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PARAMETRIC LIBRARY OF JAPANESE JOINERY

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ABSTRACT: This research is about using Japanese joinery in a BIM workflow. The objective is to create a digital library of Japanese timber joints by collecting them from various sources and modelling them into parametric Revit families. So, they can be used by designers in BIM projects and shared between BIM software via IFC models. The results of this paper show the modelling process of two types of joints, that are: Ari Tsugi and Kai No Kuchi Tsugi and the parameters that define their dimensions to allow their geometry to adapt to different timber sections.

KEYWORDS: Japanese joinery, Parametric library, BIM.

1 – INTRODUCTION

In many countries including Japan wood is the traditional construction material because of its availability in abundant forests, and since the 1960s demand for wood has increased worldwide due to its cost efficiency and the need to build more with renewable materials. However, the BIM software focus remained in steel and reinforced concrete with less adaptation to wooden design projects [1] such as Japanese traditional architecture.

2 – BACKGROUND

In Japan the carpenters called "Miyadaiku" shape the traditional wooden buildings such as temples and shrines following the same method since centuries. When they build these structures for the first time, they mark timber with black indelible ink that is a reference for future refurbishments. Later the structure can be disassembled to repair the damaged parts of it or to move it and reuse it somewhere else. And Japanese joinery is the key of this process. It is a large panel of complex wooden joints, that are meticulously carved by highly skilled carpenters who spend years mastering this art.

Japanese joinery is generally called "Kigumi" (木組み) by carpenters, which is a broad term meaning timber frame. However, in academic literature it is referred to as "Tsugite-shiguchi" (継手仕口) a combined word that includes "Tsugite" (継手) which means extending a timber with another, and "Shiguchi" (仕口) which means connecting two timbers with an angle. Also "Shiguchi" refers to both "Kumite" (組手) which is the intersection of two timbers, and "Sashiguchi" (差口) which is inserting one timber to the side of another[2].

The oldest written references available today about Japanese joinery are 21 manuals dating to the Edo period (1603-1868), and the oldest one of them (held by Tokyo Metropolitan Central Library) was written in 1728. From these manuals were identified 129 types of joints with their variable terminologies and geometrical characteristics [3]. However, in fact, there is a far larger number of joints because each basic type was developed into more complex variants by generations of carpenters. For example there are more than 50 variants for the Kama Tsugi (gooseneck joint) alone[4].

Previously digital archives of traditional buildings including Japanese joinery have been made for different purposes. First, to facilitate the management of a large number of technical drawings, and the collaboration between different project actors like in the refurbishment of the Hishi Yagura watchtower of Kanazawa castle[5]. Then, to perform different kind of simulations as in the project of the five story pagoda of Hokekyoji temple [6] which can be accessed online[7]. Also, to make the project components more detailed and to parametrise the process of modification like in the Himeji castle project[8]. These different purposes are specifically developed in BIM software however, the complexity of Japanese joinery requires designers who want to use them to pass by a long phase of parametric modelling each time, because BIM software don't include a preset library of Japanese joints.

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Also, at least 145 papers about the structural analysis of several types of Japanese joints, evaluated during refurbishment projects were published in journals and conference proceedings. Which means that there is precise data about the structural behaviour of joints that can be used in new wooden building projects in a BIM workflow.

The oldest BIM software released in the market was Archicad in 1982 and it was previously used in some digital archives of Japanese traditional buildings [6]. And currently there are six main software: Revit, Archicad, Vectorworks, Digital Project, Allplan, and OpenBuildings. In recent years they have integrated plug-ins for wood construction but only Archicad has a built-in tool called Trussmaker [1]

Revit used to have one add-on called Timber Framing or REX, but it is no longer available since 2018. And now for Revit there are plug-ins developed by other companies like Offsite Wood which is free. Also, Wood Framing by Arkance and MWF Pro Wood which have an extra cost.

For interoperability with other software Revit provides fully certified IFC (Industry Foundation Classes) import, and export based on buildingSMART data exchange standards. This is an important feature to exchange designs and information between the different BIM software.

3 – Methodology

This research uses four Japanese joinery books because they contain a large collection of the known types of joints, their classification, and fabrication drawings. These books are “The Complete Japanese joinery” by Sato and Nakahara [9], “The Art of Japanese Joinery” by Seike [10] and “Wood joints in classical Japanese architecture” by Sumiyoshi and Matsui [11]. These three were all published first in Japanese in 1967, 1970, and 1989 respectively, however their translated versions were used, and the process of their translation to English resulted into different terminologies from one book to another for many joints. The forth book used is “Mokuzō kenchiku no Tsugite to shiguchi” by Togashi in Japanese version[12].

From these books, joints were classified according to their terminology, geometry and reference. Also joints which have the same geometry in the different books were counted as one in the collection.

The Parametric design of joints was done in Revit software and Revit has two types of files, “Project files” that contain the building model, and “Family files” that contain Elements like doors, beams, furniture…etc. So, the Project file contains a collection of Elements that are pre-designed separately in Family files. Also, a collection of Family files is called a Library, and it is stored to be used in different Projects.

The joints that were collected are being modelled one by one to make a Revit library that can be used by designers in their wood building projects. To do so each joint is carved in an existing beam or column Family file according to its appropriate use. So, the Family file is modified and the tenon and mortise are realized into two separate Families for the simple joints and more Families are necessary if the joint has several members interconnected, so they can be integrated into a wooden structure as separate elements.

The joint’s geometry is carved as a void in a timber beam or column Family and the parameters of its dimensions are set in reference to the section of the timber. So that if the section of the timber is modified the geometry will automatically adapt to the new section. The ratio of the geometry dimensions is either specified in the books or calculated in accordance with the basic joint dimensions available again in the books.

In some cases, a joint with one geometry can have two or more versions of dimensions, and in this case the functions that characterize the dimensions, according to the section of the timber in the parameters, can be modified later.

In this paper two joints from the library will be shown with their dimension parameters. And these joints are Ari Tsugi (dovetail joint) and Kai No Kuchi Tsugi. The first is used in beams and the second is used in columns and they are designed in Revit according to their respective use.

4 – RESULTS

In the precedent step, of this study 263 joints were collected from the source books, from which 78 of them are splice joints, 108 are connection joints and 35 are complex joints with more than two elements inter-connected in the same joint. The joint Yatoi hozo sashi, (see in Fig. 1) is one of the most complex and it is used in the first floor, to connect four beams to a single pillar. A few common joints are shown in Table 1, which can be found in all the 4 books or in 3 of them.

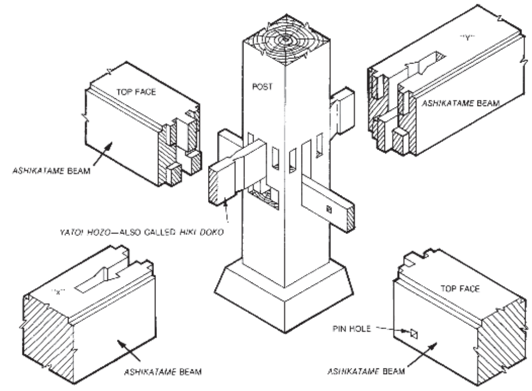

Figure 1. Yatoi hozo sashi joint.[9]

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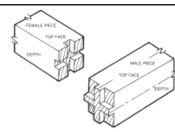
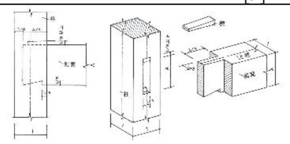
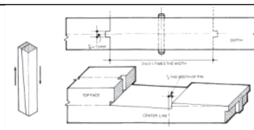
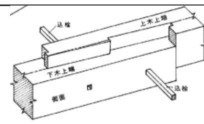
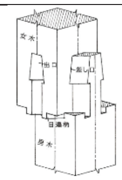
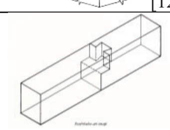
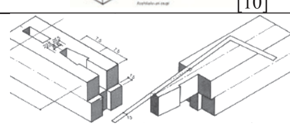
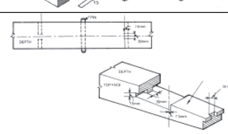
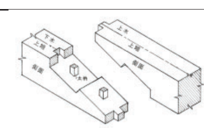
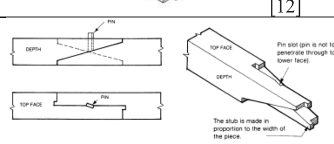
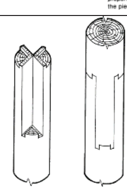
Table 1. Common Japanese joints in the four books (O: means the joint is included in the book, X: means the joint is not included in the book).

Joint name	**3D shape**	**Type of joint**	**Sato / Nakahara** [9]	**Seike** [10]	**Sumiyoshi / Matsui** [11]	**Togashi** [12]
Cross shaped tenon and mortise joint[9] (Juuji Mechigai Tsugi)[10]	 [9]	Splice (Tsugite)	O	O	O	O
Half dovetailed joint (Katasage Ari)[11]	 [12]	Connection (Shiguchi)	O	O	O	O
Mortized rabbeted oblique splice (Kanawa Tsugi)[11]	 [9]	Splice (Tsugite)	O	O	O	O
Rabbeted oblique scarf joint (Okkake Daisen Tsugi)[11]	 [9]	Splice (Tsugite)	O	O	O	O
Four faced gooseneck joint (Shiho Kama tsugi) [9]	 [12]	Splice (Tsugite)	O	X	O	O
Half lapped dovetail joint (Ari Tsugi)[9]	 [10]	Splice (Tsugite)	O	O	O	X
Stepped gooseneck splice (Koshikake Kama Tsugi) [11]	 [11]	Splice (Tsugite)	O	X	O	O
Blinded and stubbed, dadoed and rabetted scarf joint (Shiribasami Tsugi) [9]	 [9]	Splice (Tsugite)	O	X	O	O
Oblique scarf joint with stub tenon (Daimochi Tsugi)[10]	 [12]	Splice (Tsugite)	O	O	X	O
Rabbeted halves scarf joint (Sumikiri Isuka Tsugi)[9]	 [9]	Splice (Tsugite)	O	X	O	O
X-shaped ship (or open) end joint (Kai-no-kuchi Tsugi) [9]	 [9]	Splice (Tsugite)	O	X	O	O

In the 3D modelling step the joints were designed into existing Families of timber beam or column, which were first inserted into a "Project file" to check their behaviour alongside the process of modelling and parametrising the joints. And so, each joint requires at least two families for the tenon and mortise parts as was the case for the Ari Tsugi and Kai No Kuchi Tsugi, then more complex joints would need more families according to the members inter-connected in it.

For Ari Tsugi the tenon and mortise parts are of different geometries that imbricate in each other, so their design process is different. But Kai No Kuchi Tsugi the tenon and mortise parts are the same, so after designing one part, to get the other one the reference plane of the void extrusion is changed to the opposite side of the timber.

Each timber Family was modified in its separate environment, by carving the timber with voids. The type of void used was extrusion void and it required one or several voids to get the exact geometry of each joint. For the Ari Tsugi mortise, one void extrusion was enough, however for the tenon two voids were necessary (see Fig 2 and Fig.3). For the Kai No Kuchi Tsugi they were four, two for the central X shape and two for the corner sides, because the extrusion depth of opposite sides is the same and it is different from the other different sides (see Fig. 2 and Fig. 4).

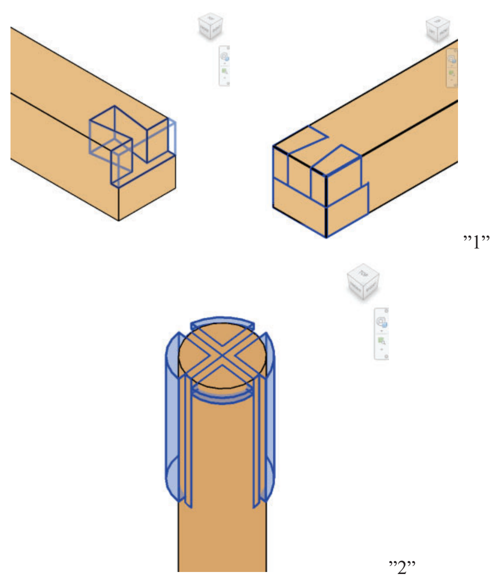


Figure 2. Ari Tsugi mortise and tenon "1" and Kai No Kuchi Tsugi "2" with their void extrusions.

To make these parametric models, each dimension of their geometry was defined by a function that refers to the section of the timber. For Ari Tsugi, the dovetail shape was the main term used to define the dimensions of the geometry (see Fig 4). Also, The timber section is the standard used in Japan 105x105mm and it is also the same used in the book of Sumiyoshi [11]. However, there were no specified ratios in the books, so the ratios were calculated according to the initial specimen. For example, the dovetail head width function is, the width of the timber section divided by 2.1 and resulting in 50mm. Decimals had to be used in the ratios here to meet the geometry and all the functions are shown in Fig. 3. The same job was done for the tenon part of the joint in a separate Family model.

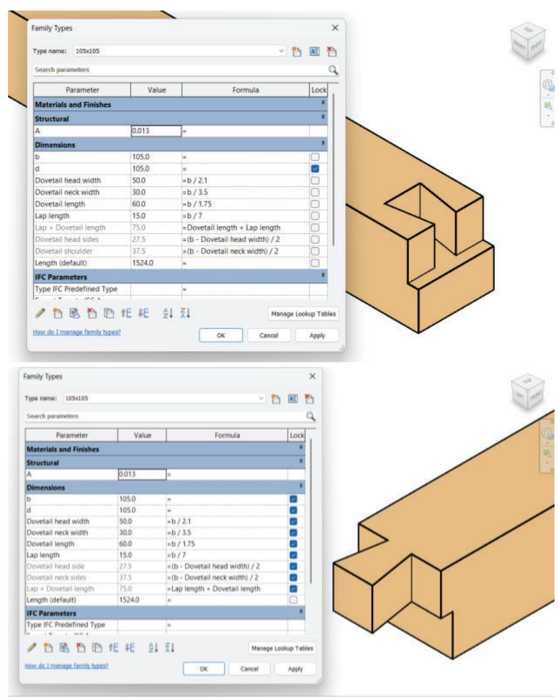


Figure 3. Ari Tsugi mortise and tenon parameters.

For Kai No Kuchi Tsugi, the section is a circle, so all the dimensions refer to its diameter (see Fig 4). Here finding the right terminology for the geometry dimensions was tricky, so the main shape or X was defined as Wings because it looks like it when the joint is completed, so all the dimensions refer to the wings. Here, the ratios are defined in the book of Togashi [12], and this is why they are fixed numbers without decimals.

For example, the Wings' thickness is the diameter of the section divided by ten and the other dimensions' function are shown in Fig. 4.

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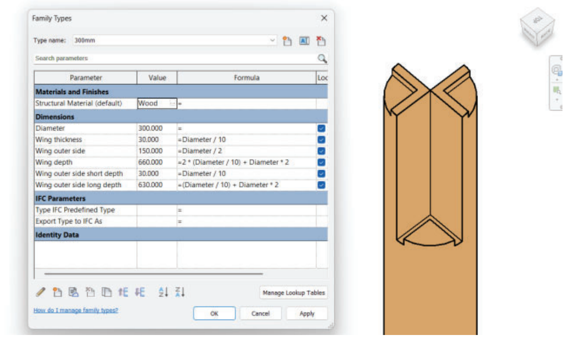
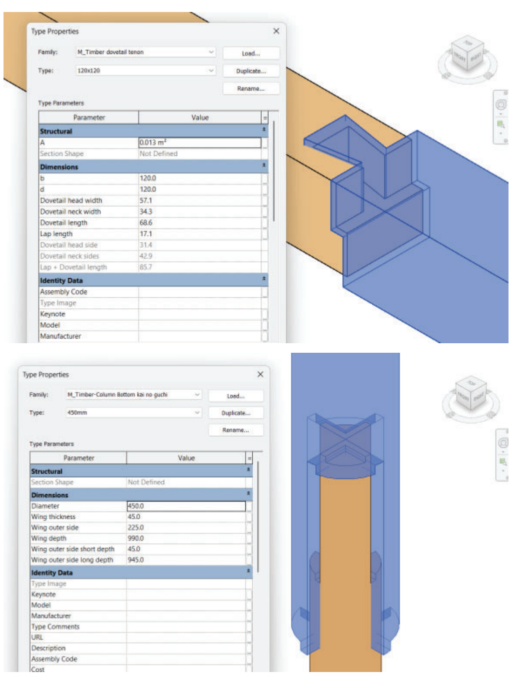


Figure 4. Kai No Kuchi Tsugi parameters.

The joints were inserted in a Project environment to test the connection of the two parts of each joint, and the adaptability of the geometry when the parameters are modified. And for the Ari Tsugi "1" the section of the tenon was set to 120x120mm while the mortise was left to 105x105mm. The geometry adapted correctly, and the scale difference shows that the ratio is correct (see Fig.5).

The same process was done to Kai No Kuchi Tsugi "2" where the column with the joint on its top, section diameter was left to 300mm, while the column with bottom joint was changed to 450mm. And the corresponding geometry change happened (see Fig. 5).



"1"

"2"

Figure 5. Ari Tsugi mortise and tenon "1" and Kai No Kuchi Tsugi "2"

5 – CONCLUSION

This paper experimented the possibility of making Revit parametric families of Japanese joinery with two example joints, that are Ari Tsugi and Kai No Kuchi Tsugi. Also, it included a brief introduction to the history of Japanese joinery and its application with computer aided design as digital archives of traditional buildings.

The end goal of this study is to model all the common joints found through this classification, in a Revit library and make them available for designers to use them in their wood building projects. And lastly to share them with other BIM software as IFC models.

Finally, it is important to note that the number of carpenters specialised in traditional building is significantly decreasing in Japan, therefore, to keep their knowledge and make it accessible to AEC professionals, Japanese joinery needs to be adapted to BIM parametric design and digital fabrication tools.

6 – REFERENCES

[1] D. Lobos Calquin et al., "Implementation of BIM technologies in wood construction: a review of the state of the art from a multidisciplinary approach," Buildings, 2024, vol. 14, Issue 3, no. 584, doi: 10.3390/buildings14030584.

[2] Daiku dōgu kenkyūkai, Kigumi tsugite to kumite no gihō. Seibundo Shinkosha, 2011.

[3] A. Naito, K. Watanabe, and S. Wakayama, "The bibliography and types of 'tsugite-shikuchi-hinagata': A study on the architectural manuals 'tsugite-shikuchi-hinagata," Journal of Architecture, Planning and Environmental Engineering (Transactions of AIJ), vol. 360, pp. 70–75, 1986, doi: 10.3130/aijax.360.0_70.

[4] T. Iwatate, "615 About changes in the Kamatsugi style over time part 1: research on tsugite and shiguchi NO2 (Architectural history/ Architectural design)," in Architectural Institute of Japan, Feb. 1975, pp. 385–388.

[5] Y. Shimokawa, "Development of browsing system for traditional wooden building on the web - functions for browsing information of shikuchi&tsugite using 3D structural frame model- Web," Architectural Institute of Japan Information Systems Technology, vol. 26, pp. 91–96, Dec. 2003.

[6] G. Hirasawa and K. Kado, “Generating Vibration Analysis Model of Five-Storied Pagoda with High-Quality Digital Archive,” AIJ Journal of Technology and Design, vol. 17, no. 35, pp. 397–400, 2011, doi: 10.3130/aijt.17.397.

[7] “WebDA3D-test-.” Available: http://yanaka50.hlab-arch.jp/da/hokekyo/

[8] K. Kado, T. Tanaka, H. Takabayashi., and G. Hirasawa, “Study on representation of tsugite-shiguchi using programming language,” AIJ Journal of Technology and Design, no. 49, pp. 1297-1300, Oct. 2015.

[9] H. Sato and Y. Nakahara, The complete Japanese joinery. USA: Hartley and Marks, 1983.

[10] K. Seike, The art of Japanese joinery. New York. Tokyo. Kyoto: Weatherhill/Tankosha, 1977.

[11] T. Sumiyoshi and G. Matsui, Wood joints in classical Japanese architecture. Japan: Kajima Institute Publishing, 1991.

[12] S. Togashi, Mokuzō kenchiku no tsugite to shiguchi. Tokyo: Rikōgakusha, 2010.

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