HOW HAVE CAD-CAM SYSTEMS CHANGED JAPANESE CONVENTIONAL WOODEN CONSTRUCTION IN THESE THREE DECADES?

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Abstract:

The new house-building market in Japan can be divided into two parts. A half is occupied with detached houses built by large prefabricated house manufacturers as well as rather small local builders. The composition of the detached house-building market is:

A little less than 20 % occupied with prefabricated house manufacturers, a little less than 10 % with North American platform construction builders a little less than 70% with conventional wooden house builders and the rest with other kinds.

While order-made houses are mainly built in each of these three categories, prefabrication and industrialization have been advanced in each category so far. In this paper the state-of-the-art of such prefabrication and industrialization especially in the field of conventional wooden house-building is made clear.

The major means of industrialization of conventional wooden house-building have been the application of CAD-CAM systems for processing wooden posts and beams. In this paper, the application of CAD-CAM in such a conventional field and its effects are clarified after a historical review on its technological development and its diffusion process.

Keywords: conventional wooden house-building, industrialization, CAD-CAM, precut

1. INTRODUCTION

About 1.2 million housing units have been newly built in Japan every year although the new house-building market in Japan has gradually declined after the end of "Bubble Economy" period in early 1990s. It means that 9 to 10 housing units per 1000 inhabitants have been newly built every year. This number is still much more than other countries', such as 6 in USA, 4 to 5 in Germany and France and 3 in UK.

This huge market can be divided into two parts. A half is occupied with detached houses built by large prefabricated house manufacturers as well as rather small local builders. Another half is occupied with multi-family dwellings built by general contractors. This paper's focus is on the former half, namely the detached house-building market in Japan.

The composition of the detached house-building market is: A little less than 20 % occupied with prefabricated house manufacturers, a little less than 10 % with North American platform construction builders, a little less than 70% with conventional wooden house builders and the rest with other kinds.

While order-made houses are mainly built in each of these three categories, prefabrication and industrialization have been advanced in each category so far. In this paper the state-of-the-art of such prefabrication and industrialization especially in the field of conventional wooden house-building is made clear.

2. TECHNOLOGICAL DEVELOPMENT OF PRECUT MACHINES

2.1 Pre-CAD-CAM systems development

The major work of carpenters in conventional wooden house-building had been post & beam planning, lumber sorting, ink-marking on lumber and processing of them for a long time. The early development of Precut systems (**Fig.1**) was to accomplish the processing of posts and beams without carpenters' hands and skill.

The first Precut machine invented in around 1970 was a table with four circular saws to ease processing mortise-and-tenon joint. The machine maker, Matsuura Kougyou, improved it to process dove tail joint and arrow joint as well and sold several machines in a Precut line to a builders' association in Nagano prefecture in 1973.



Fig.1 Precut Factories and Precut Lumber

An important invention was added in 1976 by another machine maker, Miyagawa Kouki. It changed angular shapes to round shapes of joints to accomplish one joint's processing with only one movement of a cutter(**Fig.1,Fig.2**). This invention could improve Precut machines' productivity so much that every Precut machines have applied it so far.

2.2 CAD-CAM systems

Although about ninety lumberers and builders had established Precut factories at the least by 1983 (**Ref.1**), they had faced with some difficulties caused by ink-marking on lumber.

Firstly, ink-marking process (**Fig.3**) needed rather plenty of person-hours and was not easy to be rationalized. It was also an obstacle to improvement of production speed. According to the time survey on the processing done in 1983 (**Ref.1**), ink-marking process of posts and beams needed 0.029 person-days per square meter while processing of posts and beams did 0.042 in a rationalized Precut factory.

Secondly, there could be mistakes of the position and the shape of joints because ink-marking workers could misread beam plans(**Fig.4**). It was said that such mistakes could not be entirely stopped.

Such difficulties continued to be until 1985 when machine makers succeeded in development of CAD-CAM Precut systems which did not need ink-marking process at all. In case of CAD-CAM Precut systems, what workers had to do other than lumber sorting, putting lumbers into machines was only to input beam plans. After confirming beam plans, the system itself automatically generated all the necessary data to control Precut machines. So mistakes could happen only in the input phase (**Fig.5**).



Fig.2 Round Shapes Processing Invented in 1976



Fig.3 Ink-Marking

Fig.4 A Beam Plan



Fig.5 A CAD~CAM Precut Facotry

3. DIFFUSION OF PRECUT SYSTEMS

3.1 Four Nation-Wide Surveys

The first nation-wide survey on Precut factories was done by Matsumura and others in 1983 (**Ref.1**). The second one was also done by Matsumura, Jo and others in 1990 (**Ref.2**). And the third one was done by Fujisawa's group In 1996 (**Ref.3**) when Ministry of Agriculture, Forestry and Fisheries did its first nation-wide survey on Precut factories (**Ref.4**).

Here the diffusion process of Precut systems is analyzed based on those nation-wide surveys.

3.2 A Survey in 1983

The survey in 1983 was done on 54 factories which was equivalent for 60 % of all factories on the lists made by machine makers.

There were two major groups from the viewpoint of their original business, namely lumberers and builders. While 25 of 54 factories belonged to the former group, 22 the latter one. The former group's purpose of investment was mostly to make their business more value-added. The latter one's was mostly reduction of labor and improvement of processing accuracy.

As for the production quantity, it varied from less than 50 houses per year to more than 500 houses per year.

As for the purchaser of precut lumber, they could be also divided into two groups, namely the factories that sell more than 90 % of their products to others and the factories that use more than 90 % themselves. Few factories belonged to neither of them.

3.3 A Survey in 1990

Precut factories had rapidly increased to 357 all over Japan according to machine makers' lists. More than half were established during "Bubble Economy" period, namely 1987-1990. It can be thought that there were two main reasons. Firstly, it had become easier to establish Precut factories without much knowledge and skill on post and beam processing owing to the appearance of CAD-CAM Precut systems. Secondly, it had been difficult to employ skillful carpenters as they faced to rapid growth of the newly-built houses market during the period. As for their original business, the number of lumberers became twice as many as that of builders.

Although the variation of production scale was almost the same as in 1983, the types of the purchaser were a little different from 1983. There appeared the third group, namely the factories that sold as well as used their products in a well-balanced manner. Although most of them had mainly used their products themselves before, they started to sell their products to others in order to stabilize the production quantity.

Another considerable difference from 1983 was that the factories that sold their products to indefinite many builders had increased so far. In case of selling the products to others in 1983, others had been mostly composed of several large builders, because not so many builders could recognize the merit of Precut systems and most carpenters didn't trust machines' processing. But such a change in 1990 clearly showed us that Precut systems had become more and more popular among conventional wooden house builders and even carpenters.

3.4 Two Surveys in 1996 and Estimation in 2004

According to the survey by Ministry of Agriculture, Forestry and Fisheries, the number of Precut factories was 726 at the least in 1996. It also grasped the production records of 706 factories in 1995 and recognized the average as 217 houses per year and total amount as 153 thousand houses. It equals to about 28 % of total newly built wooden detached and row houses in 1995. Considering that the number of factories on the machine makers' lists then reached 785, Precut systems surely occupied over 30 % of the conventional detached house market in 1995. The number of Precut factories established during August 1992 to July 1996 equaled to 44.5 % of total number of Precut factories. The number of the factories with CAD-CAM machines equaled to 66.8 % of total number.

Fujisawa's survey in 1996 showed where their products went to in 103 factories' cases. According to it, the factories that sold their products entirely to others equaled to a little more than 40 % and the factories that entirely used their own products themselves equaled to only 20 %. It meant that most of newly established factories were to sell their products to others.

Fujisawa also estimated market occupancy rate of Precut systems in 2004 based on the lists of machine makers. It shows that conventional wooden houses built with Precut systems occupy 76 % of total amount of newly built conventional wooden houses (**Ref.5, Fig.6**).

4. INFLUENCE OF PRECUT SYSTEMS ON CONVENTIONAL WOODEN HOUSE-BUILDING

4.1 Quality Control of Lumber

Although the introduction of Precut systems was just mechanization of processing, their rapid diffusion had much influence on conventional wooden construction.

Firstly, the application of Precut systems made lots of lumberers as well as builders keen to quality control of lumber, especially drying up lumber. For, as Precut factories had appealed to customers for processing accuracy, they could not ignore drying up process. For instance, Fujisawa's survey in 1996 (**Ref.3**) showed that a half of factories applied kiln dry lumber or laminated lumber for posts and a quarter of them did for beam



Fig.6 The Number of Newly Built Wooden Houses Including Platform Construction, Prefabricated Construction as well as Conventional Construction (Yoshikazu Fujisawa, 2004 Ref.5)

Such influence can be highly evaluated as an unexpected contribution of Precut systems to the evolution of conventional wooden construction.

4.2 Structural Engineering

Secondly, Precut systems had notable influence on structural engineering of conventional wooden houses.

Beam planning had been one of the most important role of skillful carpenters for a long time. Even after the introduction of Precut systems, this situation had continued. However the introduction of CAD-CAM systems has gradually changed this situation. For, some factories began to receive orders from builders only with simple floor layout plans which pointed out only the position and the dimension of posts. In such a case, CAD operators at the factories, who are not skillful carpenters nor engineers mostly, make and input beam plans following the received floor layout plans. In 1996 more than a half of Precut factories acted in this manner (Fujisawa, **Ref.3**).

Nowadays the factories that produce and sell not only precut posts and beams but also precut braces, precut wall boards and wall/floor panels have increased. In such cases, even the position, the dimension and the joints of seismic-loading braces can be decided by the operators at Precut factories.

So Precut factories' role as structural engineers should be made emphasis on today. For fulfilling the new role, they should have enough in-house structural engineers and a good education system for CAD operators.

4.3 Prefabrication

Although Precut systems originated in machine processing of posts and beams, they have involved other kinds of prefabrication so far. It has mainly two reasons.

Firstly, as Precut systems introduced modernized production lines, the concept of prefabrication and their effects to the society of conventional house-building, lots of builders have become interested in prefabrication and industrialization as their applicable methods.

Secondly, Precut systems, especially CAD-CAM ones, made the society recognize the worth and the importance of information technologies as well as information itself. With the application of CAD-CAM, they started to input beam plans to generate all the necessary data to process posts and beams. As Japanese conventional wooden building has its own modular coordination system usually based on 303 mm, this input can generate not only processing data of posts and beams but also various data of other building elements such as secondary wooden elements.

Lots of factories naturally recognized it and have tried to effectively use those data. As the result of that, some factories started to process secondary wooden elements as is mentioned above and panelize walls and floors. But it is not enough utilization of the data. In near future it is possible for them to play an essential role as distribution centers of all the necessary components and parts to build conventional wooden houses.

5. CONCLUSION

On one hand it is made clear how a new production technology such as Precut system has been introduced to conventional building society in this paper – chapter 2 and 3. On the other hand it is also clarified how mere application of machines to a few steps of the production process of houses can change the whole process and more the structure of the production society in chapter 4.

Prefabricated detached house production can be called as a closed industrialized system because each manufacturer has its own factories producing its own building parts and components. It had been much advanced than conventional wooden houses by rather small builders from the viewpoint of prefabrication and industrialization for 25 years.

But since conventional wooden house production came to have lots of Precut factories all over Japan, it has rapidly and drastically changed to catch up with prefabricated house production from the point of view. It can be called as an open industrialized system because every small builder can order Precut components from any factory as he/she likes.

As Precut systems could make conventional wooden houses competitive in the market, the market share of prefabricated houses stopped to grow. In near future the superiority or the inferiority of an open system against a closed system in Japanese house-building market will be revealed.

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