DESIGN AND CONSTRUCTION

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TECHNICAL SHEETS

Pinned tenon and mortise with an angle

Structural category :Load-bearing joint

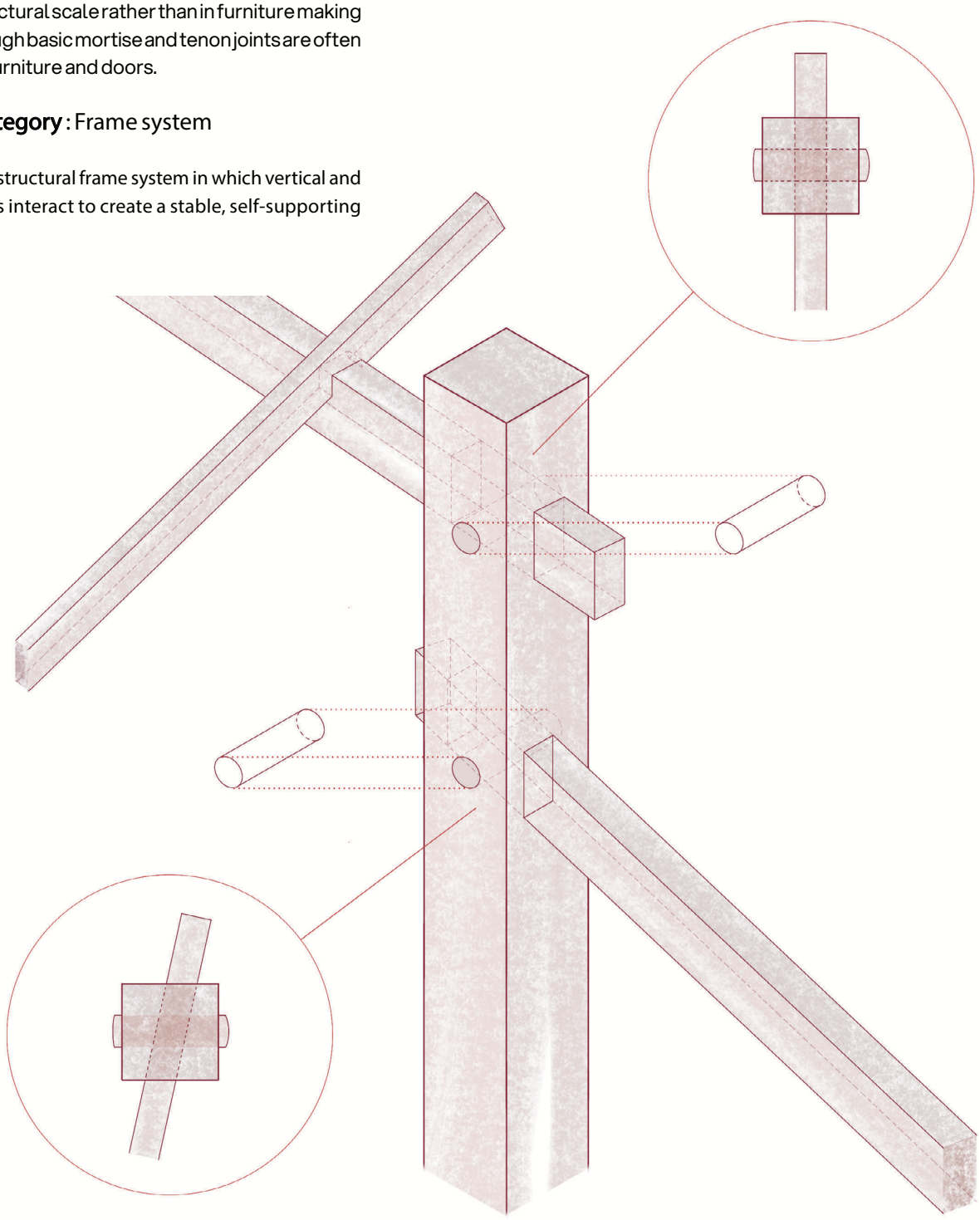
This joint is designed to transfer structural loads from horizontal beams into a vertical central pillar. The wooden pin provides mechanical locking and increases resistance to shear and withdrawal forces.

Craft Category :Carpenter's joinery

This joint is traditional carpentry and wood construction, generally on an architectural scale rather than in furniture making or cabinetry, although basic mortise and tenon joints are often found in wooden furniture and doors.

Architectural Category : Frame system

The joint is part of a structural frame system in which vertical and horizontal elements interact to create a stable, self-supporting structure.



TECHNICAL SHEETS

PINNED TENON AND MORTISE JOINERY (COLUMNS AND BEAMS):

The mortise-and-tenon joint is used to assemble the pavilion's structural columns and beams. By inserting a wooden key (pin) through the tenon, the beam is securely locked to the column. This method not only ensures stability but also highlights the joinery as an expressive architectural feature, turning a structural necessity into a central aesthetic element.

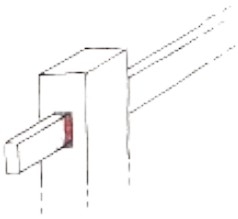
In this project, the joint is applied to a central vertical pillar crossed by two straight through tenons:

- One beam passes through the pillar perpendicularly (90°)
- A second beam passes through the same pillar via a mortise cut at a 10° angle

The angled mortise is entirely executed inside the pillar, while the tenons remain straight. This configuration allows the beams to radiate from the central post, enabling the creation of a circular or radial structural system.

CONSTRAINTS:

- Limited tolerance for mistakes (inaccuracy may weaken the system) ; High precision required with complex execution.

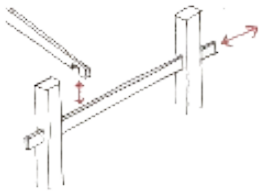


- Time consuming in the workshop phase



ADVANTAGES:

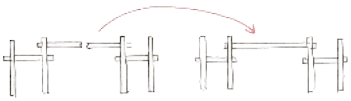
- Demountable x Quick and easy to build ; Mechanical locking



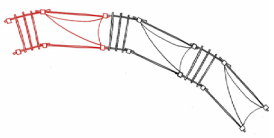
- No need for additional materials to connect the pieces together (nails, glue etc ...)



- Flexibility: parts can be replaced individually if damaged



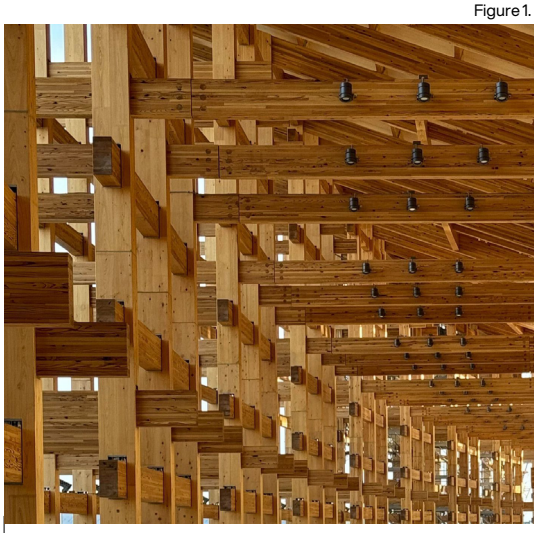
- Adaptable to angled geometries



APPLICATION IN ARCHITECTURE

Mortise-and-tenon joinery, especially when pinned with wooden pegs, is a traditional wood-to-wood connection where a projecting tenon fits into a mortised opening. Widely used in architecture, this joint provides strong structural connections without metal fasteners, allowing durability, disassembly, and expressive craftsmanship in both historic and contemporary timber construction.

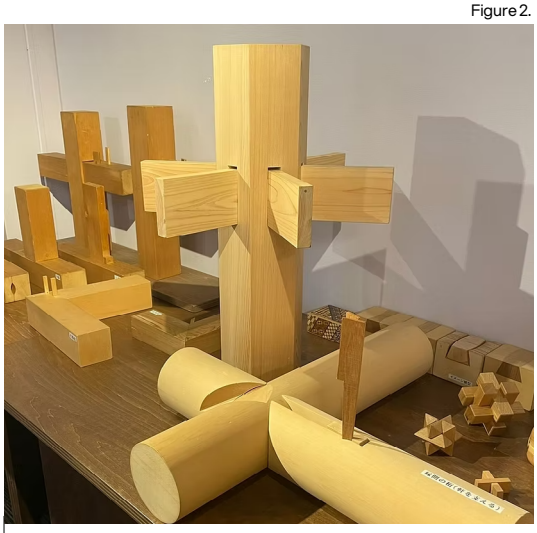
Figure 1.



GRAND RING — EXPO 2025 OSAKA

Large timber beams interlock using pinned mortise and tenon joints, ensuring structural stability without exposed metal connectors. The project reinterprets traditional Japanese joinery at an architectural scale, combining craftsmanship with modern engineering requirements.

Figure 2.



HISTORIC JAPANESE TEMPLE CARPENTRY (KIGUMI TRADITION)

Traditional kigumi carpentry relies on mortise and tenon joints, often secured with wooden pegs, to connect columns and beams. These joints allow buildings to resist seismic forces while remaining durable and repairable over centuries.

Figure 3.



FURNITURE DESIGN

A solid wood bench assembled using through mortise and tenon joints, where the tenon passes through the leg and is locked in place. This joint creates a strong, metal-free connection while making the structure and craftsmanship clearly visible.

Figure 4.



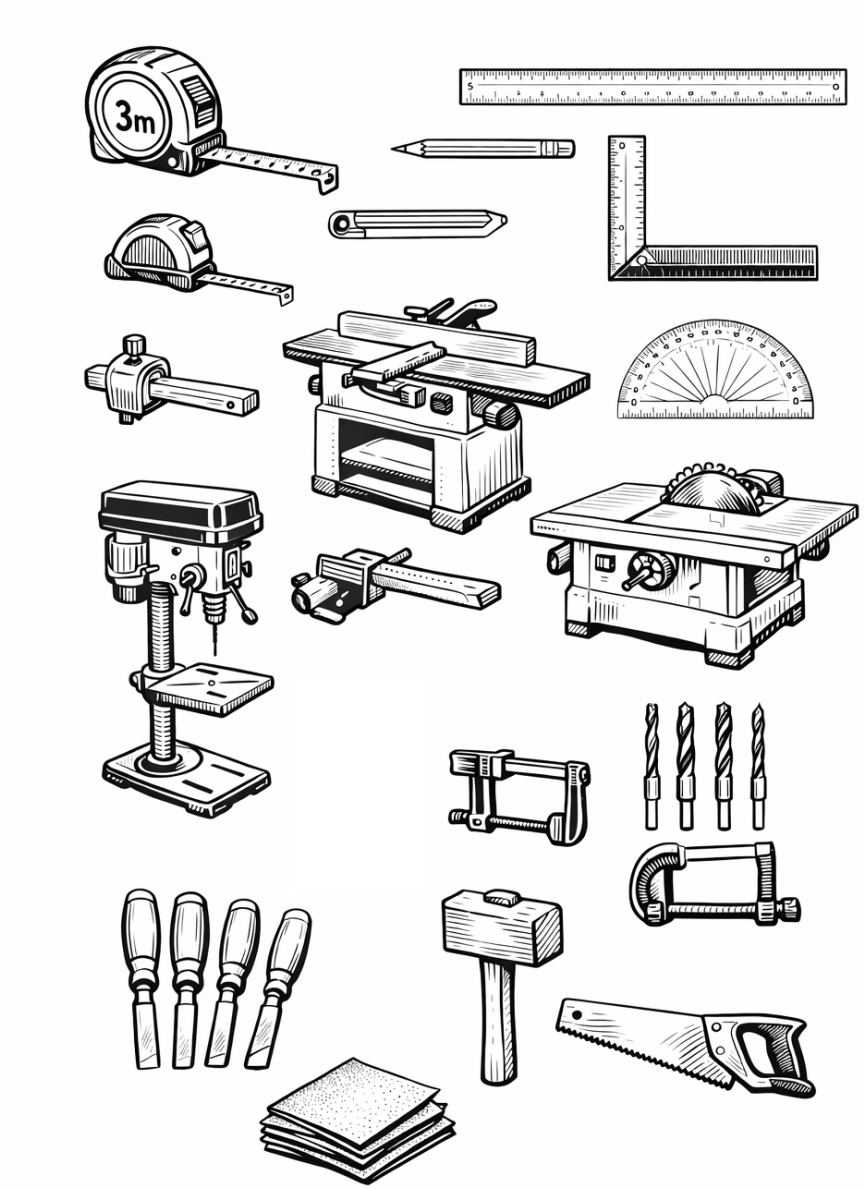
TRADITIONAL TIMBER FRAMING

In traditional timber roof structures, beams and posts are connected using pinned mortise and tenon joints. Wooden pegs secure the tenon inside the mortise, ensuring efficient load transfer and long-term structural stability without metal fasteners.

TOOLS REQUIRED

TOOLS

1. Measuring tape
2. Steel ruler
3. Pencil
4. Carpenter's square (try square)
5. Bevel gauge (sliding bevel)
6. Protractor
7. Marking gauge
8. Jointer
9. Thickness planer
10. Table saw
11. Drill press
12. Brad-point drill bits
13. Clamps
14. Wood chisels (various widths)
15. Wooden mallet
16. Hand saw
17. Sandpaper (various grits)



MATERIALS

18. Solid timber beams
19. Central wooden pillar
20. Wooden pin (dowel)

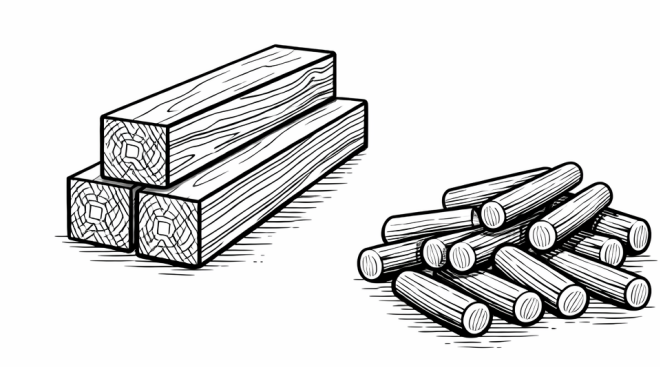


Figure 5.

STEP-BY-STEP PROCESS

STEP 1 – SELECTION OF TIMBER AND SCALE DEFINITION

The process began with the selection of available timber pieces. Based on their dimensions, a working scale of 1:4 was defined for the joint, ensuring structural clarity while remaining feasible within the workshop constraints.

STEP 2 – PREPARATION OF THE TIMBER

All three wooden elements (central pillar and two beams) were planed and jointed to achieve straight faces, square edges, and accurate final dimensions. This step was essential to ensure precision during layout and assembly.

STEP 3 – LAYOUT AND MARKING

The mortise positions were carefully marked on the central pillar using pencil and a marking gauge. Two through mortises were defined:

One perpendicular mortise (90°)

One mortise cut at a 10° angle

Special attention was given to transferring the angle accurately on all faces of the pillar.

STEP 4 – INITIAL MATERIAL REMOVAL (DRILLING)

For both mortises, parallel holes were drilled using an electric drill to remove the majority of the material. This allowed for controlled excavation while preserving the layout lines.

STEP 5 – ROUGH CHISELING

After drilling, the remaining material between the holes was removed using chisels. At this stage, the mortises were shaped roughly, following the marked geometry.

STEP 6 – PRECISION CHISELING AND CONTROL

The mortises were refined gradually with careful hand chiseling.
The pillar was regularly rotated during this process to avoid over-cutting and to maintain alignment, especially for the angled mortise. This step required patience and continuous checking.

STEP 7 – HAND SANDING AND FINAL ADJUSTMENT

Once the mortises reached their final shape, hand sanding was performed to improve surface accuracy and ensure a precise fit for the tenons. (with sandpaper)

STEP 8 – TEST FITTING OF THE BEAMS

Both straight through tenons were inserted into the pillar to verify fit, alignment, and angle accuracy. Adjustments were made where necessary.

STEP 9 – DRILLING FOR THE WOODEN PINS

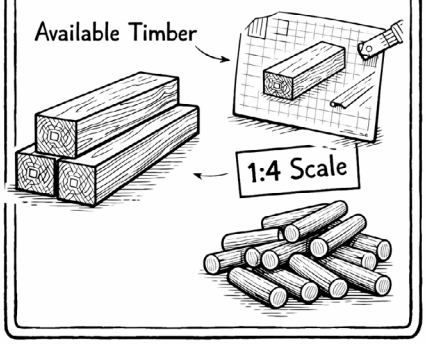
With the joint fully assembled, the entire connection was drilled using the diameter corresponding to the wooden pins. This ensured perfect alignment between mortise and tenon.

STEP 10 – INSERTION OF THE WOODEN PINS

The wooden pins were inserted and driven into place using a mallet, locking the joint mechanically and completing the assembly.

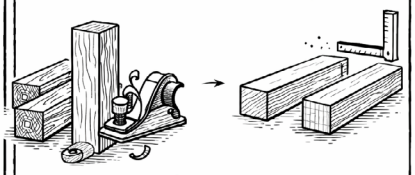
STEP 1

Available Timber



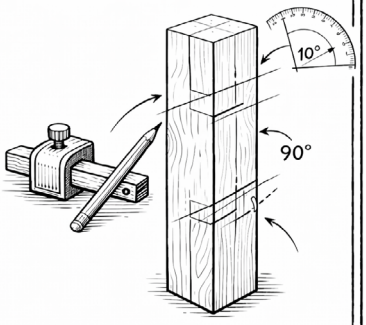
1:4 Scale

STEP 2



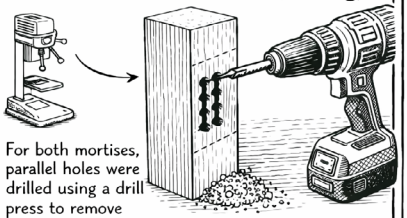
Planed & Jointed

STEP 3



STEP 4

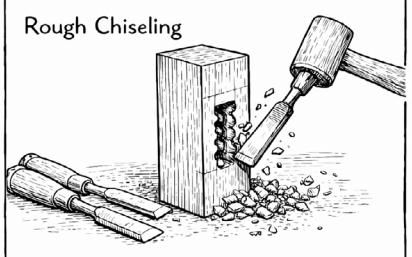
Initial Material Removal (Drilling)



For both mortises, parallel holes were drilled using a drill press to remove the majorite of material. This allowed for controlled excavation while preserving the layout lines.

STEP 5

Rough Chiseling



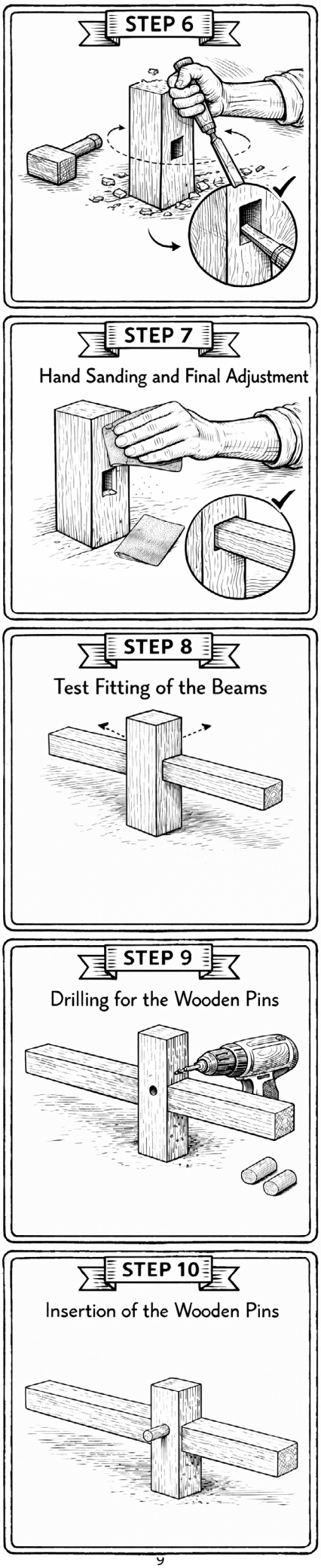

STEP 6
STEP 7
Hand Sanding and Final Adjustment
STEP 8
Test Fitting of the Beams
STEP 9
Drilling for the Wooden Pins
STEP 10
Insertion of the Wooden Pins

Figure 6.

PICTURES

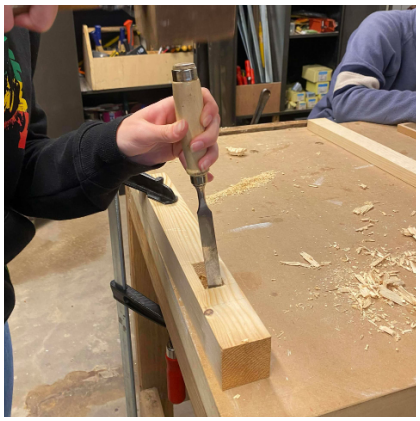




JOINING AND PLANNING

CHISELING









DRILLING FOR THE WOODEN PINS

FINAL RESULT





Figure 7.

POINTS OF ATTENTION

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1 TOLERANCE OF THE MORTISES

The through mortises had to be tight enough to ensure structural stability, but not forced. This was managed by removing material gradually with chisels and regularly testing the fit of the beams.

2 ALIGNMENT OF PERPENDICULAR AND ANGLED MORTISES

Cutting two intersecting mortises in the same pillar required constant verification of alignment. The pillar was frequently rotated during the process to maintain consistency and avoid deviation.

3 EXECUTION OF THE 10° ANGLED MORTISE

Maintaining a constant 10° angle through the full depth of the pillar was challenging. This was addressed by careful layout on all faces and slow, controlled chiseling.

4 RISK OF OVER-CUTTING

Over-cutting during chiseling could not be corrected. To prevent this, material was removed symmetrically from both sides of the pillar and refined progressively.

5 TEAR-OUT AND SURFACE QUALITY

Chiseling against the grain caused local tear-out. This was reduced by adjusting chisel direction and finishing the mortises with hand sanding.

6 PIN ALIGNMENT AND DRILLING ACCURACY

Once the joint was drilled for the wooden pins, the assembly became irreversible. Final alignment was therefore carefully checked before drilling and pin insertion.

BIBLIOGRAPHY

Figure 1. Sou Fujimoto Architects. The Grand Ring at Expo 2025 Osaka. Photograph by Expo Osaka 2025 / William Mulvihill, 2025. Published in ArchDaily and Designboom.

Figure 2.Yamada, Shinya. "Discover the Art of Japanese Woodworking Joints: Kigumi Experience." ninjakotan-travel.com (blog), March 5, 2024; updated September 24, 2024. Photograph illustrating traditional Japanese woodworking joints (kigumi). Accessed [date]. https://www.ninjakotan-travel.com/post/discover-the-art-of-japanese-woodworking-joints-kigumi-experience. (accessed on 11 janvier 2026)

Figure 3. Harris, Caleb. "Dining Bench." Photo. YouCanMakeThisToo, March 5, 2019. YouCanMakeThisToo.com. https://www.ycmt2.com/blog/dining-bench
(accessed on 11 janvier 2026)

Figure 4. Boiserie Le Creff. Charpente traditionnelle / Charpente Manoir / Charpente Chapelle [photographies]. Boiserie Le Creff. https://www.boiserielecreff.fr/boiserie-le-creff-charpente
(accessed on 11 janvier 2026).

Figure 5. ChatGPT. Tools and Materials. Original drawing created for the Kigumi Lab project, January 2026.

Figure 6. ChatGPT. Step by Step Process. Series of 10 original drawings created for the Kigumi Lab project, January 2026.

Figure 7. Marichal, Joaquim. Series of 8 photos taken on iPhone. Kigumi Lab Project, January 2026.