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EXPERIMENTS AND RELIABILITY ANALYSIS ON FRAME-TO-SHEATHING JOINTS IN LIGHT WOOD FRAMED SHEAR WALLS

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ABSTRACT

To exploit the spruce-pine-fir (SPF) panel and the parallel strand bamboo (PSB) panel used in light wood framed shear wall and investigate the lateral behaviors of frame-to-sheathing joints in light wood framed shear wall with different characteristics, the experimental investigation and reliability analysis were carried out under monotonic load. The test configurations included joints with perpendicular-to-framing-grain load or parallel-to-framing-grain load, with SPF sheathing panel or PSB sheathing panel and with nail or screw. The results suggested that nailed joints with PSB panel occurred ductile failure but other joints occurred brittle failure. Moreover, the ultimate bearing capacity and the elastic stiffness of the joints under perpendicular load were higher than that of the joints under parallel load. The use of PSB panel and screw increased the ultimate bearing capacity of the joints. Furthermore, based on Johansen yield theory and experimental results, the reliability analysis was carried out through first-order reliability methods. The results showed that the SPF-nail joints, the PSB-nail joints, and PSB-screw joints achieved the reliability requirements.

KEYWORDS: Frame-to-sheathing joint, monotonic load test, lateral performance, reliability analysis, light wood framed shear wall.

INTRODUCTION

Light wood frame construction is widely used due to its advantages of better seismic performance and construction flexibility (Dobrila and Premrov 2003). Light wood framed shear walls are the primary components of light wood structural systems, which mainly resist the lateral forces from earthquakes and wind loads (Guíñez et al. 2019, Seim et al. 2016). Generally, a light wood framed shear wall is composed of a timber frame that is sheathed with panels using fasteners. The lateral force resistance performance of the wall mainly depends on the skin effect of the sheathing panels, which is due to the fastened joints between the sheathing panels and bottom plates, studs respectively (Tekic et al. 2019). Accordingly, the frame-to-sheathing joints have a significant influence on the load carrying capacity and over all structural performance of the light wood framed shear walls (Dorn et al. 2013, Sartori and Tomasi 2013).

The joints in light wood framed shear walls with different sheathing like ply-woods, OSBs and GFBs have been considered in the past studies (Casagrande et al. 2020, Hassanieh and Valipour 2020). Recently there has been a renewed interest in using bamboo in light wood frame construction, and their results indicated that bamboo-based panel can be used as construction elements (Varela et al. 2013, Wang et al. 2017). Zhi Li et al. (2015) investigated the mechanical models and capacity equations for nail connectors used in light wood framed shear walls with cross-prefabricated ply-bamboo sheathing panels. The equations to predict the bearing capacity of timber-bamboo nail joints was obtained from the theoretical and experimental study. So far, most of the experiments have mainly focused on frame-to-sheathing nailed joints (Liu et al. 2018, Jockwer et al. 2018, Judd and Fonseca 2005), and less attention has been paid to the joints with screws and other sheathing panels. Parallel strand bamboo (PSB) is a potential building material which integrating social, economic and ecological benefits. It is well known as bio-composites which was made from original bamboos and shaped through complex processes (Guo et al. 2018, Wang et al. 2019). Furthermore, spruce-pine-fir (SPF) has been used by humanity for thousands of years because this natural fiber material meets the requirements of structural application, in terms of high ratio of strength to weight, low production cost, and ease of manufacturing (Dias et al. 2018, Sartori and Tomasi 2013, Bader et al. 2018). But, the PSB panel and the SPF panel has not well been exploited and utilized in light wood framed structure.

Thus, to effectively use PSB panels and SPF panels as sheathing panels in light wood frame structures, a new type of end narrow panels reinforced light wood frame shear wall was considered, which was intend to improve the lateral performance of walls by setting PSB sheathing panels or SPF sheathing panels at the ends of the wall. Existing studies clearly revealed that the behavior of a wall is mostly governed by the performance of frame-to-sheathing joints (Li et al. 2015). Therefore, the performances of the joints between different panels and framing elements were experimental studied under various conditions in this paper. Since PSB sheathing panels are relatively hard compared with conventional sheathing panels, proper fastener should be studied first. Based on constructability with conventional carpentry, common nails and screws were selected as the connectors between sheathing panels and framing elements. In order to obtain the design value of bending yield moment of the fasteners, the three-points bending tests were conducted. Moreover, the lateral performance of frame-to-sheathing joints was investigated by monotonic tests. This study offers a theoretical and experimental support for the application of PSB panels and SPF panels in light wood framed shear walls.

The goal of the research presented in this paper was to experimentally characterize the mechanical behavior, in terms of bearing capacity and stiffness, of frame-to-sheathing joints in light wood frame shear walls. In order to the reliability analysis of frame-to-sheathing joints, the experimental data obtained in this research were necessary to compare with design values obtained from Eurocode 5 (2004). Reliability index of the strength limit state of such joints were computed by first-order reliability methods. The application and design suggestions of the joints with different characteristics in light wood framed shear wall were discussed.

MATERIAL AND METHODS

Material specifications

The material and specifications used in the test joints were selected according to GB50005 (2017) and ASTM D1761 (2012). The details of the specimens are shown in Tab. 1. For this study, spruce-pine-fir (SPF) had a density of 420 $kg \cdot m^{-3}$ and parallel strand bamboo (PSB) with a density of 1100 $kg \cdot m^{-3}$. The moisture content of the SPF and PSB were 13% and 6% respectively during the tests.

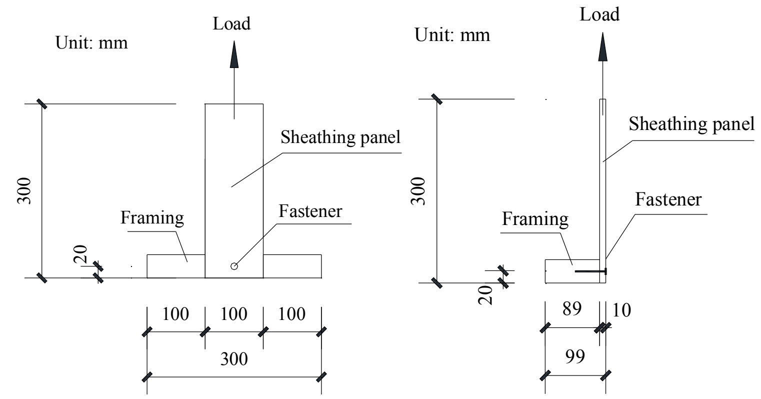
Tab. 1: Material specifications of the test wall.

Element	Material	Specifications
Framing	SPF	Cross-sectional dimensions: 38 mm × 89 mm
Sheathing panel	PSB	b = 100 mm, h = 300 mm, t = 10 mm
	SPF	b = 100 mm, h = 300 mm, t = 10 mm
Fastener	Nail	d_n =2.5 mm, l =50 mm
	Screw	d_e =2.5 mm, l =50 mm

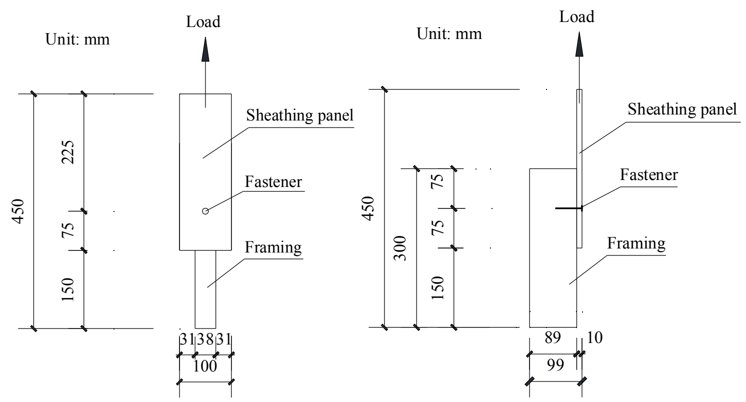
Notes: b- width; h- height; t- thickness; l- length of a fastener; d_n- diameter of a nail; d_e- effective diameter of a screw; SPF - spruce, pine, fir; PSB- parallel strand bamboo.

Specimen design and fabrication

The parameters of the test joints are shown in Tab. 2, in this research, 80 specimens were manufactured and tested to investigate the behavior of the frame-to-sheathing joints considering the following aspects: *(1)* loading direction, *(2)* sheathing panel type, and *(3)* fastener type. Two different loading types of frame-to-sheathing joints were tested under monotonic loads: representative of bottom plate to sheathing and stud to sheathing joints, joints loading perpendicular to timber grain direction of SPF frame and parallel to timber grain direction of SPF frame, respectively (Fig. 1). There was a predrilled hole in every joint at location on the fastener. The diameter of predrilled hole was 2.5mm.



a)



b)

Fig. 1: Details of the test specimens: (a) loading perpendicular to the grain of the framing, (b) loading parallel to the grain of the framing.

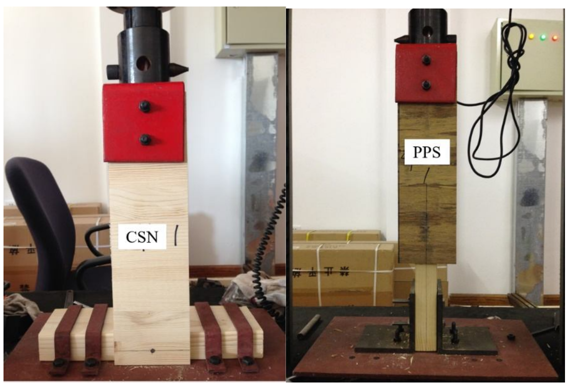
Tab. 2: Test matrix of the test.

Loading direction	Test group	Sheathing panel type	Fastener type	Number of tests
Perpendicular	CSN	SPF panel	Nail	10
	CSS		Screw	10
	CPN	PSB panel	Nail	10
	CPS		Screw	10
Parallel	PSN	SPF panel	Nail	10
	PSS		Screw	10
	PPN	PSB panel	Nail	10
	PPS		Screw	10

Experimental testing procedure

Bending yield moment of fasteners were tested according to ASTM F1575-03 (2013). The load was applied to the nail at the center between the two bearing points, and the rate of loading was 6.25 mm·min^{-1}.

The steel jigs used for frame-to-sheathing joints are shown in Fig. 2. Monotonic lateral tests of joints were performed under deformation control with a loading rate of 2.54 mm·min^{-1} for nail joints in accordance with the ASTM D1761 (2012).



a) *b)*

Fig. 2: Experimental setup of the joints: (a) loading perpendicular to the grain of the framing, (b) loading parallel to the grain of the framing.

Several parameters were obtained and calculated from the tests. The ultimate bearing capacity P_{max} and the corresponding displacement $\Delta_{P\max}$ were obtained from tests. According to the load-displacement curve, it can be seen that the load-displacement curve of joints at the initial stage of loading was greatly affected by the loading direction, so the elastic stiffness was defined as Eq. 1:

$$K_e = \frac{0.4P_{\max} - 0.2P_{\max}}{\Delta_{0.4P_{\max}} - \Delta_{0.2P_{\max}}} \quad (\mathrm{N \cdot mm^{-1}}) \tag{1}$$

Reliability analysis model

The reliability analysis carried out in this study used first-order reliability methods (FORM) (Folz et al. 1989). To determine the reliability index and the failure probability, the failure of the joint is defined by the limit-state function as follows:

$$Z = g(\mathbf{x}) \tag{2}$$

where: x denotes the vector of random variables.

Eq. 2 separates the failure domain from the safe domain (Nikolaidis et al. 2004, Zhang et al. 2018) as shown in Fig. 3.

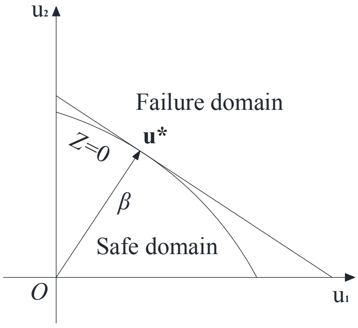


Fig. 3: FORM approximations for a component problem.

The failure probability of joints can be expressed as follows:

$$P_f = \int_{g(\mathbf{x})\le 0} g(\mathbf{x})d\mathbf{x} = \Phi(-\beta) = 1 - \Phi(\beta) \tag{3}$$

(5)

The reliability index of joints can be expressed as follows:

$$\beta = \frac{\mu_z}{\sigma_z} = \frac{g(\mathbf{u}^*) + \sum_{i=1}^{n} \frac{\partial g(\mathbf{u}^*)}{\partial x_i}(\mu_{x_i} - u_i^*)}{\sqrt{\sum_{i=1}^{n} \left[\frac{\partial g(\mathbf{u}^*)}{\partial x_i}\right]^2 \sigma^2_{x_i}}} \tag{4}$$

where: u^* is located on the limit-state surface, and has minimum distance from the origin in the standard normal space.

Due to the maximum load carrying capacity of joints are mostly governed by the bending performance of fasteners, and the large variability in the mechanical properties of wood and bamboo, the analysis main focus on the fastener element. Therefore, the limit-state function is written as:

$$Z = g(\mathbf{x}) = R_{test} - R_{theory} \tag{5}$$

where: $x = \{R_{test}, M_{y,d}\}^T$ is the vector of random variables, $M_{y,d}$ is the design value of bending yield moment of fasteners, R_{test} is the ultimate bearing capacity of joints, R_{theory} is the bearing capacity of joints calculated according to Eurocode 5.

In the absence of large set of experimental data, a normal distribution for maximum load carrying capacity of the joints and bending yield moment of the fasteners were assumed (Shadravan and Ramseyer 2018, Dobrila and Premrov 2003). Durations of load effects were not included in the calibration procedure for the system modification factor.

Design value of bending yield moment of fastener

The characteristic value of bending yield moment of fasteners was calculated according to:

$$M_{y,k} = \mu - 1.645\sigma \qquad (\mathrm{N \cdot mm}) \tag{6}$$

where: μ is the mean of bending yield moment for fastener obtained from tests, σ is the standard deviation of bending moment for fastener.

The design value of bending yield moment of fasteners was calculated according to Eq. 7:

$$M_{y,d} = \frac{M_{y,k}}{\gamma_M} \qquad (\mathrm{N \cdot mm}) \tag{7}$$

where: γ_M is the partial factor for fastener, according to Eurocode 5 (2004) $\gamma_M = 1.3$.

The characteristic value and design value of bending yield moment for each group of fasteners are provided in Tab. 3.

Tab. 3: The characteristic value and design value of the fasteners.

Common nail				**Screw**			
μ (N·mm)	σ (N·mm)	$M_{y,k}$ (N·mm)	$M_{y,d}$ (N·mm)	μ (N·mm)	σ (N·mm)	$M_{y,k}$ (N·mm)	$M_{y,d}$ (N·mm)
2232.66	116.25	2041.42	1570.33	4909.67	277.64	4452.96	3425.35

Design formulas for joint

In accordance with the observations obtained by the research reported in this paper, the failure can be classified into brittle and ductile failure modes. All of joints, except the nailed joints with PSB sheathing panel, were brittle failure modes. The nailed joints with PSB sheathing panel were ductile failure modes. Base on the Johansen theory, the joints occurred brittle failure according to the failure mode ''d''. Instead, the specimens occurred ductile failure according to the failure mode " f ".

For the test joints occurred brittle failure mode the characteristic load carrying capacity according to Eurocode 5 (2004) was calculated as:

$$R_{\text{theory,k}} = 1.05\frac{f_{\text{h1,k}}t_1 d_e}{2+\beta_h}\left[\sqrt{2\beta_h(1+\beta_h)+\frac{4\beta_h(2+\beta_h)M_{\text{y,Rk}}}{f_{\text{h1,k}}t_1^2 d_e}}-\beta_h\right]+\frac{F_{\text{ax,Rk}}}{4} \quad \text{(N)} \qquad (8)$$

where: t_1 is the thickness of the sheathing panel, $f_{\text{hi,k}}$ is the characteristic embedment strength in timber member i, d_e is the effective diameter of fastener, $M_{\text{y.Rk}}$ is the characteristic fastener yield moment, β_h is the ratio between the embedment strength, $\beta_h = f_{\text{h2,k}}/f_{\text{h1,k}}$, $F_{\text{ax,Rk}}$ is the characteristic axial withdrawal capacity of the fastener.

For the test joints occurred ductile failure mode the characteristic load carrying capacity according to Eurocode 5 (2004) was calculated as:

$$R_{\text{theory,k}} = 1.15\sqrt{\frac{2\beta_h}{1+\beta_h}}\sqrt{2M_{\text{y,Rk}}f_{\text{h1,k}}d_e}+\frac{F_{\text{ax,Rk}}}{4} \quad \text{(N)} \qquad (9)$$

The characteristic embedding strength for the SPF timber with predrilled hole was calculated according to Eurocode 5 (2004) as follows:

$$f_{\text{hs}} = 0.082(1-0.01d_{\text{e}})\rho_{\text{k}} \quad (\text{N·mm}^{-2}) \qquad (10)$$

where: ρ_k is density of the timber, ρ_k =420 kg.m^{-3}.

The characteristic embedding strength for the PSB sheathing was calculated according to Eurocode 5 (2004) as follows:

$$f_{\text{hp}} = 30d_{\text{e}}^{-0.3}t^{0.6} \quad (\text{N·mm}^{-2}) \qquad (11)$$

where: t is thickness of the PSB sheathing panel.

The characteristic withdrawal capacity of the common nail was calculated according to Eurocode 5 (2004) as follows:

$$F_{\mathrm{ax,Rnk}} = \begin{cases} f_{\mathrm{ax,k}} d t_{\mathrm{pen}} \\ f_{\mathrm{ax,k}} d t + f_{\mathrm{head,k}} d_{\mathrm{h}}^{2} \end{cases} \quad \text{(N)} \tag{12}$$

$$f_{\mathrm{ax,n}} = 20 \times 10^{-6} \rho_{\mathrm{k}}^{2} \quad (\mathrm{N \cdot mm^{-2}}) \tag{13}$$

$$f_{\mathrm{head,n}} = 70 \times 10^{-6} \rho_{\mathrm{k}}^{2} \quad (\mathrm{N \cdot mm^{-2}}) \tag{14}$$

where: $f_{\mathrm{ax,n}}$ is the characteristic pointside withdrawal strength, $f_{\mathrm{head,n}}$ is the characteristic heads pull-through strength, d is the nail diameter, t_{pen} is the pointside penetration length or the length of the threaded part in the pointside member, t is panel thickness, d_{h} is the nail head diameter.

The characteristic withdrawal capacity for the screw was calculated according to Eurocode 5 (2004) as follows:

$$F_{\mathrm{ax,Rsk}} = f_{\mathrm{ax,k}} d_{\mathrm{e}} l_{\mathrm{ef}} k_{\mathrm{d}} \quad \text{(N)} \tag{15}$$

$$f_{\mathrm{ax,k}} = 0.52 d_{\mathrm{e}}^{-0.5} l_{\mathrm{ef}}^{-0.1} \rho_{\mathrm{k}}^{0.8} \quad (\mathrm{N \cdot mm^{-2}}) \tag{16}$$

$$k_{\mathrm{d}} = min \begin{cases} \dfrac{d_{\mathrm{e}}}{8} \\ 1 \end{cases} \tag{17}$$

where: $f_{\mathrm{ax,k}}$ is the characteristic withdrawal strength perpendicular to the grain, d_{e} is the effective diameter of screw, l_{ef} is the penetration length of the threaded part.

The characteristic value and design value of elements in joints were calculated according to Eurocode 5 (2004) and the results are given in Tab. 4. The calculated data were used in the subsequent reliability analysis.

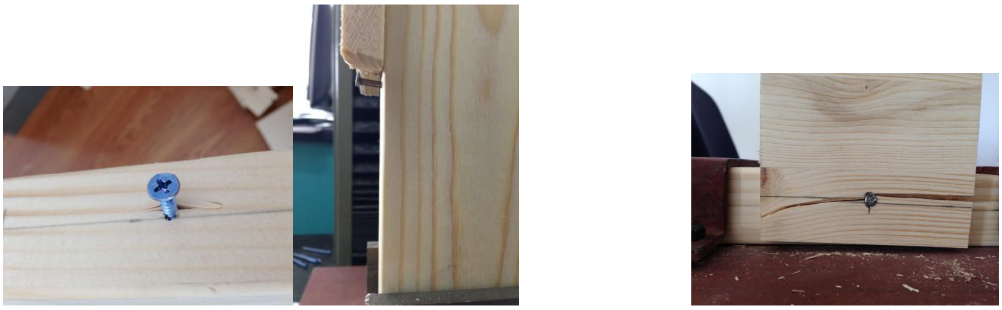
Tab. 4: Calculated results of joints.

	Embedding strength ($\mathrm{N \cdot mm^{-2}}$)		**Withdraw strength** (N)		**Lateral load capacity of joints** (N)			
	SPF	PSB	Nail	Screw	SPF-nail	PSB-nail	SPF-screw	PSB-screw
Characteristic value	33.579	90.728	352.800	743.183	528.614	901.643	768.341	1062.567
Design value	25.830	69.790	271.385	571.679	436.299	693.562	644.560	865.555

RESULTS AND DISCUSSION

Failure modes

The ultimate failure modes of the joint between SPF sheathing and SPF frame are shown in Fig. 4. The ultimate failure modes of the joint between PSB sheathing and SPF frame are shown in Fig. 5. There were two ultimate failure modes of joints with SPF panel in monotonic tests: *(1)* bending of fastener and *(2)* brittle failure of SPF sheathing panel. On the other hand, there were three ultimate failure modes of joints with PSB sheathing in monotonic tests: *(1)* nail yielding followed by withdrawal of nail from the wood member, and *(2)* brittle failure of screw. The main damage patterns of joints with SPF panel was brittle failure of SPF sheathing panel, whereas, in joints with PSB panel, was failure of fastener.



a) *b)*

Fig. 4: Failure modes of the joints with SPF sheathing: (a) bending of fastener, (b) brittle failure of SPF sheathing panel.

a) *b)*

Fig. 5: Failure modes of the joints with PSB sheathing: (a) bending of fastener, (b) brittle failure of screw.

Load-displacement relationships

The average curves for different joints were obtained and compared in Fig. 6. According to Fig. 6, the curves under the parallel load test had obvious horizontal section. This is due to the weak shear resistance between the framing fibers parallel to grain, resulting in the slippage of the fasteners parallel to grain (Li et al. 2015). The fiber grain direction perpendicular to the load direction can better limit the displacement of the fastener, so the load displacement curve under the vertical load test had no horizontal section.

The joints with SPF sheathing panel had relatively low level of strength and stiffness, and after reaching the force peak value at a displacement level of 8-12 mm, a sudden impairment of strength was observed due to the tear of the SPF sheathing panel. Even though the experimental results showed good performance in terms of the strength and stiffness of screwed joints with PSB sheathing panel, the ductility properties of this joint seem very poor. In the case of nailed joints with PSB sheathing panel, the strength capacity was lower than screwed one, but shown a more ductile behavior.

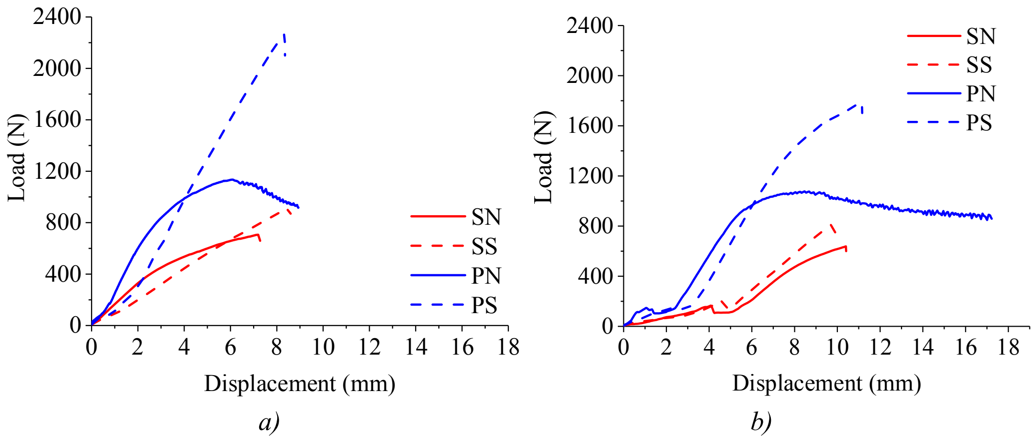


Fig. 6: Load-displacement curves of the test specimens: (a) perpendicular test, (b) parallel test.

The mean, standard deviation, and coefficient of variation of the parameters for each group of joints are shown in Tab. 5. The following discussion presents the major conclusions, which can be drawn based on the results of Tab. 5.

Tab. 5: Parameters of the lateral behavior of the joints.

	P_{max} (N)			Δ_{Pmax} (mm)			K_e (N·mm^{-1})		
	Mean	SD	CoV (%)	Mean	SD	CoV (%)	Mean	SD	CoV (%)
CSN	702.64	139.28	19.82	7.28	1.39	19.09	171.90	29.57	17.20
CPN	1204.59	205.20	17.04	6.94	1.21	17.44	361.86	81.37	22.48
CSS	900.98	174.37	19.35	8.42	1.51	17.93	139.36	26.30	18.88
CPS	2264.54	369.43	16.31	8.34	1.30	15.59	333.29	45.85	13.76
PSN	633.64	125.01	19.73	10.39	2.40	23.10	123.79	10.93	8.83
PPN	1026.95	159.79	15.56	8.68	1.54	17.74	263.56	49.27	18.69
PSS	805.26	141.59	17.58	9.70	1.63	16.80	136.86	25.89	18.92
PPS	1782.53	321.59	18.04	11.16	1.76	15.77	290.83	57.11	19.63

Effects of the loading direction

According to Tab. 5, the loading direction had a significant effect on the monotonic lateral behaviors of the joints. In contrast, the bearing capacity of the joints under perpendicular load was significantly higher than that under parallel load, which is due to the full utilization of the compressive strength perpendicular to grain of the framing element under the perpendicular load. Under the parallel load, the fastener exerts a concentrated force on the surrounding wood fibers parallel to grain to make it tear, resulting in less resistance. Due to the large slip of the fastener under the parallel load, the displacement at the ultimate bearing capacity and the elastic stiffness of the joints under the parallel load were higher than those under the perpendicular load.

Effects of the panel type

Compared with the joints with the SPF sheathing panel, the bearing capacities of the joints with the PSB sheathing panel were significantly increased. The ultimate bearing capacity of the joints with PSB panel was 62% -150% higher than that of the joints with PSB panel, which is because the compressive strength and tensile strength of SPF panel are significantly higher than those of SPF panel. The fasteners in the joints with PSB panel can give full play to their bending and shear strength, so that the damage of the joints with PSB panel is ultimately the damage of the fastener. However, since the tearing of the SPF panel precedes the bending of the fasteners, the mechanical properties of the fasteners in the joints with SPF panel cannot be fully utilized. The elastic stiffness of the joints with PSB panel was 110% higher than that of the joints with SPF panel. This is because the density and hardness of PSB panel are significantly higher than that of SPF panel, and the contact between PSB panel and the fastener is rigid. Due to the small stiffness and large deformation of SPF panel, the elastic stiffness of the joints with SPF panel was relatively small. Accordingly, it could be observed that the improvements of the lateral behavior of the frame-to-sheathing joints increased with the use of PSB sheathing panel. This is attributed to the fact that a greater material performance of PSB panel leads to all materials into full play.

Effects of the fastener type

The conclusion can be obtained that the bearing capacity of the screwed joints was higher than that of nailed joints. In the joints with PSB panel, the ultimate bearing capacity of joints using nail was increased by 87% by using screw. In the joints with SPF panel, the use of screw increased the ultimate bearing capacity of joints using nail by approximately 28%. The reason is that the bending strength of screw is higher than that of nail. On the other hand, there was a correlation between the enhancement effect of the screw on the joint and the panel performance. Among the screwed joints, the improvements of the bearing capacity for the screwed joints with the PSB sheathing panel were more remarkable than those of the screwed joints with the SPF sheathing panel. Because the bending strength and stiffness of the two types of fastener are similar, the type of fastener had little influence on the elastic stiffness of the joints, which was about 10%. Moreover, the elastic stiffness of the screwed joints was slightly lower than that of the nailed joints in perpendicular tests, whereas in parallel tests, screwed joints showed higher elastic stiffness. The primary reason for this effect is that the bending capacity and the withdraw capacity of the screws significantly higher than that of the nails.

Evaluation of lateral performance

The reliability index and the failure probability of joints were calculated and the results are given in Tab. 6. The comparison of the reliability index for joints are shown in Fig. 7.

Tab. 6: Reliability index and failure probability of joints.

	CSN	CPN	CSS	CPS	PSN	PPN	PSS	PPS
β	1.8968	2.4839	1.4504	3.0823	1.5608	2.0733	1.1095	2.3006
P_f	0.0289	0.0065	0.0735	0.0010	0.0593	0.0191	0.1336	0.0107

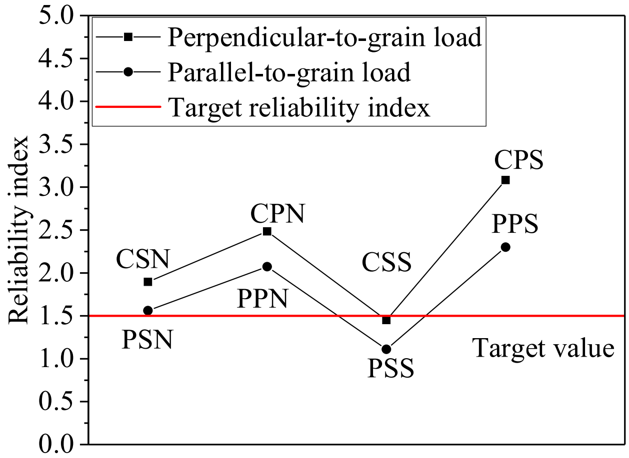


Fig. 7: Reliability index of joints.

Based on the calculated reliability index the influence of the varied parameters can be evaluated. According to the results and observations from Tab. 6, higher reliability index, which means lower failure probability, were achieved for the joint occurred ductile failure. The reliability index of the joints occurred brittle failure in perpendicular tests was higher than that in parallel tests. The primary reason for this is the influence of the loading direction on the lateral performance of the joints is not considered in the design. In addition, the joints under the parallel load generally only play the role of transfer, not the main lateral-bearing part. The joints under the perpendicular load are the main lateral-bearing elements in the light wood framed shear wall. Therefore, the reliability index of joints under perpendicular load should achieve the safety requirements. Since the light wood framed shear wall is composed of many joints, too low reliability index will lead to insecurity of the structure, while too high reliability index will lead to waste of materials and brittle failure. Generally, the reliability index of joints is within the range of β = 1.5 to β = 2.0 (Smardzewski 2009, Schick and Seim 2019). However, the reliability index of the new type joints is within the range of β = 1.11 to β = 3.08. It is suggested that although the lateral design value can calculate according to the Eurocode 5 (2004), the design methods still need further study and modify to achieve the specific reliability level. The target reliability index β = 1.50 was adopted for the assessment of probabilistic results in order to verify the applicability of design method.

By comparing the reliability index obtained from the calculation with β = 1.5, it can be concluded that the lateral strength design values of the joints obtained by the Eurocode design method can meet the minimum reliability requirements, except the SPF-screw joints. In addition, the reliability index of the joints with PSB panel was significantly higher than that of the joints with SPF panel. Therefore, it is recommended to use PSB-screw joints in structures with high reliability and strength requirements. Because the SPF panel has a higher strength-to-weight ratio and lower cost than PSB panel, SPF-nail joints can be used in non-important parts of the structure, which can not only provide resistance, but also reduce the self-weight of the structure to reduce the earthquake effects.

CONCLUSIONS

Experimental investigation and reliability analysis were conducted in order to study the influencing factors on the lateral performance of frame-to-sheathing joints under monotonic load, including those of loading direction, sheathing panel type and fastener type. The experimental results of the 80 frame-to-sheathing joints were reported and discussed. Additionally, the bending experiments of fasteners were conducted in order to obtain the design value of bending yield moment. Moreover, the reliability analysis used first-order reliability methods of the joints was developed for further studies. At last, the practical application suggestions of different joints were provided. Based on the results of these studies, the following conclusions can be stated: *(1)* Based on the experimental data and reliability analysis, the results suggested that the joints with PSB sheathing panel can be applied in light wood framed shear wall as mainly bearing elements. The joints with SPF sheathing panel can be applied in light wood framed shear wall as non-important parts of the light wood framed shear wall. *(2)* Based on the Johansen yield theory and reliability analysis, the reliability index of the joints in perpendicular tests was higher than that in parallel tests. The reliability index of joints with PSB panel was higher than that with SPF panel. The reliability index of lateral design value of joints calculated by Eurocode is within the range of 1.11 to 3.08. The reliability index of joints under perpendicular load met the minimum reliability requirements, except the SPF-screw joints. In order to meet the specific requirements of structural design code, the further modifications of the design method of the frame-to-sheathing joints with different sheathing panel are necessary. *(3)* The lateral capacity and the elastic stiffness of the frame-to-sheathing joints under perpendicular load were higher than those of the frame-to-sheathing joints under parallel load. The lateral capacity and the elastic stiffness of the frame-to-sheathing joints with PSB sheathing panel were higher than those of the frame-to-sheathing joints with SPF sheathing panel. The lateral capacity of the frame-to-sheathing screwed joints were higher than that of the frame-to-sheathing nailed joints. The type of fastener had little influence on the elastic stiffness of the joints period.

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