ABSTRACTS (PH D THESIS)

Development of High Rigidity Joint and its Application to Wooden Frame Structure

(Laboratory of Structural Function, RISH, Kyoto University,
Present: Forest Products Research Institute, Hokkaido Research Organization)

Yasunobu Noda

According to the act for promotion of use of wood in public buildings, small-scale constructions are desired to be built of wooden materials. In addition, considering the act about long life quality housing, future wood constructions should have easy-renovation system. In those social situations, it could be said that wooden frame structure has an advantage in the room re-arrangement like steel constructions. Therefore several moment resisting joints developed for heavy timber structures have been improved and put to practical usages in recent detached houses and small-scale constructions.

In practical structural design, the horizontal stiffness of wooden portal frame structure tends to be insufficient when it is designed with general-produced medium-sized glulams. One of the reasons is that most mechanical joints have low rigidity. According to the annual meeting reports of Japanese Architecture Institute for the past ten years [1], the studies on moment resisting joints of which cross section sizes of the beam were ranged from 120 x 300 to 150 x 450 mm, reported that the rigidity of mechanical joints were less than 2000 kN･m/rad, on the other hand, that of several glued joints achieved more than 5000 kN･m/rad. Then requirements for rigidity and strength of joint were simulated by an imaginary three-story wooden structure consisting of 6 m span portal frame at 2 m interval in the first floor. In the case that the member of the cross section of more than 120 x 360 mm is used for column and beam, the mechanical joints with rigidity of at least 1800 kN･m/rad are available when the column-leg joint in the portal frame have the same rigidity of the bema-column joint. When the column-leg joints are pin node, however, it is impossible to satisfy the requirement of the Japanese design code even if beam-column joints were fully rigid. In case of more than 120 x 480 mm member, about 5000 kN･m/rad rigidity is required when the beam-column joints are pin node. It is natural that using heavier timber gives higher rigidity and strength to the joint of portal frames, however, it is worth giving an available option of improving joint rigidity for small scale constructions to be composed of minimum size members. Therefore, this study aspired for fully rigid and full strength joint for wooden frame constructions.

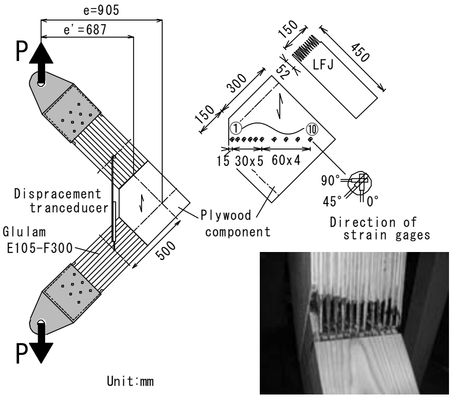

Figure 1. Improved LFJ corner joint test and finger joint inside of plywood type.

First, I focused on the improvement of the Large Finger Joints (LFJ) made of karamatsu (*Larix kaempferi*) glulam of intermediate-member-installed type which is one of adhesive type joints. The plywood laminated member of karamatsu, OSB laminated member or Cross Laminated Timber of karamatsu were employed to replace the intermediate member of a glulam to improve the joint performance. The result of full scale joint tests (Figure.1) suggested that plywood type shows the best performance in terms of the strength and ductility. The strain measurements of the intermediate member of plywood type showed that the shear strength of the intermediate member would be higher than the bending strength. However the sufficient strength value was not obtained due to occurrence of the bending crack to 45 degree direction against the fiber direction of the surface layer which is the weakest direction of plywood bending strength. Moreover, it was thought that triangular pyramidal voids of the finger joint inside of the intermediate member were the weak points [2].

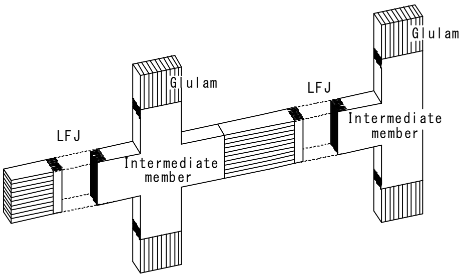

Figure 2. Concept of invented new joint.

Therefore, it was found that achieving the joint of higher performance is possible by applying more strengthened intermediate member and putting the LFJ part distantly from the intersection area of the column and beam. The concept of the invented new joint system is shown in Figure. 2. On this concept, a technology of compressed wood was applied to strengthen the intermediate member. And the longitudinal joint performance of the LFJ between the intermediate member and the glulam was also verified.

The strength of the LF-Jointed glulam of karamatsu was estimated using results of small scale tensile and bending tests of LF-jointed laminae. The 5th percentile lower limit value of bending strength of glulam connected by the LFJ of 120 mm width was estimated by an equation for modulus of rupture (MOR) using observed tensile and bending strength of the LF-jointed laminae of 30 mm thick and 120 mm width. The strength values of LF-jointed glulams (E105-F300) of different cross sections (120×120, 120×180 and 120×300 mm) were measured by bending test. The estimated value of 5th percentile lower limit of 14.0 N/mm^2 in the case of infinity depth of beams was lower than the LF-jointed glulam test results. It was concluded that the joint efficiency of this LFJ was 46% [3].

Figure 3. Developed joint method of compressed cross-lapped joint.

The developed joint method named a compressed cross-lapped joint (CCLJ) for the intermediate member is shown in Figure. 3. Rectangular veneers with phenol formaldehyde (PF) resin impregnation were arranged at right angles to adjacent layers, aligned at each layer's corners and compressed by a hot-press machine. The moment resisting performance of the CCLJ was tested. The L-shaped specimens of 120 × 180 mm in cross-section made of PF-treated todomatsu (*Abies sachalinensis*) veneer were employed. They were connected to karamatsu glulam (E105-F300) by the LFJ to elongate the moment arms for the test. The bending failure of the L-shaped specimens occurred at the boundary of the cross-lapped part and the arm part, or the LFJ. The bending strength of the boundary was more than 30 N/mm^2. Material property test results of cross-lapped and arm parts suggested that the CCLJ could be regarded as a rigid joint. Also, the strain distribution on the cross-lapped area showed that the shear strength of the cross-lapped area would be higher than the bending strength of the boundary [4].

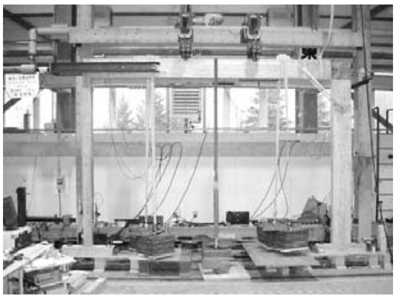

Figure 4. Portal frame racking test with dead load.

And also, the racking performance of the full scale portal frame with the CCLJ was verified in un-symmetrical L-shaped test condition with 3910 mm in span and 2730 mm in height (Figure. 4). The beam and column member of karamatsu glulam (E105-F300) of 120×300 mm in cross-section were jointed to the L-shaped member made of todomatsu veneers by wooden dowel joints with hard maple (*Acer saccharum*). A support column of 120×120 mm in cross-section of karamatsu glulam (E85-F300) was attached at the left side of the frame, connected with a template metal connector (HOWTEC BH255) as semi-rigid node. The horizontal stiffness and the strength of the frame with and without dead load were predicted by explicit formulas for the moment and horizontal displacement relationship introduced from the compatibility of rotation angles at the semi-rigid nodes. The obtained horizontal stiffness of the frame subjected to horizontal load with and without dead load of 20 kN were higher than the predicted results. The strength with dead load was 19% smaller than without dead load. It was concluded that the reduction of the rotational rigidity of template metal connector joint by dead load caused a change of the moment distribution on the beam, which resulted in the moment concentration at the L-shaped member part.

References

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