ICCEPM 2024 https://dx.doi.org/10.6106/ICCEPM.2024.0495
The 10th International Conference on Construction Engineering and Project Management
Jul. 29-Aug.1, 2024, Sapporo

Changes in the Information Transfer of Wooden Post and Beam Construction with Precutting in Japan

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Abstract: This paper aims to make clear the transition process of information transfer in wooden post and beam construction in Japan during the introduction and development of machine precutting technology. The machine precutting technology started from 1970s and developed toward line production or automated CAD-CAM production and have got over 90 % market share in the Japanese newly built wooden houses. Based on literature review and interviews with manufacturers of precutting machines, the transition of wooden post and beam construction houses was divided into four periods: i) before the introduction of precutting, ii) the introduction of precutting (the early stage), iii) the automation of precutting, and iv) the maturity of precutting, and the review reveals how the information of design and processing was made and transfered in each period. In addition, the modeling and comparison of information transfer in each period visually shows the transition of information transfer with the development of machine precutting technology. Before the introduction of precutting, when carpenters were responsible for the generation of both design and processing information, information was coordinated at each stage of the process based on expert knowledge, but highly precise and uniform processing of machine precutting reduced the need for such coordination skills. On the other hand, the review suggested that the precut processing technology has changed step by step based on the traditional technical system, which has maintained the rational transfer of information.

Key words: wooden post and beam construction, precutting, information transfer, CAD-CAM

1. INTRODUCTION

BIM and computational design shed light on the issue of increasing information in the process of building design and construction. Japanese conventional wooden post and beam houses, for example, experienced changes in the information transfer with the spread of machine precutting of timber joints. While some pointed out that the conventional system realizes rational generation and transfer of information, it remains unclear if the rationality of the system has been kept in the process of introduction and spread of machine precutting. This paper aims to reveal the change of information transfer in the process of designing and constructing wooden post and beam houses after the introduction of machine precutting.

There are many previous studies on machine precutting in Japan. A series of studies by Ono and Fujisawa, which conducted a multi-faceted analysis on machine precutting from the development of precutting machines to the early time of automation, pointed out that traditional carpentry skills were segmented and replaced by precutting machines [1][2]. Kanisawa pointed out that insufficient standardization of carpentry work and changes in the production system due to precutting separated schematic design and structure design, which resulted in increasing number of irrational structures [3]. Murakami, which conducted a survey of wooden post and beam houses with some specific indexes, pointed out the problem of framing plan [4]. However, no previous studies on the machine precutting

in Japan put a primary focus on the information transfer. This paper focuses on the transition of information transfer in wooden post and beam houses to clarify how rational information transfer has been maintained in the face of replacement by machines.

Literature review and interviews were conducted. With regard to the information transfer in the design and construction of wooden post and beam houses, literature materials on the housing production with the conventional system in Japan were examined and interviews with manufacturers of precutting machines were conducted. The transition of housing production with the conventional system was divided into four periods in accordance with the change of information transfer: i) before the introduction of precutting, ii) the introduction of precutting (the early stage), iii) the automation of precutting, iv) the maturity of precutting. The technological transition and characteristics of information transfer in each period were summarized and the information transfer in each period was described visually with an original model.

This paper divides the information required for processing the members of wooden post and beam houses into two types of information: structure information and processing information and focuses on what knowledge and skills were used in each type of information. Structure information is on how to construct each frame and processing information is on how to fabricate each member. Processing information is prepared based on structure information.

2. LITERATURE REVIEW

2.1. Before the introduction of precutting [5][6]

Before the introduction of machine precutting, information for wooden post and beam construction was mainly prepared by a master carpenter. A master carpenter first designed the floor plan reflecting the client's requests and created a drawing called *itazu*. Based on this, they designed the structure, drew the framing plans, calculated the quantity of wood necessary (i.e., material take off), and determined the structure information. Based on the structure information, the processing design of each member was conducted. Drawing processing lines directly on each wood based on the properties of wood determined the processing information.

The structure design and processing design were determined based on the experience of a master carpenter. The information on framing plan, structure, and processing was described by a master carpenter on the *itazu*, so much of the information could be understood only by the carpenter themselves. In addition, a master carpenter added information to the *itazu* during the process. For example, each time they draw processing lines, they added the result on the *itazu*. Thus, before the introduction of precutting, the same person was responsible for both structure design and processing design. The information prepared by a master carpenter including information that was added during the process was managed in a unified manner on the *itazu*.

2.2. The introduction of precutting (the early stage) [1][2][7][8]

Precut processing machines were developed in the 1970s. Housing suppliers such as contractors and builders established precut factories to stabilize quality and improve productivity, while wood distributors established precut factories to give added value to their wood. Subsequently, machine precutting became widespread against the backdrop of a shortage of skilled carpenters, and designers took over structure design, while precut factories took over processing design and processing.

In the early days, although the shape was defined by the machine, marking was done and machining was manually controlled based on the marking. Since determining the properties of wood and marking the processing lines required specialized knowledge, experienced carpenters at precut factories were often in charge. Machine precutting that required marking was also seen after the introduction of CAD and was called semi-automatic as opposed to the fully automatic type.

However, precutting machines increased productivity through highly precise and uniform machining, thus reducing the need for coordination skills related to manual processing based on markings. In addition, the standardization of the shape of joints made it possible to define the shape of joints without drawing processing lines. As a result, processing design was separated from marking, and marking became a process of drawing the location and direction of machining on each wood based on the machining drawings. In large factories, marking was done by simple marks to improve efficiency.

2.3. The automation of precutting [7][8][9]

As precut processing machines developed, marking, which required specialized knowledge and man-hours, was recognized as a bottleneck in production, and the goal was to develop a fully automated line without the marking process. The CAD-CAM control system developed around 1985 fully automated the precut line. Marking was eliminated, and processing information was automatically generated from the framing plan input by the CAD operator at the precut factory. In addition, since machine precutting could not be adjusted for each individual member, and high accuracy was achieved when the properties of wood were constant, the importance of wood drying was reaffirmed, and drying facilities were installed in some factories.

2.4. The maturity of precutting [4][9][10]

Today, the ratio of machine precutting exceeds 90%, and in most wooden post and beam construction houses, the frames are fabricated by precutting. On the other hand, the number of precut factories has been declining since the late 1990s, and in particular, small precut factories have been disappearing. This is because machine precutting with CAD-CAM control system was mainly introduced to wood distributors, and construction companies have begun to outsource processing to large-scale factories.

Since precut factories have their own processing rules, it is more efficient for the precut factories to be responsible for the preparation of floor plans rather than the designers. In addition, the number of designers with knowledge of structure has decreased, thus in most cases the structure design is done by a precut factory and the design information for wooden post and beam construction is now accumulated at precut factories. Besides, the need to sort wood has decreased as the use of kiln-dried timber and glued laminated timber has expanded in terms of processing accuracy and quality.

The current precutting is as streamlined as the highly integrated production process by carpenters before the introduction of precutting, in that the same entity is responsible for preparing information for both the structure and processing. However, there are issues with the situation where a house can be built automatically with a floor plan. Currently, the designer generally approves the structure information, but if the role of the designer is reduced, the problem of liability in the event of a defect in the structure arises. This issue did not arise when a master carpenter undertook a complete set of the process.

3. MODEL

The process by which wood is processed into members involves operations that are based on the information prepared, i.e., sorting, marking, and processing. On the other hand, the information required for each of these operations is prepared through a process that requires knowledge, i.e., structure design and processing design. In addition, when operations are performed based on the prepared information, knowledge-based coordination skills are required. The figure illustrates this relationship before the introduction of pre-cutting.

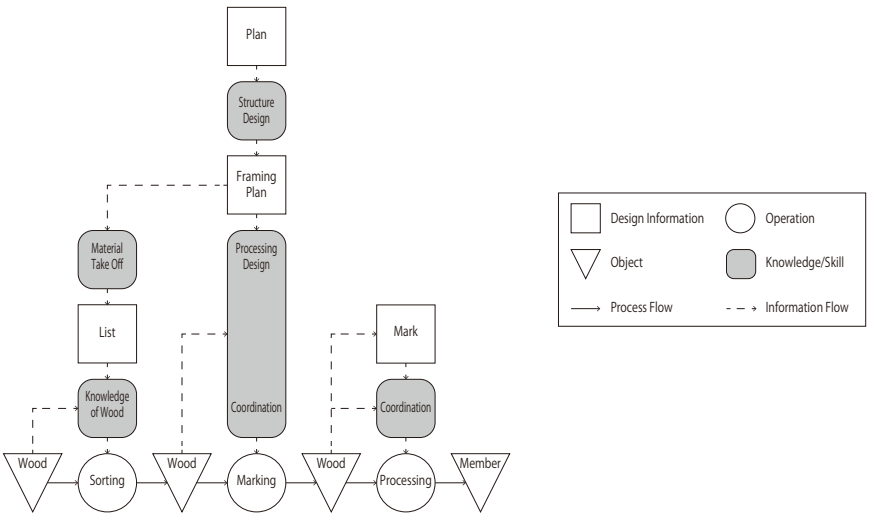

Figure 1. Before the introduction of precutting

The process flow proceeds from left to right and is represented by objects (triangles) and operations on objects (circles). Wood is sorted, marked, and processed. The flow of information, on the other hand, proceeds from top to bottom, with the design information prepared ultimately guiding the operations on the objects. Furthermore, in the process of information transfer, there are various processes that require knowledge (rounded squares).

Before the introduction of precutting, the list of wood necessary was created based on material take off by carpenters, which required the expertise of carpenters. In addition, wood sorting was done by considering the condition and properties of wood, which required knowledge of wood. Marking was an operation on wood, and at the same time, it was a process that prepared a kind of processing information by drawing processing lines. Since carpenters drew processing lines directly based on the framing plan, the processing information was not explicitly indicated. In addition, marking required coordination based on the properties of wood, and processing required a fine adjustment based on an assessment of the fiber direction and dryness of wood.

The other three periods are illustrated in the same manner, showing the scope of the carpenter's responsibility and that of the precut factory. During the introduction of precutting (the early stage), processing information such as machining drawings and marking coexisted. The fact that workers adjusted and fixed the machining positions one by one suggests that a certain level of coordination skill was required. Although there was no significant change in the model compared to the period before the introduction of precutting, the emergence of precut factories separated the entities responsible for designing the structure from those responsible for processing design.

During the automation of precutting, the input of structure information into CAD automatically generated processing information, which eliminated the need for marking. As more information was automatically processed, the coordination skills were no longer necessary, and the model became simpler.

During the maturity of precutting, CAD began to play an important role in structure design as its design support capabilities developed. In addition, the expanded use of glued laminated timber and the stabilized quality of wood made the process of sorting unnecessary. Thus, wooden post and beam construction in Japan has developed in a direction that makes knowledge unnecessary for designers through the refinement of design information, standardization of wood, and automation. However, it is possible that the traditional technical system has been the foundation of the method, and that rational information transfer has been maintained through gradual replacement of the traditional system. In addition, it is assumed that wooden post and beam construction has contributed to the replacement of knowledge and skills because the structure can be determined only by information on cross-sections, lengths, and joints, which facilitates information transfer.

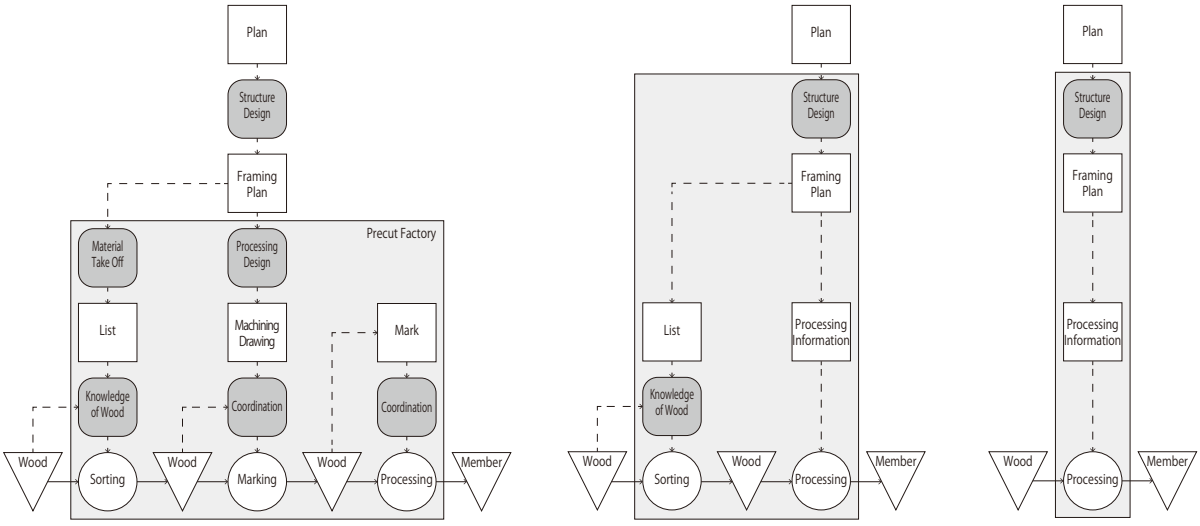

Figure 2. From the left is the introduction of precutting (the early stage), the automation of precutting, and the maturity of precutting

4. DISCUSSION

Fujimoto described the process of manufacturing as “transfer” of product design information to materials and the product as the imprint of design information distributed to the production process in the form of equipment or manuals onto a medium. In other words, the development is an activity of creating design information, and the production is an activity of transfering design information onto a medium. The concept of “transfer” makes it possible to describe the entire process from development to production in a unified manner [11].

In the transfer model, design information does not change during the process of transfer. On the other hand, the transfer process in the wood processing of wooden post and beam construction adjusts the design information using knowledge-based coordination, which is the difference between manufacturing and building production. In building production, knowledge is a production factor that coordinates design information, materials, and transfer, as the information transfer was simplified by using highly abstracted knowledge in a production system based on traditional knowledge systems before the introduction of precutting.

As the need for coordination decreases and production becomes more efficient, processes requiring knowledge may be perceived as bottlenecks in production, but the advantages of knowledge may be lost as processes are fixed by automation. The use of knowledge can reduce the amount of design information, but challenges remain in evaluating knowledge and assuring building performance, and information transfer is difficult to simplify in a production organization that does not share common knowledge.

5. CONCLUSION

This paper reviews literature materials on the housing production with the conventional system in Japan and described the transition of wooden post and beam construction in terms of information transfer. In addition, it shows an original model to illustrate the flow of information in the wood processing of wooden post and beam construction. Furthermore, it compares the model with the transfer model, which suggests the characteristics of building production with the need for knowledge-based coordination in the information transfer. Finally it pointed out the advantages and challenges of using knowledge in building production.

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