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by Yakni Idris

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Utilization of Compressed Sugi Dowels to affect the performance of Wood Floor System

Yakni Idris[1], Anis Saggaff[1], Kohei Komatsu[2]

1. Civil Engineering Department, Sriwijaya University, Palembang, Indonesia
2. Research Institute of Sustainable Humanosphere, Kyoto University, Gokashu, Uji Kyoto 611-0011 Japan

An experimental study of the lateral shear performance of wood floor system sheathed with thick sugi plywood using compressed sugi dowels is described. The objective of this investigation are 1) to study the in-plane shear resistance of wood floor system sheathed with sugi timber dowels, 2) to determine the effects of the number of compressed sugi dowels on the performance of wood floor system.

In this study, 3 specimens of wooden floor system were tested. Each of wooden frame floor system consists of 2 horizontal beams, 3 vertical beams, 4 horizontal supporting beams. All beams were made of solid wood of Japanese pine (Sugi). Each specimen consists of 6 floor panels which are nailed to the wood frame floor system by sugi timber dowels. Each specimen use different number of compressed sugi dowels on the edge of each floor panels, that is, 3, 4, and 5 sugi dowels. From this study, results indicate that the number of compressed sugi dowels will significantly affect lateral shear performance of wood floor system.

Keywords: *lateral shear performance, floor system, sugi plywood, compressed sugi dowels.*

1. Introduction

While seemingly ordinary in construction, the wood floor system is a very complex structural system that includes various types of load bearing members and connections. In the connection of the wood-members in wooden houses, the nail, bolt, and steel connector which are superior in strength reliability and workability are often used. However, the removal of the nail,bolt, and steel connector is needed when these wood-members are recycled or reused. Considering cost for these works, a substitution method of these connections using timber dowel is thought.

Research has been conducted in the past to study in-plane shear resistance of wall panels in residential buildings. Shipp, Castle, et.al (1999) conducted cyclic load testing on plywood sheathed shear walls on wood framing, using code required bolted or nailed hold-down devices installed at the inside of the end post. Komatsu, Hwang and Itou (2002) performed static cyclic lateral loading tests on nailed plywood shear walls, and proposed a simplified calculation method for predicting shear deformation of semi-rigid glulam portal frame with nailed plywood shear wall panel. Komatsu, Idris, et.al (2004) performed the experimental in-plane shear resistance of LVB floor panels which were made from Larch, Radiata Pine, and Falcata .

An experimental investigation has been conducted at RISH, Kyoto University, to study lateral shear performance of wood floor system sheathed with thick sugi plywood using compressed sugi dowels.

2. Materials and Methods

The dimension of floor panels was 35 mm in thickness, 850 mm in width and 850 mm in length. Each frame floor system consists of 4 horizontal beams (1810mm in length, with cross section of 120 mm in width by 180 mm in height), 3 vertical main beams (2580mm in length each), 2 vertical main beams (2730mm in length, with cross section of 150 mm in width by 240 mm in height), and 1 vertical supporting beam (2730mm in length, with cross section of 120 mm in width by 180 mm in height). Each specimen consists of 6 floor panels of thick sugi plywoods. These sugi plywoods are embedded into the floor beams by handpressing and then nailed to the wood frame floor system by sugi dowels of 12mm in diameter and 100mm in length 6. Each specimen use 3 different number of sugi dowels as shown in Figure 1, 2, 3, and 4.

Figure 1. Specimen Model

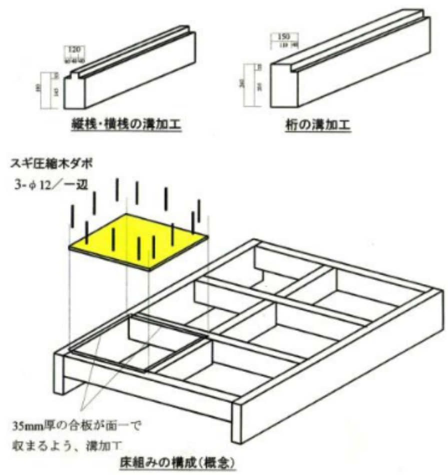

Figure 2. Specimen #1 with 3 dowels on each edge

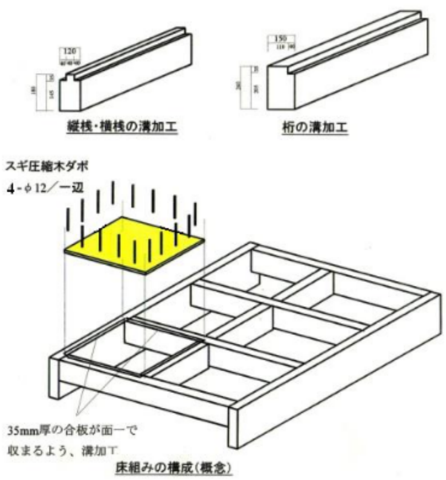

Figure 3. Specimen #1 with 4 dowels on each edge

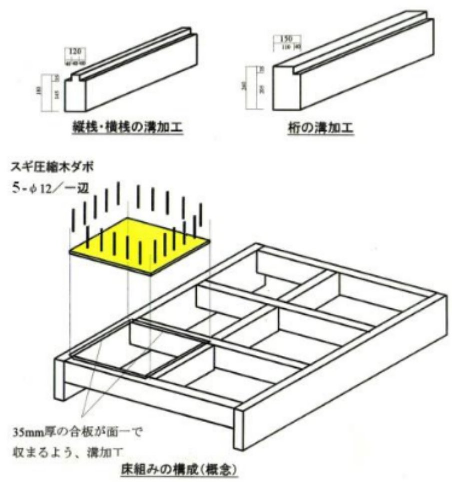

Figure 4. Specimen #1 with 5 dowels on each edge

Test panels specimens were attached at the sill plate to a rigid steel I beams, bolted to the steel I beams. The test panel was vertically braced against out-of-plane movement with steel tie rods, but was allowed to rotate and displace in the plane of the panel (cantilever wall condition). The loading ram was operated cyclically by a computer under displacement control at a frequency and magnitude of displacement in conformance with the testing protocol. No superimposed vertical load on the panel other than the self-weight and the weight of the loading channel was present during the test. The weight of these elements was considered to be negligible (See Figure 5, 6, 7, 8 and 9).

Under cyclical displacement control, the net force at the top of the test panels was recorded using a load transducer installed in-line with the hydraulic loading ram, and net displacement at the top of the test panels was also recorded using a displacement transducer.

Figure 5. Floor beams system

Figure 6. Sheathing floor beams with sugi plywood

Figure 7.Sugi dowels

Figure 8. Nailing sugi dowels to panels

Figure 9.Testing the specimen

In addition, at the bottom of the test panels, 3 linear variable displacement transducers (LVDTs) for recording relative displacement vs. time and net force were wired for input into a computer workstation.

During the cyclical testing, relative displacement between the following components was electronically measured and recorded, as a function of time and the racking shear force at the top of the panel:

- Horizontal displacement at the top panel
- Horizontal and vertical displacement at the bottom of the test panels, relative to the rigid base .

3. Results and Discussions

Load (P) – Deformation angle (γ) relationship from 3 specimens are shown in Figure 10, 11, and 12.

At present in Japan, it is widely acceptable to estimate shear wall performance by using so called 'perfect bi-linear approximation' method.

Figure 13 shows definitions and schematic explanation of the perfect bi-linear method. The Japan Housing and Wood Technology Center proposed this method, and the calculation is performed as follows. Firstly, an envelope curve of P- γ relationship should be drawn at least for the data in the quadrant in which last loading was performed. Secondly, by using $0.1P_{max}$, $0.4P_{max}$, and $0.9P_{max}$, a yield load P_y and initial stiffness K are determined. At last, P_u is determined so as to equalize the trapezoid area enclosed by line V, VI and γ_u to the S area enclosed by the envelope curve.

Experimental data was analysed by using enveloped data and perfect bi-linear value, and Load (P) – Deformation angle (γ) relationships are shown in Figure 14, 15 and 16.

Observed and calculated quantities using perfect bi-linear plot for the specimen are tabulated in Table 1.

Using observed and calculated quantities from perfect bi-linear plot, Floor Strength Index is approximated and calculated by equation (1) and (2) as follows:

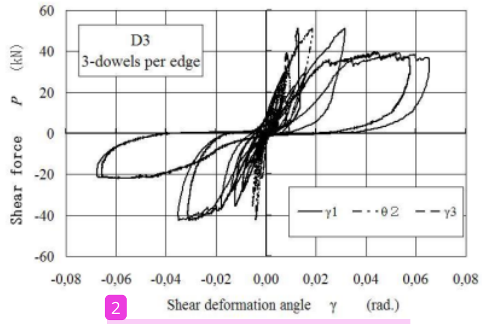

Figure 10. Shear force vs shear angle of Spec#1 with 3 dowels

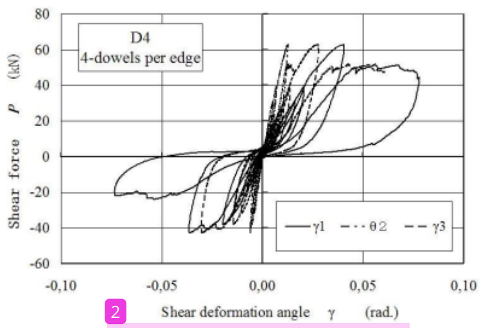

Figure 11. Shear force vs shear angle of Spec#2 with 4 dowels

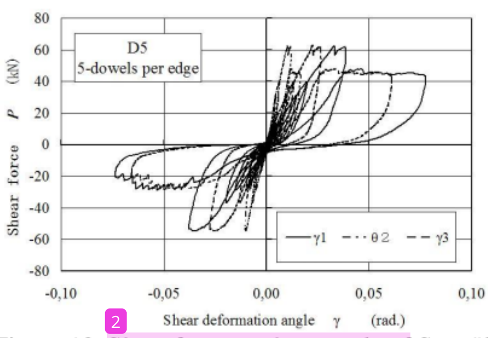

Figure 12. Shear force vs shear angle of Spec#3 with 5 dowels

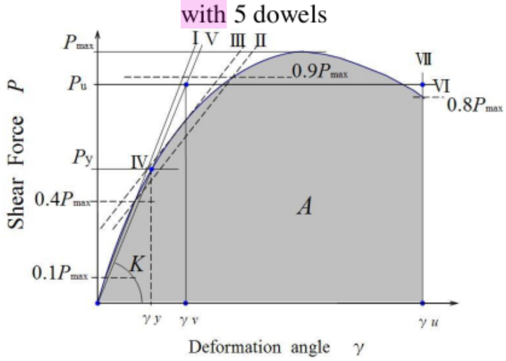

Figure 13. Perfect bi-linear approximation

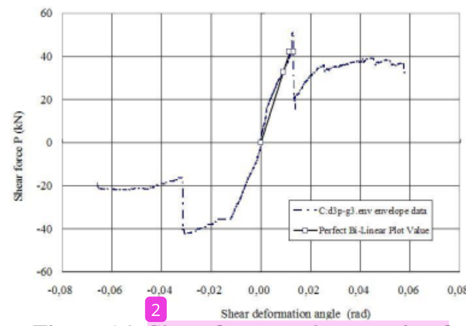

Figure 14. Shear force vs shear angle of Spec#1 by perfect bi-linear method

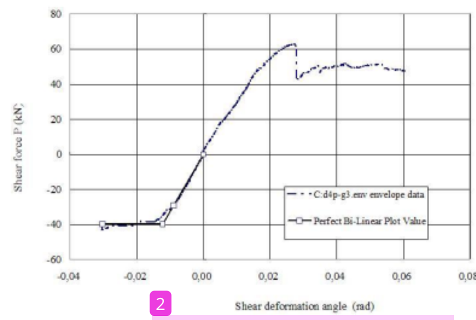

Figure 15. Shear force vs shear angle of Spec#2 by perfect bi-linear method

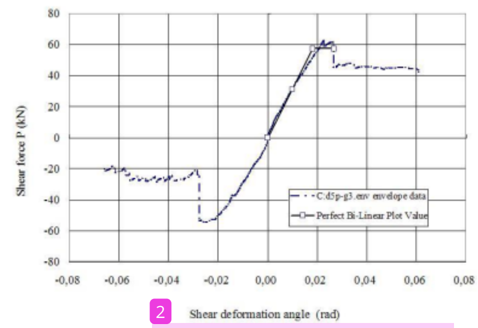

Figure 16. Shear force vs shear angle of Spec#3 by perfect bi-linear method

$$\mathbf{Pa} = \mathbf{Minimum}\left\{\frac{2}{3}\mathbf{Pmax}, \mathbf{P1/150}, \mathbf{Py}, 0.2\frac{\mathbf{Pu}}{\mathbf{Ds}}\right\} \quad (1)$$

where:
Pmax=Observed maximum shear force
P1/150=Shear value observed at shear deformation angle of 1/150 radian
Pu=Ultimate shear value

$$\mathbf{Ds} = \frac{1}{\sqrt{(2\mu - 1)}} \quad \text{and} \quad \mu = \frac{\gamma_u}{\gamma_v} \; ;$$

μ = ductility factor

Table 1. Observed and calculated quantities for the specimen

Specimen	Pmax(kN)	Py(kN)	Pu(kN)	γ_y(rad)	γ_v(rad)	γ_u(rad)	K(kN/rad)
3 dowels	51.0657	32.7073	42.174	0.00884709	0.0114077	0.013156	3696.95
4 dowels	42.8615	29.174	39.759	0.00889035	-0.012116	-0.030151	3281.51
5 dowels	62.7062	31.1871	57.332	0.00992375	0.0182431	0.0266615	3142.67

Table 2. Observed and calculated quantities for Floor Strength Index

Specimen	μ	Ds	L(m)
3 dowels	1.15325	0.874873563	1.82
4 dowels	2.48856	0.501436164	1.82
5 dowels	1.46146	0.721139678	1.82

Table 3. Calculated quantities for Floor Strength Index

Specimen	2/3Pmax(kN)	P1/150(kN)	Py(kN)	0.2Pu/Ds	Pa(kN)	Floor Strength Index
3 dowels	34.044	27.894	32.707	9.641	9.641	2.703
4 dowels	28.574	22.998	29.174	15.858	15.858	4.446
5 dowels	41.804	21.987	31.187	15.900	15.900	4.457

$$\text{FloorStrengthIndex} = \frac{Pa}{1.96L} \quad (2)$$

where:
L = floor length (m)

Calculated quantities for approximation of Floor Strength Index are shown in Table 2 and Tabel 3.

It should be noted from the calculation above that, Floor Strength Indexes are high and strong if compared with the Standard Floor Strength Index which is 3. The reason is that, in this experimental study, only one replicate of each specimen was used. Consequently, those numbers should be reduced to account for the coefficient of variations of the specimens. Other reason is partly because the size of the floor beams is very thick and the sugi plywood configuration is embedded into the floor beams. The shear deformations of embedded sugi plywood were mostly restrained by the floor beams. Floor Strength Indexes are all determined by ductility factors.

4. Conclusions

Experimental results of of the lateral shear performance of wooden floor system sheathed with thick sugi plywood using compressed sugi dowels were explained in this paper.

From Floor Strength Index in this investigation, it is found that wooden floor system sheathed with thick sugi plywood using 5 compressed sugi dowels per edge has the strongest lateral shear resistance. And wooden floor system sheathed with thick sugi plywood using 3 compressed sugi dowels per edge has the least strong lateral shear resistance.

In this study, results indicated that the number of compressed sugi dowels significantly affected lateral shear performance of wood floor system.

Acknowledgements

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