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# Reconsidering traditional timber joinery for sustainable structures

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## Abstract

Timber construction plays an important role in architectural history, in modern construction methods and in sustainable design, for which wood-only joinery techniques have been used for centuries. Traditional joinery typologies are the product of successive, empirical improvements over generations of artisans [1]. However, over the industrialization era, many traditional wood-only construction techniques were abandoned in favor of more profitable connections with mechanical fasteners [2]. This shift of practice lead to the development of connections with quantifiable capacity but neglecting the intrinsic anisotropic properties of natural timber. Specialized knowledge of carpenters and typical building traditions were lost.

Yet, examples of historic timber buildings with a life span of multiple centuries have demonstrated many advantages of interlocking timber joints, e.g. in severe loading cases as in the case of earthquakes [2]. New technologies and recent developments in digital fabrication allow the custom and automated manufacturing of traditional wood-only connections for new buildings [3]. A big potential of such contact-only connections is their fast assembly and non-destructive disassembly. Remarkable examples include the Japanese Ise-Shrines, which are rebuilt in a 20-year frequency for the past 1300 years. Traditional joinery techniques allow for sustainable solutions through the replacement, long-term maintenance and repair of structural elements [4]. They also ease recycling and energy-recovery. In times of global environmental problems where the building sector is highly responsible for resource depletion, greenhouse-gas emissions and waste pollution, these advantages will become even more important for regenerative architecture or transformable building design. Buildings need to become more adaptable to frequent changes in ownership or use to avoid superfluous demolition. For example in Japan in the past, entire cities made from timber were constructed for disassembly and transport in order to accommodate for recurrently changing administrative centers [3]. Some joint typologies were designed to allow the later vertical or horizontal extension of buildings [2]. In Japan also, contemporary buildings are not understood as permanent edifices but as structures made to be replaced or removed. This could only be achieved through highly developed timber joinery techniques. A combination of traditional joinery with contemporary post and beam construction and CNC prefabrication is already well established in Japan in the construction of residential buildings [3].

However, a straightforward application of traditional joinery techniques in today’s construction is not always possible. In the past, the structural integrity of traditional joinery techniques was proven mainly through in-situ, de-facto testing. Today, building codes include little-to-no information about the application of wood-only carpentry connections in comparison to those with mechanical fasteners [2]. Research on interlocking joints concentrates on a very precise analysis of few different joint typologies. There are limitations in literature in terms of analyzing a variety, or a library of ancient interlocking wood joints to develop an extensive relative comparison between them.

As a first step, the present research initiates a FEM campaign to catalog a library of Asian joints. To align traditional techniques with modern construction and typically used North American timber, solid Douglas fir was considered as the material. The goal of the analysis is to extract the relative capacity and stiffness of different joints to understand their mechanical behavior.

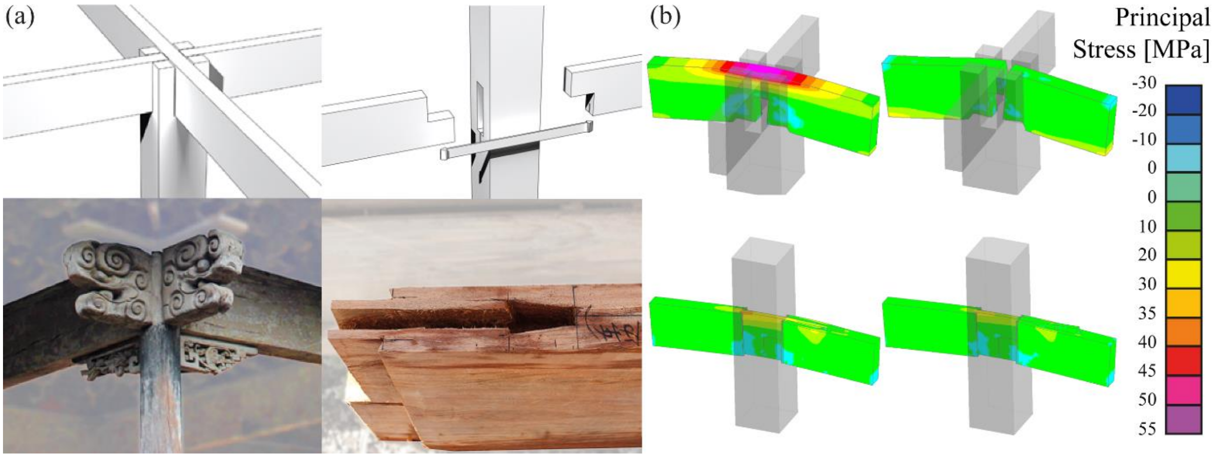


Figure 1. (a) Selection of traditional Asian beam-to-post connections, (b) deformed shape and stresses in joints at different states of incremental loading.

Figure 1 exemplarily illustrates the principal stress distribution (parallel to grain axis) and the deformed geometries (10x magnified) for two joint topologies at different states of incremental loading until failure. It is identified that the geometry of the cross-section at the joint is a direct correlation to the capacity and moment-rotation behavior of the joint.

This comparative record, which should be extended to additional Asian and European joint types, will allow academics and designers to push the capabilities of these ancient techniques while benefitting from modern materials, construction techniques and fabrication tools. Other research will also address the optimization of joint geometries to customize demanded capacity or stiffening. In addition, Life Cycle Assessment of constructions with conventional and advanced traditional joinery technology will be carried out to quantify potential environmental savings.

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## Keywords

traditional technology, timber, joints, assembly, disassembly, sustainability