Preliminary

Reinforcement of Large Finger Joint for Progressing Mechanical Properties of Glued Laminated Timber Corner Joints

Yasunobu NODA*[1,2], Kohei KOMATSU*[1] and Takuro MORI*[1]

(Received May 31, 2003)

Keywords: glued laminated timber, frame corner, wooden dowel, reinforcement, open-mode moment

Introduction

Large Finger Joints (LFJ) have been used in European countries for large scale Glued Laminated Timber (GLT) frame structures. Distinction of LFJ frame corner is adhesive type joint and no steel wares are used. This type joint, therefore, has been considered as another type of GLT frame corner in Japan. There are some reports and papers about LFJ in European countries[1)], however, almost all their concern is limited to the case of close-mode failure and open-mode failure is not important because there is no earthquake. In contrast, we have been attacked by earthquakes so that it is necessary to evaluate both cases of open- and close-mode failures, especially for open-mode failure. Preliminary test showed that open-mode failure was brittle, and maximum load was almost half of that of close-mode failure. To resolve this undesired property, we insist on reinforcement for open-mode failure.

Former research result[2)] suggested that open-mode brittle failure was coursed by the stress perpendicular to the grain. This stress is, what we called, radial stress, which is seen in curved GLT on open-mode failure and is to be neglected in simple bending test on straight GLT beam. We recognized that most important things would be to prevent failure from radial stress for improving frame corner strength property. In this paper, we report possibilities of reinforcement by inserting wooden dowels to prevent conventional LFJ flame corner joints from brittle failure.

The Mean of Reinforcement

Fig. 1 shows how radial stress occurs by subjected to open-mode moment. When LFJ flame corner is exposed under open-mode moment, the forces shown in Fig. 1 (left) are caused by the resultant force of compression stress at outside of corner and the resultant force of tensile stress at inside of corner. Radial stress is caused by this pair of forces. If this radial stress is prevented, it will be possible to evaluate the ultimate strength of LFJ corner frame by shear failure of bonded layer of LFJ.

Fig. 2 shows design of LFJ frame corner reinforced with wooden dowels. The largest radial stress will be occured be happened on LFJ area, it will be, therefore, the most effective to reinforce in this area. However, if reinforcement is designed on LFJ area, it will be difficult to fabricate LFJ frame corner. We, therefore, adopted the mean of reinforcement that wooden dowel can be bonded before jointing LFJ.

At first, we did tensile tests of GLT block with 45 degrees of grain angle with wooden dowel for the reinforcement, for making sure preliminary the effect of dowel reinforcement to reveal the availability of reinforcement with wooden dowel.

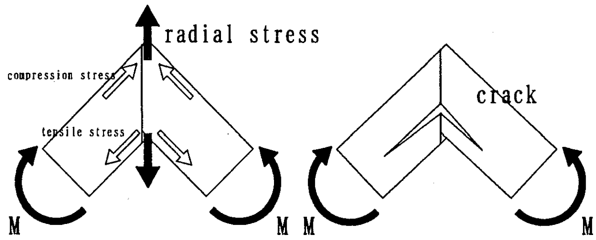

Fig. 1. left: The mechanism of radial stress, right: The image of failure caused by radial stress. M: Moment.

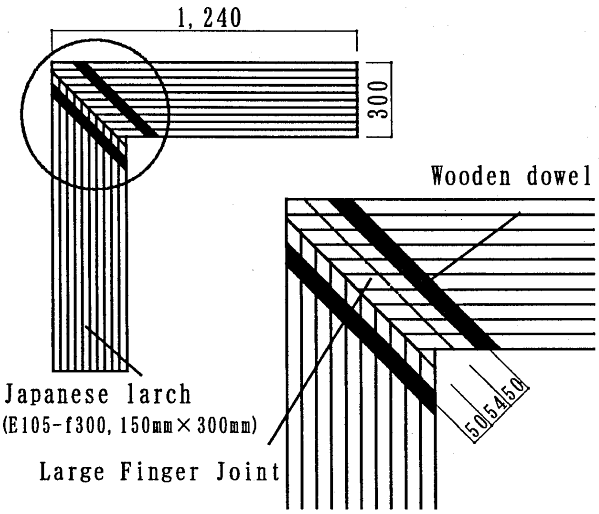

Fig. 2. Design of LFJ frame corner reinforced with wooden dowel (Unit: mm).

Experiments

Tensile test of GLT block with 45 degrees of grain angle reinforced with wooden dowel

The tensile test of GLT block with 45 degrees of grain

*[1] Laboratory of Structural Function.
*[2] Present address: Hokkaido Forest Products Research Institute.

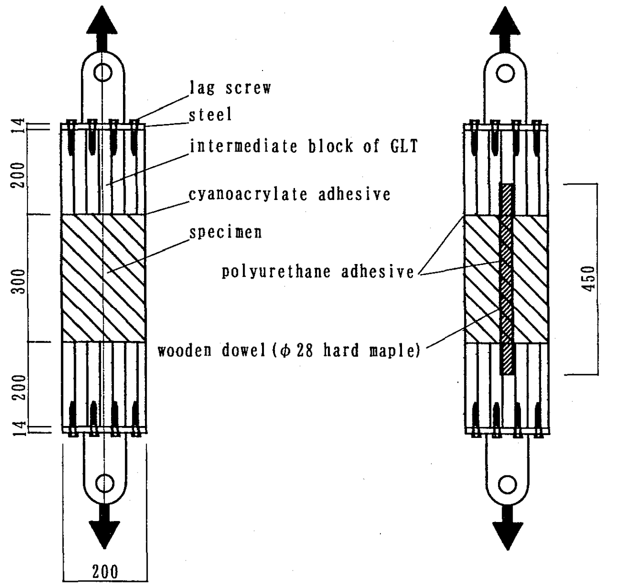

Fig. 3. Tensile test of GLT block cut off at 45 degrees to the grain (Unit: mm).

angle was referred to prEN 1,193, European Standard[3]. Fig. 3 shows the design of specimen. Left one is non-reinforcement, right one is reinforcement type specimen. As shown in Fig. 3 two intermediate blocks of GLT are glued both side of specimen as recommended in informative annex B of prEN 1,193 for avoiding concentration of tensile stress on specimen. And connection between intermediate block and test machine were fixed by lag screws. Wooden dowel used is hard maple, which inserted simultaneously with bonding intermediate block with polyurethane adhesive. The reason of the wooden dowel extended into the each intermediate blocks is that polyurethane adhesive layer should not become the weakest point. The elongation of specimen was measured by displacement transducer.

Results and Discussions

Tensile test of GLT block with 45 degrees of grain angle reinforced with wooden dowel

Table 1 shows results of reinforcement and non-reinforcement type GLT block tensile test. In some of specimens, failure occurred in bonded layer between specimen and intermediate block so that it is difficult to conclude about strength of material, although it is likely to be increased. On the other hand, Young's modulus

Table 1. Results of tensile test of GLT block 45 degrees to the grain

	Non-reinforcement		Reinforcement	
	E (GPa)	σmax (MPa)	E (GPa)	σmax (MPa)
	1.16	—	1.46	—
	1.15	2.09	1.44	1.72
	1.04	—	1.52	—
	1.25	1.46	1.23	2.22
Average	1.15	—	1.41	—

E: Young's Modulus, σ: Tensile Strength.

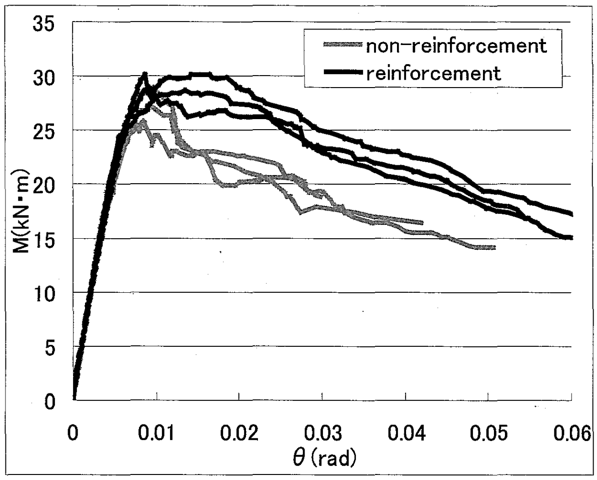

Fig. 4. Comparison between non-reinforcement and reinforcement type LFJ frame corner tests. M: Moment, θ: Rotational Angle.

Table 2. The result of LFJ frame corner test.

	Non-reinforcement		Reinforcement	
	Average	C.V	Average	C.V
Mmax (kN·m)	27.36	0.06	28.94	0.04
G (kN·m)	4,501	0.04	4,464	0.03
Energy	0.39	0.35	0.79	0.07
μ	3.50	0.39	5.41	0.10

M: Moment, G: Rotational Rigidity, μ: Ductility Factor.

increase 1.2 times. We presumed that inserting wooden dowel was effective to prevent GLT from cracking.

The result of LFJ frame corner reinforced with wooden dowels

Fig. 4 and Table 2 show the results of LFJ frame corner reinforced and non-reinforced with wooden dowel. There is little distinction between non-reinforced ones and reinforced ones on maximum moment and rotational rigidity. However, energy stored up to failure was thought to be increased, which might bring ductile failure. The reason why maximum moment did not increase will be that wooden dowel inserted did not prevent radial stress perfectly. Actually, the crack which caused radial stress was observed even in reinforced specimens. On the other hand, it was also observed that wooden dowel endured from pull-out by the role of polyurethane adhesive even after cracking occurred. Thus, if more rigid adhesive such as epoxy type adhesive is used for connecting wooden dowel, the failure from radial stress might be prevented, and maximum moment might be increased. As an alternative ways, it might be effective to insert wooden dowel (s) to another direction. This will be further research subject.

References

1) For examples, S. Aicher, V. Bornschlegl and J. Herr: International Conference of IUFRO S5.02 Timber Engineering, Copenhagen, 239–258 (1997).
2) A. Nitta and K. Komatsu: *Wood Research,* **88**, 56–57 (1999).
3) S. Aicher and G. Dill-Langer: *Otto Graf Journal,* **6**, 246–274 (1995).