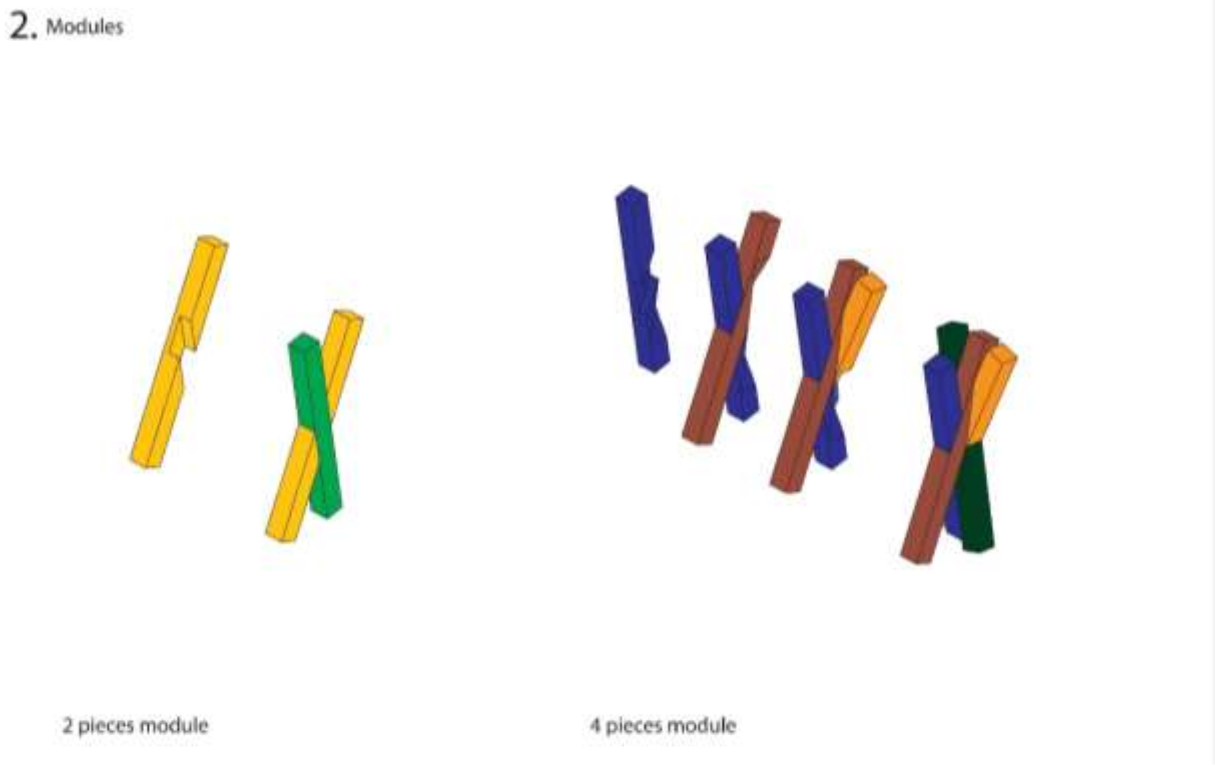


Figure 106 "Hell Set" diagram, curtesy of Kengo Kuma & Associates

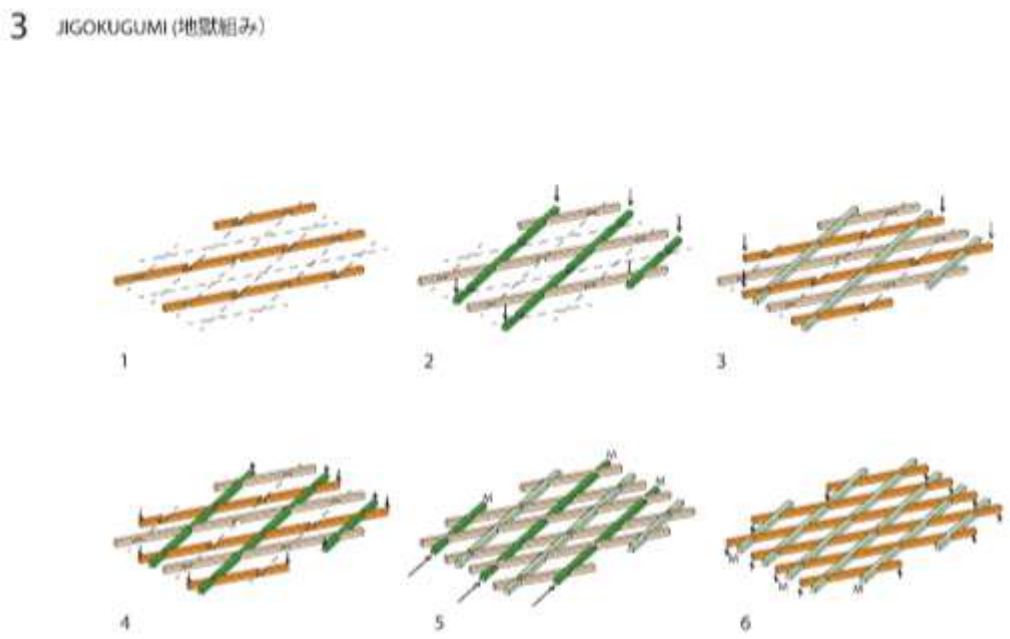


Figure 107 "Hell Set" diagram, curtesy of Kengo Kuma & Associates

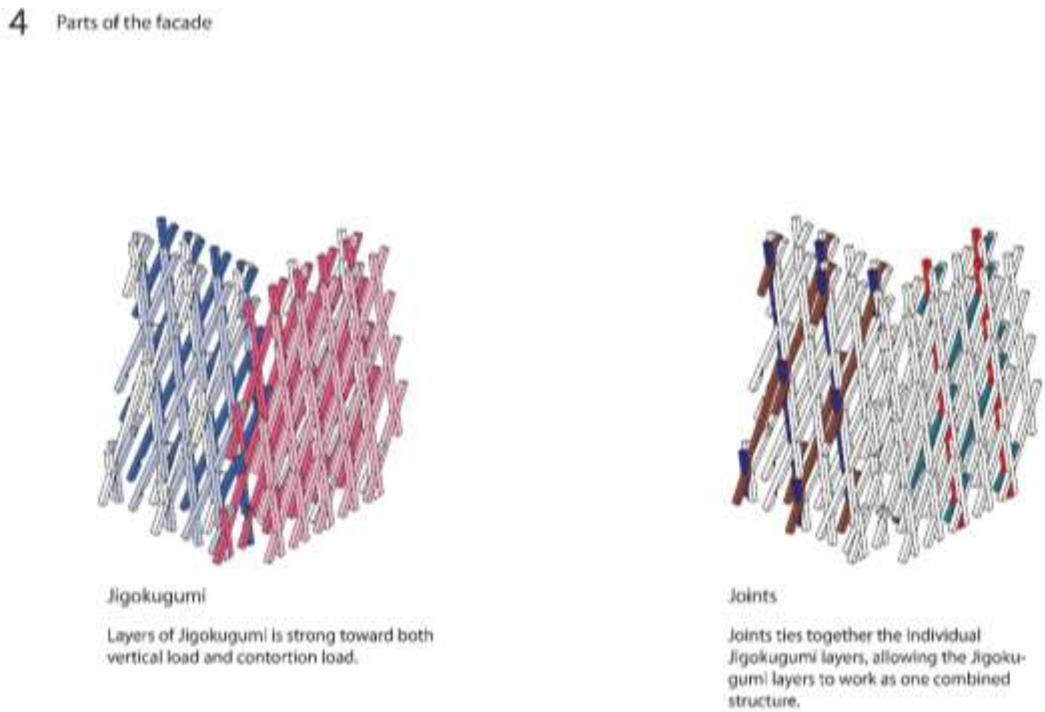


Figure 108 "Hell Set" diagram, curtesy of Kengo Kuma & Associates

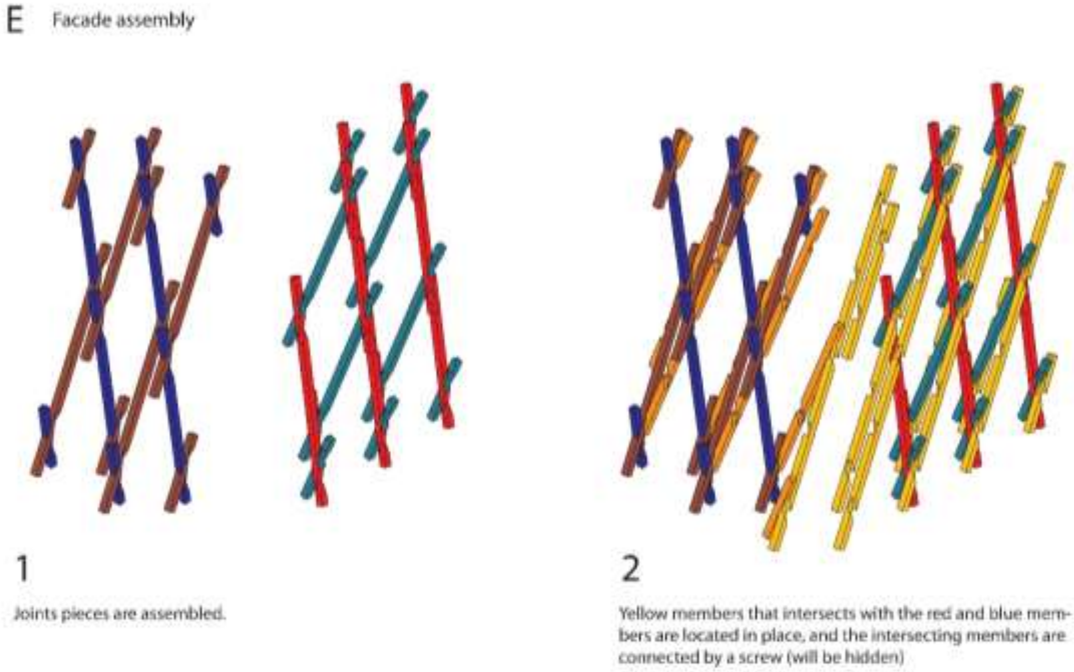


Figure 109 "Hell Set" diagram, curtesy of Kengo Kuma & Associates

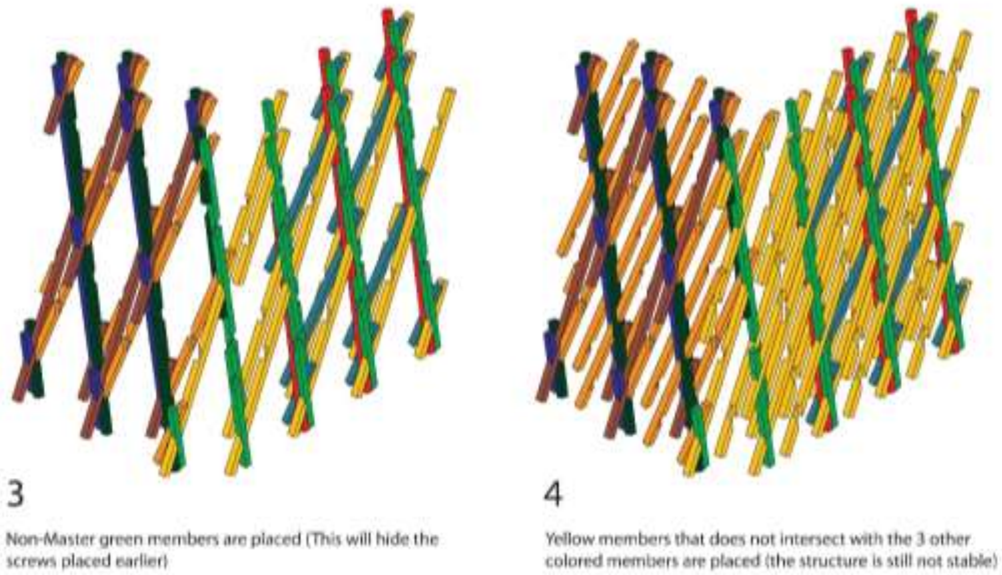


Figure 110 "Hell Set" diagram, curtesy of Kengo Kuma & Associates

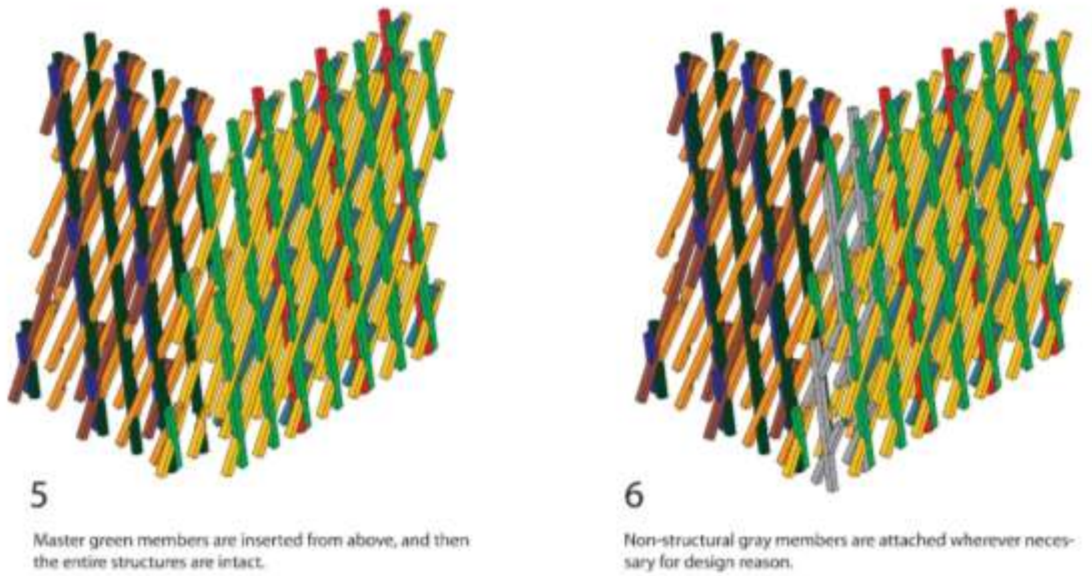


Figure 111 "Hell Set" diagram, curtesy of Kengo Kuma & Associates

9.1.5 GC Prostho - Museum Research Centre

By Kengo Kuma & Associates

Figure 112 Photo curtesy of Kengo Kuma & Associates

“The inspiration for its design was an old Japanese game called “chidori”. In it, one puts together wooden sticks with joints of a unique shape. The shapes you achieve just change by rotating the wood, without any nails or other metal. This game's tradition passes from one generation to the next in the small mountain city of Hida Takayama, where there are still many skilled craftsmen.

Jun Sato, structural engineer for the project, conducted a compressive and flexure test to check the strength of this system, and verified that even the device of a toy could be adapted to ‘big’ buildings. This architecture shows the possibility of creating a universe by combining small units like toys with your own hands. We worked on the project in the hope that the era of machine-made architectures would be over, and human beings would build them again by themselves.” [Kengo Kuma & Associates]

Figure 113 Photo curtesy of Kengo Kuma & Associates

xxvi

9.1.6 Mokuzai Kaikan - Headquarters of Tokyo Timber Wholesaler Association

By Tomohiko Yamanashi & Takeyuki Katsuya, Nikken Sekkei

Shinkiba, Koto, Tokyo

Project Year 2009

Area 1011.0 sqm

Architect Tomohiko Yamanashi & Takeyuki Katsuya (Nikken Sekkei, Japan)

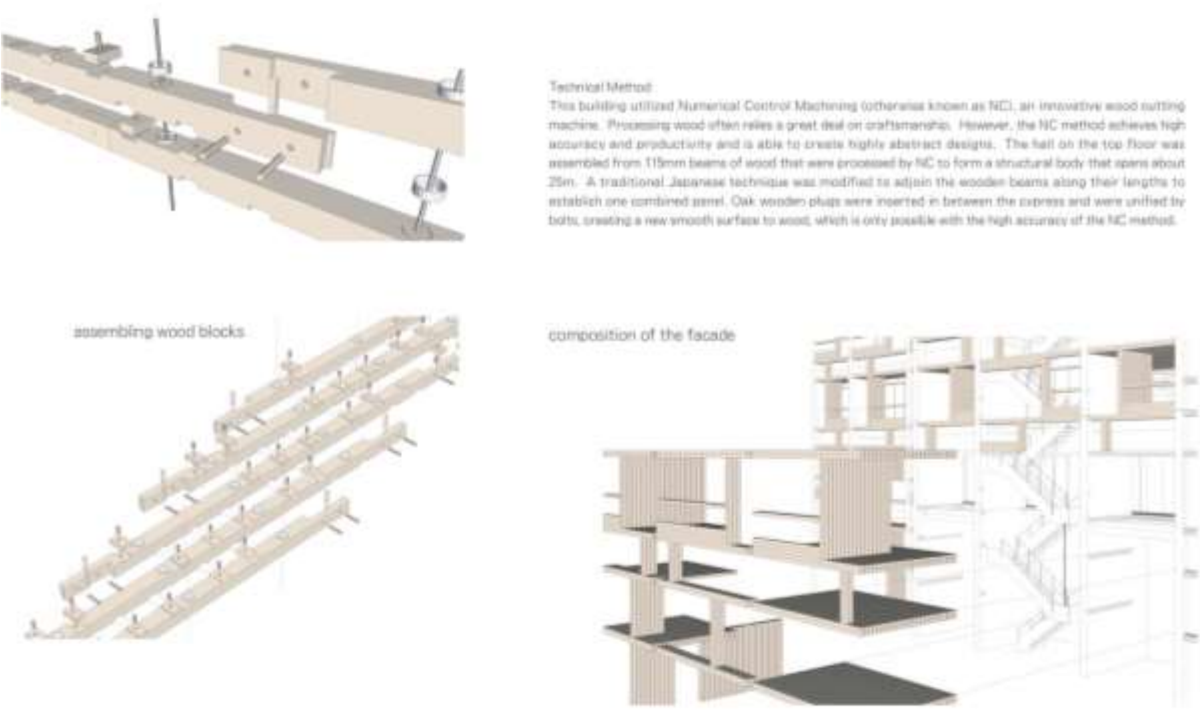
"The purpose of this project was to display the various possibilities of wood in the hope of reviving its popularity as an urban construction material. The 7582 square meter seven-story office building employs reinforced concrete for its structural frame to resist Japanese strong earthquakes, however, timber was specified wherever possible. We paid close attention to detail in order to establish equivalence between the scale and prominence of the principal concrete frame with that of the secondary timber elements. As a result, concrete was cast in slender cedar framework, maintaining the scale and grain of the timber. In terms of the timber elements themselves everything that can be seen is formed in 115 x 115 mm sections of Japanese cypress. By using a computer numerical controlled [CNC] cutting machine, a process that would traditionally rely on expert craftsmanship can now be used on larger scale projects such as this, achieving a high degree of accuracy on complicated abstract designs. We also overcame complicated fire safety issues by providing adequate ceiling height to allow smoke to accumulate." [Nikken Sekkei]

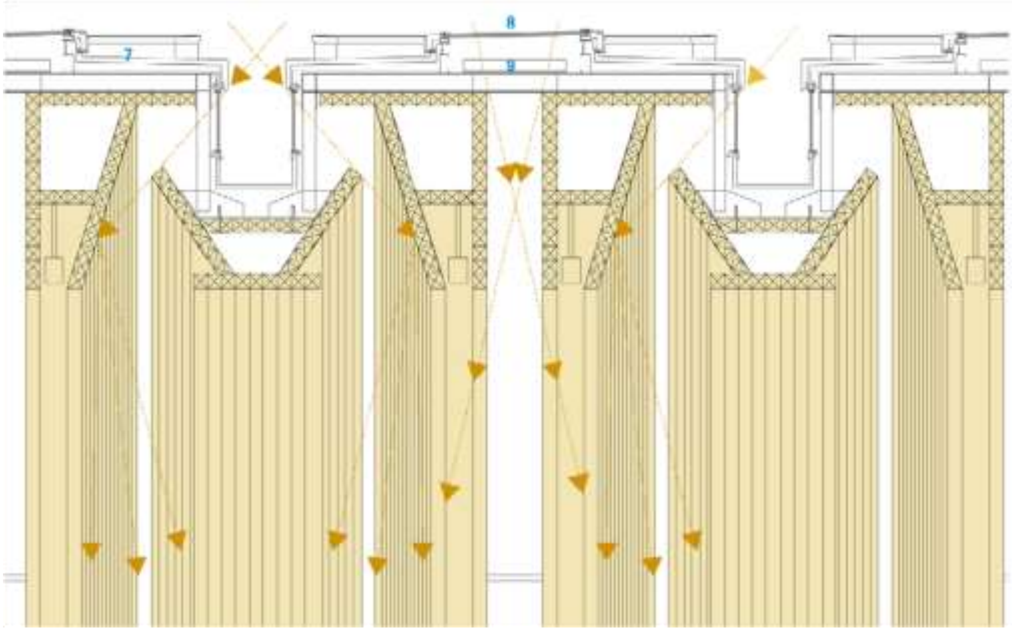
Figure 114 Mokuzaikaikan Photo: Nacasa & Partners Inc, Harunori Noda

Figure 115 Mokuzaikaikan feature wall. Relief cuts (curfing)to the back of the individual members Photo: GA

Figure 116 Mokuzaikaikan 'Timber Hall' Photo: GA

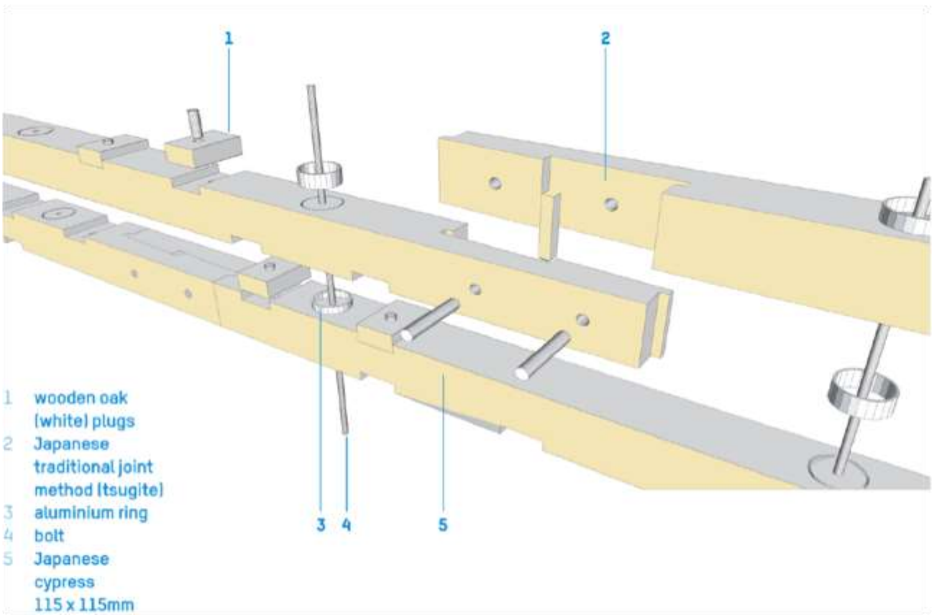
Figure 117 Mokuzaikaikan Composite Beam Detail Photo: GA

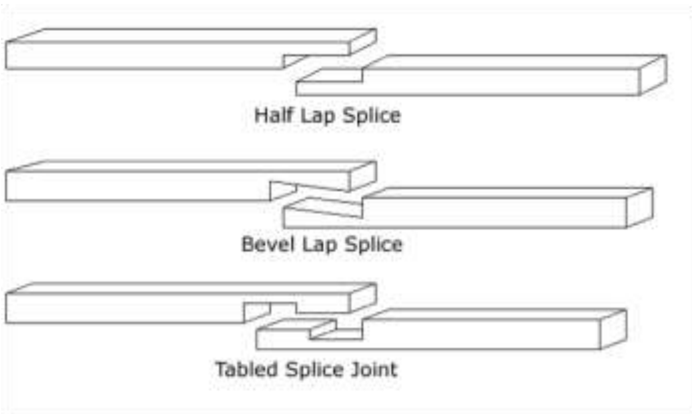


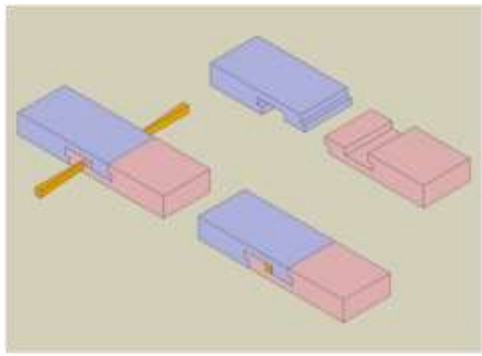


1 structure: 1.61m-deep beams, composite of Japanese cypress in 115 x 115mm sections (maximum length 4m)
2 steel sash window
3 internal blind
4 aluminium eaves panel
5 steel sliding door (2.7m wide)
6 side light
7 aluminium roof
8 top light
9 electric rolling blind
10 terrace deck in cypress
11 cypress elevation panels

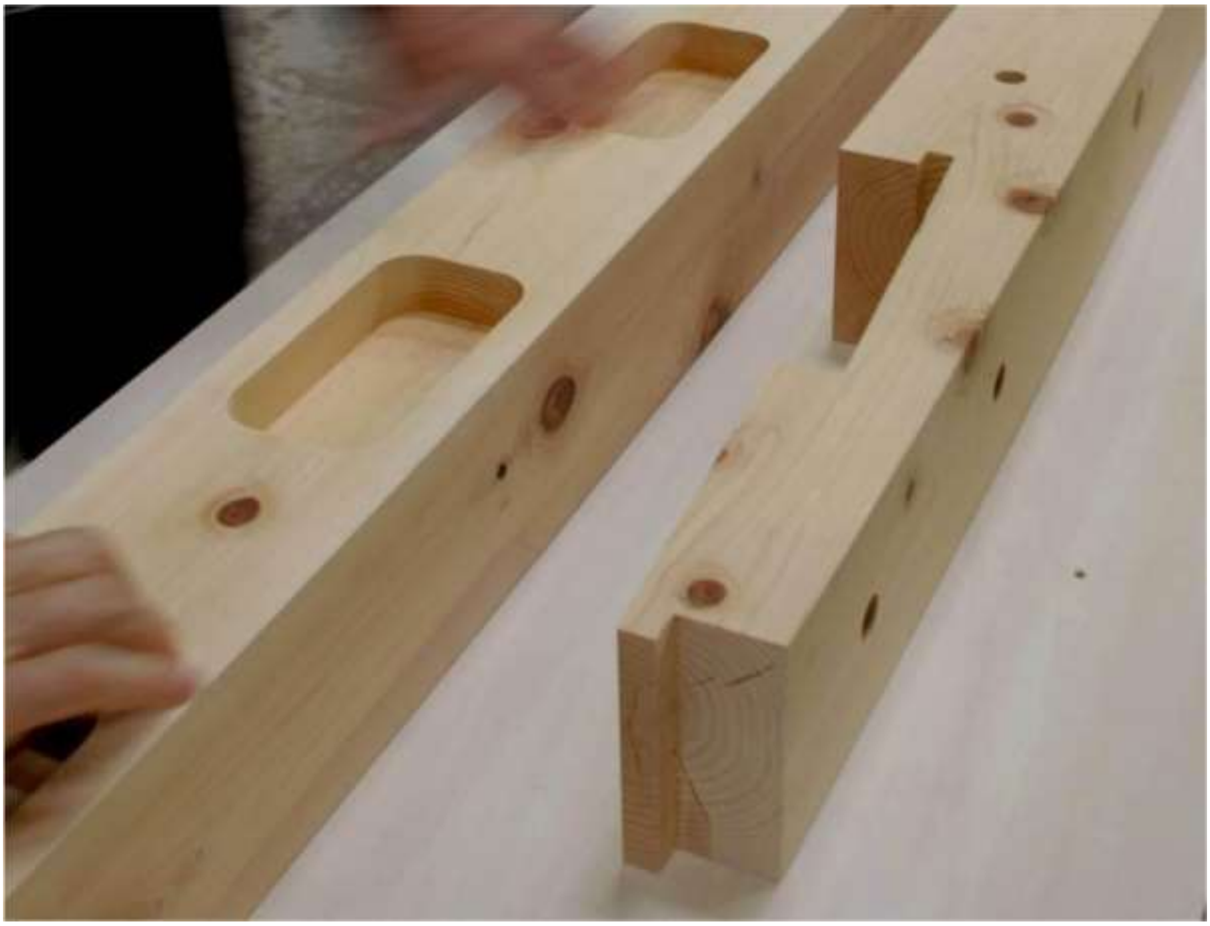
1 hall
2 terrace
3 outdoor staircase
4 stock room
5 foyer
6 EV hall
7 cloakroom







Wedged Tabled Splice Joint



xxvii

10 REFERENCES

While the author has attempted to credit all resources correctly, in some instances it may not have been possible to verify or confirm the correct source. Please contact the author if you have not been correctly credited for any source or contribution in this report.

---

[i] A Köppen climate classification map of Japan.
https://en.wikipedia.org/wiki/Geography_of_Japan

[ii] Jeffrey Hays JAPANESE FORESTS, FORESTRY AND JAPAN'S RICE PADDY ECOSYSTEM
http://factsanddetails.com/japan/cat26/sub164/item2834.html

[iii] Lead Carpenter/project manager at Koyane; Lives in Fujioka-shi, Gunma, Japan; Studied Industrial design at Carleton University

[iv] Abe N.1, Tsukahara M.2, Homma F.3, Omomo Y.3, Ishiyama T.3 The system for assessment of the Japanese cedar forest resources using space image data // Sibirskij Lesnoj Zurnal (Siberian Journal of Forest Science). 2014. N. 5: 53–68 (in English and in Russian).
http://sibjforsci.com/articles/abe-n-thukahara-m-homma-f-omomo-y-ishiyama-t-the-system-for-assessment-of-the-japanese-cedar-forest-/

[v] https://en.wikipedia.org/wiki/Kintsugi

[vi] The Kanna Finish: How to Get Glass-Smooth Surfaces in Wood Without Sandpaper or Varnish
Before this man designs his furniture, he designs his tools
BY RAIN NOE - APR 17, 2015

[vii] Making See-Through Wood at Japan's Unique Planing Competition By Spooky on May 28th, 2013
http://www.odditycentral.com/events/making-see-through-wood-at-japans-unique-planing-competition.html

[viii] Hugh Miller JAPANESE WOOD CRAFTSMANSHIP The tools, techniques and philosophies that make Japan's unique woodworking culture so special, and the lessons that can be learnt by craftsmen in the UK

[ix] Traditional Japanese Carpenters Exhibit Master Craftsmanship When Constructing Durable Buildings Without Nails;
https://laughingsquid.com/traditional-japanese-carpenters-exhibit-master-craftsmanship-when-constructing-durable-buildings-without-nails/

[x] The Tradition of Wooden Architecture in Japan; YAMATO Satoshi Agency for Cultural Affairs, Japan

[xi] JAANUS Japanese Architecture and Art Net Users System, http://www.aisf.or.jp/~jaanus/deta/k/kiku.htm

[xii] DETAIL Article https://www.detail-online.com/article/bamboo-basket-shop-by-kengo-kuma-16760/

[xiii] Indesign Live, HK
https://www.indesignlive.hk/articles/in-conversation-with-tomohiko-yamanashi

[xiv] Dr. Yoshiaki Amino Assistant Professor Dept. Structural Design and Timber Engineering, School of Architecture, Vienna University of Technology Vienna, Austria
An overview of modern Japanese wood construction – Interaction with tradition

[xv] Reciprocal Frame Structures Made Easy; Peng Song∗ Chi-Wing Fu∗ Prashant Goswami Jianmin Zheng Nanyang Technological University, Singapore Niloy J. Mitra University College London Daniel Cohen-Or Tel Aviv University
http://vecg.cs.ucl.ac.uk/Projects/SmartGeometry/reciprocal_frame/paper_docs/reciFrame_sigg13.pdf

[xvi] H. Tanahashi & Y. Suzuki Ritsumeikan University, Japan
Embedment Mechanism and Formulation of Major types of traditional wooden joints in Japan

[xvii] Wood Vibrations- Research on structural timber and vibration
https://reynoldstom.wordpress.com/connections-in-timber-structures/

[xviii] Ikea to DITCH bolts, screws, dowels and Allen keys to make furniture assembly easier, By GILES SHELDRICK.
https://www.express.co.uk/life-style/life/777137/Ikea-ditch-tools-to-make-furniture-assembly-easier

[xix] http://www.x-fix.at/en/homepage/

[xx] Blumer Lehmann NEWS, No 10, 12/2017
http://www.blumer-lehmann.ch/fileadmin/documents/10_Unternehmen/111_Erlenhof-News/Blumer-Lehmann_AG_News_2017__E.pdf

[xxi] https://newatlas.com/tokyo-sky-tree/21682/

[xxii] Japan Architecture + Urbanism, article
https://www.japlusu.com/news/yusuhara-wooden-bridge-museum

[xxiii] https://en.wikipedia.org/wiki/Toky%C5%8D

[xxiv] https://www.arch2o.com/yuhara-kinbashi-museum-kengo-kuma-associates/

[xxv] DEZEEN Article
https://www.dezeen.com/2014/02/25/sunnyhills-at-minami-aoyama-by-kengo-kuma/

[xxvi] https://www.archdaily.com/199442/gc-prostho-museum-research-center-kengo-kuma-associates

[xxvii] 18. Internationales Holzbau-Forum 2012_Mokuzai Kaikan | T. Yamanashi (Nikken Sekkei)
https://www.archdaily.com/778844/mokuzaikaikan-nikken-sekkei