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SHEAR PERFORMANCE OF STRUCTURAL PARTICLEBOARD-SHEATHED LIGHT-FRAME WALL

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ABSTRACT: The National Institute of Forest Science developed structural particleboard (PB), which is made of domestic wood, to substitute for imported OSB (Oriented Strand Board) used as a structural sheathing panel in light-frame construction. To investigate whether structural PB could be used as sheathing panel of light-frame wall or not, shear resistance of light-frame wall sheathed with structural PB compared with that of light-frame wall sheathed with OSB. Shear resistance was evaluated using a hysteresis curve by applying a quasi-static load. Shear strengths of wall sheathed with OSB and PB were 7.9 and 8.7 kN/m, respectively. It was confirmed that secant shear modulus for OSB and PB walls at 40% of the maximum load was 2.4 and 3.7 kN/mm, respectively. In addition, ductility was shown as 8.3 and 10.0 in OSB and PB walls, respectively. It was confirmed that shear resistance of PB wall was higher than that of OSB wall. From the results in this study, it is considered that structural PB manufactured using domestic wood can be used for sheathing material of light-frame construction, and it is expected that it can contribute to the national carbon stocks.

KEYWORDS: Light-frame wall, Shear resistance, OSB, Structural PB

1 INTRODUCTION

Korean wood building market is a little bit small compared with North America, Japan and etc., but constant. Since 2009, about 10,000 houses per year have been commenced steadily. From the statics about total floor area commencement, small houses having a total floor area of about 100 m^2 dominate in Korean wood building market. Because of economical and easy-to-build construction, light-frame construction is normally used for small houses.

Problem is that imported wood or wood-based products are usually used for light-frame construction in Korea. So, that need to develop substitute for the imported products occurred in view of the carbon-neutral and increasing price of materials. Because of climate crisis, increase of construction material made by domestic wood is required. By using HWP (Harvested Wood Products), it can take advantage of compliance with UNFCCC (United Nations Framework Convention on Climate Change) through carbon fixation and GHG (Green House Gas) substitution effect. On the other hand, the price change of imported dimension lumber and OSB (Oriented Strand Board) increased rapidly after COVID-19. Compared with 2020, the price of dimension lumber and OSB after COVID-19 are 2.9 and 2.7 times higher in Korea.

The National Institute of Forest Science has developed structural particleboard (PB) to substitute for imported OSB since 2020. Considering the scale of PB industry in Korea, it was concluded that it was advantageous to make a structural PB first. In a previous study, it was confirmed plant production possibility for structural PB. In this study, therefore, the shear resistance of structural PB was investigated whether structural PB could be used as a sheathing panel in light-frame construction.

2 MATERIALS AND METHOD

2.1 WOOD FRAME MATERIALS

For wood frames, dimension lumber of 2 by 6 was used, and the species was SPF. the grade of dimension lumber was 2 and better. The Structural PB was manufactured to be suitable for domestic industry conditions. A MFU (melamine-urea-formaldehyde) resin adhesive and isocyanate were used to provide water resistance. The ratio of the surface layer to the middle layer of the structural PB was 40:60, and the target density was set to 700 kg/m^3. The hot press conditions were a temperature of 200 ℃ and a time of 7.3 s/mm, and the amount of pressure was 50 kgf/cm^2. OSB imported from North America for rate sheathing was also used to compared to structural PB. The span rating of OSB was 24 per 16 inches.

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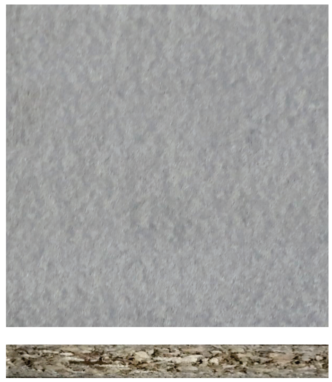

Figure 1: *Surface (top) and side(bottom) image of structural PB*

2.2 ASSEMBLY WOOD FRAME

To assemble wood frame, nailing such as nail size, number of nails, nailing spacing, etc. was done in accordance with ASTM E72. Sheathing panel was attached to the dimension lumbers by using 8d common nail at 150 mm one center at the center of a panel and at 300 mm one center at the edge of a panel, respectively. In case of nailing distance from the edge of panel, different nailing distances for each panel were used for preventing occurrence of failure in the edges. For OSB, nailing distance from the edge of panel was 10 mm, on the other hand, the nailing distance was 15 mm for structural PB. Total size of shear wall was 2,440×2,440 mm. The center distance between studs was 610 mm. Figure 2 shows shear wall configuration.

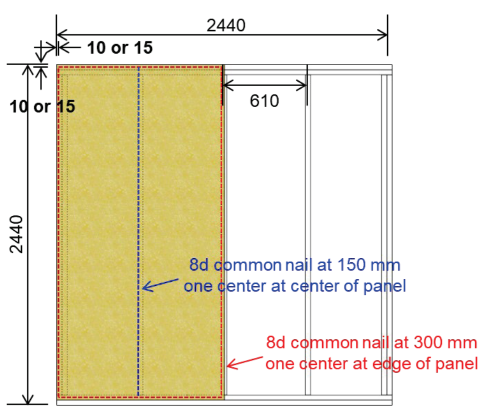

Figure 2: *Shear wall configuration (unit: mm)*

2.3 EVALUATION OF SHEAR RESISTANCE

Two hold-downs and anchor bolts were installed to fix test equipment (Dongyang, Korea). To prevent bulking during evaluation of shear resistance, four lateral supports were set up as shown in Figure 3. ISO 16670 protocol as quasi-static load in accordance with ASTM E2126 was applied to evaluate shear resistance. In the protocol, ultimate displacement was 83.3 mm, and it was determined from previous static shear wall test. The displacement pattern consists of phases, each containing three fully reversed cycles of equal amplitude, until 120 % of the ultimate displacement.

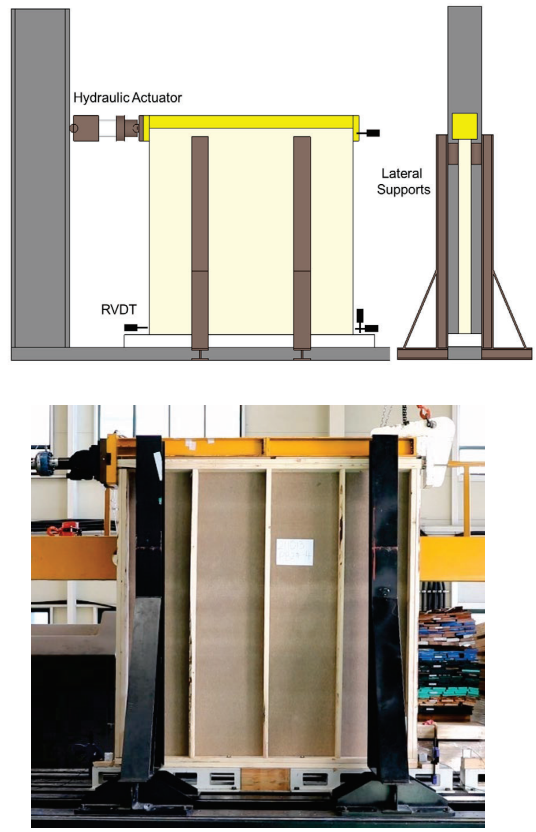

Figure 3: *Shear wall test setup (top) and picture (bottom)*

Envelop and EEEP (Equivalent Energy Elastic-Plastic) curve obtained hysteresis curve were used to calculated shear resistance such as shear strength, secant shear modulus at 0.4 of peak load and peak load, and ductility ratio. Each value for evaluating shear resistance was calculated as follows,

$$v_{peak} = \frac{P_{peak}}{L} \tag{1}$$

$$G' = \frac{P}{\Delta} \times \frac{H}{L} \tag{2}$$

$$D = \frac{\Delta_u}{\Delta_{yield}} \tag{3}$$

where, v_{peak} = shear strength (N/m), P_{peak} = maximum load resisted by the specimen in the given envelope (N), L = length of specimen (m), G' = shear modulus of the specimen obtained from test (N/mm), P = applied load, 0.4 of peak and peak load, measured at the top edge of the specimen (N), Δ = displacement of the top edge of the specimens as applied load based on test (mm), H = height of specimen (m), L = length of specimen (m), D =

ductility, Δ_u = ultimate displacement (mm), Δ_{yield} = yield displacement (mm). Detail calculation of shear resistance of wall can be confirmed in ASTM E2126.

3 RESULTS AND DISCUSSION

Figure 4 and 5 shows hysteresis, envelope, and EEEP curve for light frame shear wall sheathed with OSB and structural PB, respectively. As it was considered that the difference of positive and negative envelop curve was small for both shear wall sheathed with OSB and structural PB, average envelop curve was used to calculate shear resistance. The maximum difference of peak load was 8% for structural PB shear wall in the group of shear wall test.

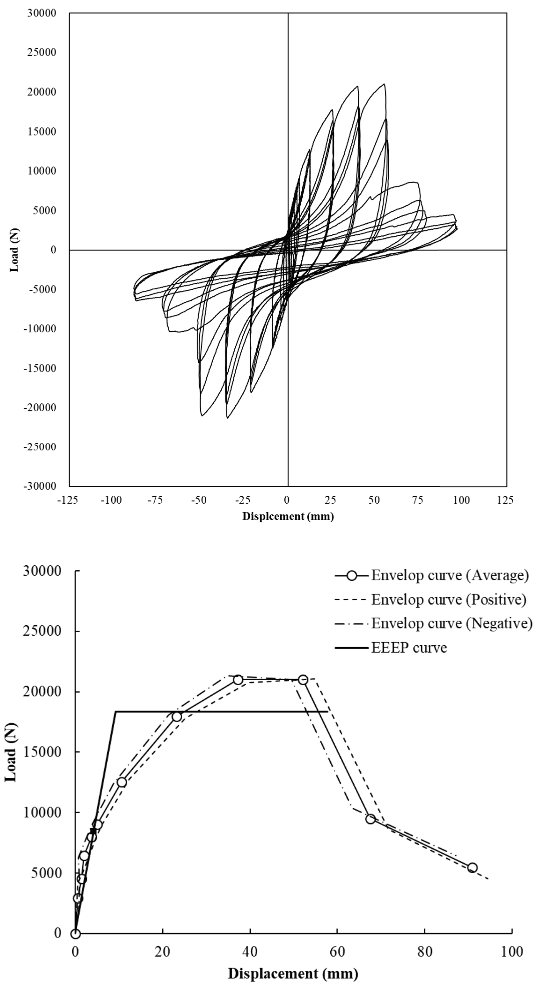

Figure 4: *Results of shear wall test of OSB sheathed light-frame wall*

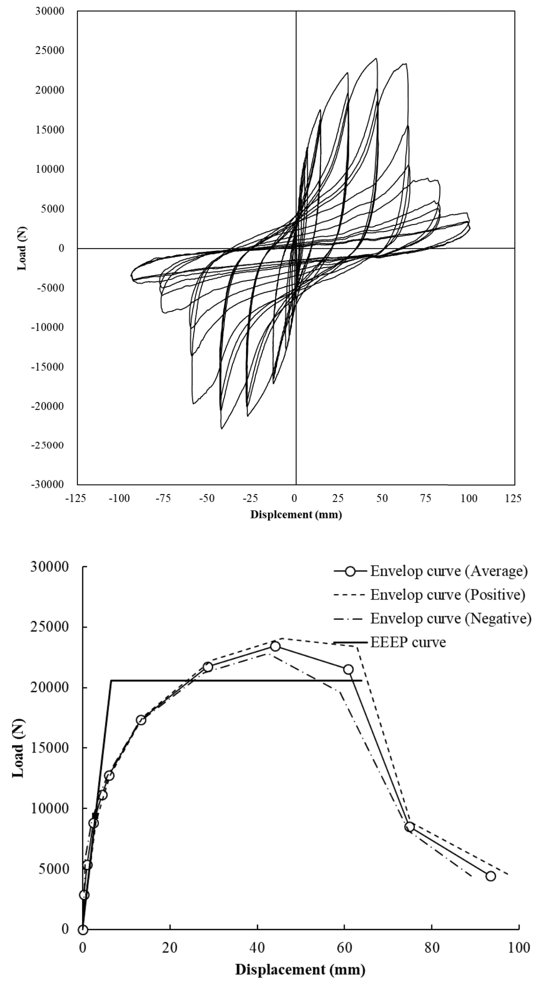

Figure 5: *Results of shear wall test of structural PB sheathed light-frame wall*

Table 1 presents the average shear resistance of wall according to the type of panel. Shear strength and secant shear modulus at 0.4 of a peak load for OSB wall were 7.9 kN/m and 2.3 kN/mm in the first order of cycles, respectively. The order of cycles means a sequence among three fully reversed cycles of equal amplitude in ISO 16670 protocol. As the order of cycles increased, shear strength decreased in case of OSB wall. But the result of ductility was inconsistent. As the order of cycles increased, ductility of OSB wall increased. The shear modulus at peak load was nearly constant regardless of the order of cycles. The shear strength and secant modulus at 0.4 of a peak load for structural PB wall were 9.0 kN/m and 3.0 kN/mm in the first order of cycles. Results of shear strength, shear modulus, and ductility according to the order of cycles is consistent in the case of that OSB wall.

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Table 1: Average shear resistance of wall

Type		v_{peak} (kN/m)	$G^{'}$(kN/mm)		D
			$0.4P_{peak}$	P_{peak}	
OSB	Cycle 1	7.9	2.3	0.5	8.3
	Cycle 2	7.1	2.7	0.5	9.9
	Cycle 3	6.7	2.9	0.4	10.6
PB	Cycle 1	8.7	3.7	0.5	10.0
	Cycle 2	8.1	3.4	0.6	10.8
	Cycle 3	7.3	3.7	0.6	11.9

The difference of shear strength between the first order cycles and the third order of cycles was 1.28 kN/m for OSB shear wall, and 1.43 kN/m for structural PB shear wall. From the difference, it was concluded that structural PB shear wall had better toughness property than OSB shear wall. As Toothman (2003) reported toughness is positive relation with energy absorb, it was considered that structural PB shear wall had advantage considering the ground motions produced by earthquakes. It was confirmed that shear resistance of structural PB wall is better than that of OSB wall for all order of cycles. It meant that structural PB wall has higher load capacity with less displacement and higher energy absorption capability.
Figure 6, 7, and 8 show failure mode during shear wall test. Regardless of the type of panel, the same failure modes were detected. One was nail shear failure between wood frame and panel, the other was bending of wood frame members within an elastic region.

***Figure 6:** Failure mode (Nail shear failure) during OSB shear wall test*

***Figure 7:** Failure mode (Nail shear failure) during PB shear wall test*

***Figure 8:** Failure mode (bending of stud in wall) during PB shear wall test*

In this study, the walls anchored fully by holddown were test. Because of that, uplift forces are transferred from the sheathing into the studs and then directly into the foundation (Seaders *et al.*, 2008). Therefore, it was concluded that the location of nail shear failure was sheathing-to-stud at edge of wall. Nail shear failure in structural PB shear wall occurred frequently compared with OSB shear wall. Moreover, Nails in the structural PB did not pull out as easily. So, it enabled the friction to continue to dissipate more energy in case of structural PB shear wall.
Because structural PB is more brittle than OSB, nailing distance from the edge of panel in structural PB is 5 mm more than that in OSB. The expected nail shear failure was achieved by increasing the nailing distance from the edge of panel in PB wall. From the results of failure modes, the theory for estimating shear resistance of OSB wall might be used to predict shear performance of structural PB wall.

4 CONCLUSION

Compared with OSB wall, shear resistance of structural PB wall was higher. In the first order of cycle, shear strength, shear modulus and ductility of structural PB wall were 1.1, 1.3 and 1.1 times higher than that of OSB

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wall. It is expected that structural PB made by domestic wood can contribute to achieving carbon neutral in the building sector.

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