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Utilization of Sandwich Insulated Panels made from Wood Composite and Cellular Natural Rubber

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ABSTRACT

Structural Insulated Panel (SIP) with nature rubber (NR) core filler, is a new building material developed in laboratories, is a kind of frameless panel which is often used for the interior construction of buildings. It weighs six times less than a brick and precast concrete wall. Then, it is suitable to be used as drywall to decrease building dead load. In this research, it aims to (1) find out suitable proportion of SIP with NR Core Filler to apply as precast wall and (2) study the detail of installation systems such as patterns and joint details that are suitable for the conditions of construction technique in Thailand. To install in the building, SIP with NR Core Filler should not be less than 6.5 centimeters in thickness, not more than 2.80 meters in height and 1.20 meters in width. The four existing patterns of Panel-To-Panel joints were tested to find the suitable methods to construct by the modular system and can be combined with another existing materials, tools and construction techniques. According to ISO 3349, the results showed that loading capacities of each pattern were similar. The designed joints gave side compressive strength around 50% of seamless wall. To fix the wall to floor and construction wall, the Galvanized Steel Frame was chosen and the tested joints could carry 80.30-90.35 Kilograms of load equal to 700 N/m^2. However, the kind of screws is a crucial factor because the strength of installation depends on the laceration between the panel wall and those screws. A panel thicker than 6.5 cm would provide more options for installation detail appropriate for construction in Thailand.

Keywords: Sandwich panel, Sustainable material, Appropriate technology, Installation technique.

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Introduction

Green Construction Technology, material and process of constructions, for building is a trend of global construction industry. The use of green building materials in construction is considered as "Sustainable Design". Green materials are the environmentally responsible materials as they help in reducing environmental impact [1]. Many architects try to design and choose green building materials and green process of construction to create the sustainable architecture. Structural Insulated Panel (SIP) with nature rubber (NR) core filler, a new building material developed in laboratory, is a kind of frameless panel often used for the interior construction of buildings. It weighs six times less than a brick and precast concrete wall. The prototype SIP has the maximum thickness of 6.5 cm with the surface maximum thickness of 5 mm. Then, it is suitable to be used as drywall to decrease building dead load. However, SIP with NR core filler is not a traditional building material for construction in Thailand. In order to develop the material, the appropriate application of SIP with NR core filler should be analyzed. Moreover, the potential of SIP to be used as the self-containing panel in building construction should be assessed.

Previous research studied the appropriate joints for SIP. Rungthonkit and Yang [2] revealed that there are three-typical joints for panel-to-panel jointing for SIP made from thin Oriented Strand Board (OSB) with foam core, including (1) OSB thin spline, (2) foam block spline or referred to as mini-SIP spline and (3) dimensional lumber spline. Figure 1 illustrates the three typical panel-to-panel joints. Morley [3] illustrated that the appropriate joint for wall-to-slab, as shown in Figure 2.

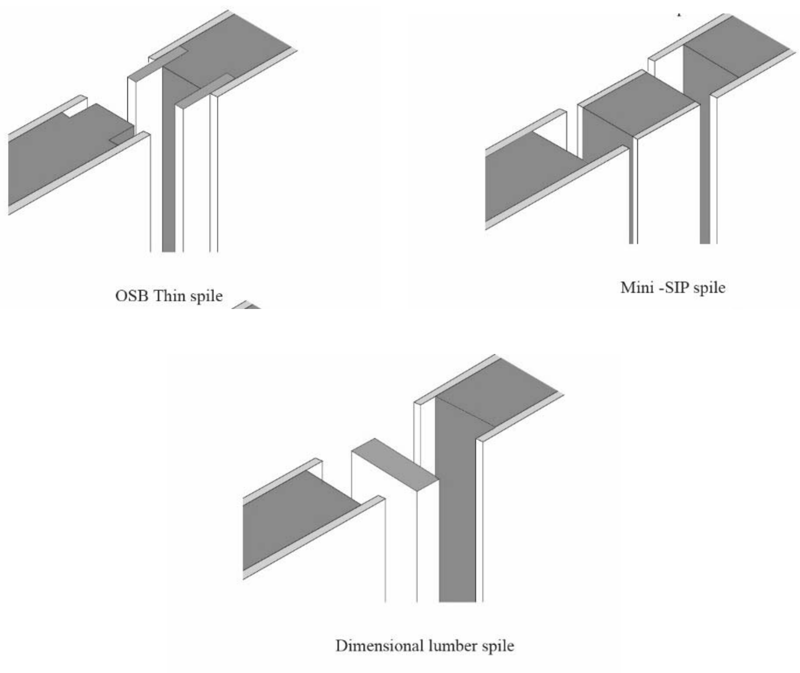

Figure 1 Typical panel-to-panel joints

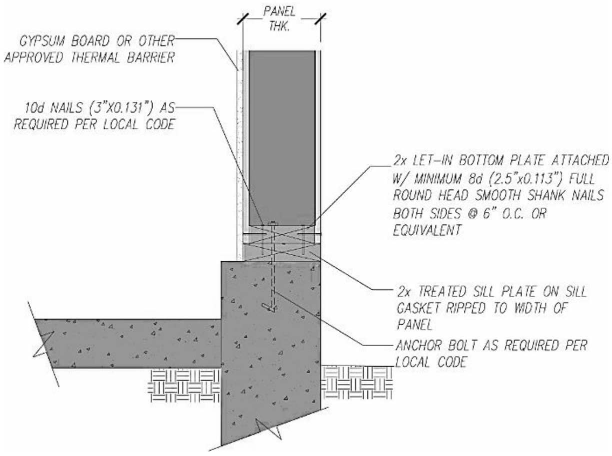

Figure 2 Typical wall-to-slab joint

Materials and Methods

Panel Production and Properties

The prototype SIP consists of oriented strand layers made form rubber wood as a facing material and insulated foam made from natural rubber filled with wood particles as an inner core, as present in Figure 3. The components of face and core material were pressed in the same mold under temperature and pressure simultaneously to yield the prototype with same major advantage. Table 1 shows the average values properties of the prototype SIP.

Figure 3 The prototype SIP.

Table 1 The average value properties of SIP made from rubberwood and nature rubber core filler [4]

Properties	Value
Density (g/cm^3)	0.40-0.45
Modulus of rupture (Mpa)	53-57
Modulus of elastic (Mpa)	7,000-8,000
Internal bonding strength (Mpa)	0.45
Thermal conductivity (W/mK)	0.086
Sound transmission Class(dB)	42

Typically, the SIP for interior construction should have a minimum thickness of 6.5 cm in order to work with general construction tools. Due to the requirements of building code of Department of Public Works and Town & Country Planning [5], rooms or parts of building used for residential purpose, living unit and hostel shall have a minimum vertical distance of 2.60 m. Consequently, the panel should be higher than 2.6 m to facilitate the ceiling. Because of size specification and modular system compatibility, the minimum dimension of SIP is 6.5 cm in thickness, 2.80 m in height and 1.20 m in width.

Potential Assessment of SIP for Self-containing Panel in Building Construction

The potential of SIP to be used as the self-containing panel in building construction can be assessed by the uniform load on edgewise of SIP or the critical buckling load.

The critical buckling load, $P_{buckling}$, caused SIP failure due to buckling is defined as [6]:

$$P_{\text{buckling}} = \frac{P_E}{1 + \frac{P_E}{AG}} \tag{1}$$

Where, A is sample area under shear stress, G shear modulus of core layer, and P_E = critical buckling load by Euler's formula calculated from equation (2) [7]

$$P_E = \frac{\pi^2 D}{L^2} \tag{2}$$

Where, D is flexural stiffness obtained from equation (3)

$$D = E_f \frac{bt_f^{\,3}}{6} + E_f \frac{bt_f d^2}{2} + E_c \frac{bt_c^{\,3}}{12} \tag{3}$$

Where, E_f is Modulus of Elasticity (MOE) of face layer, E_c MOE of core layer.

Therefore, the critical buckling load employed in this work is based on Modulus of Elasticity (MOE) of surface and core layer.

The prototype SIP was separated into the surface and core layers to be tests for MOE of each layer. Three-point static bending tests for MOE were performed in accordance with EN 310:1993 [7] and ASTM D 143-14 [8] using a universal testing machine (LLOYD 150 kN). The equations that shown in equation (4) and (5) were used to calculate MOE of surface and core layer, respectively. Then, the critical buckling load of SIP was calculated from equation (1).

$$E_f = \frac{P_{Pl} L^3}{4\delta_{Pl} b_f t^3} \quad (4)$$

$$E_c = \frac{P_{Pl} H}{\Delta_{Pl} A_c} \quad (5)$$

Where, L is span length, δ_{Pl} deflection of sample at proportional limit, b_f sample width, t sample thickness, and A_c sample area under compressive stress.

Analysis of Design Guidelines for Installation

In Thailand, the use of dry wall system to separate space in the building is the board on frame system but the prototype SIP is the frameless system and self-containing panel. Therefore, the detail of installation systems, such as patterns and joint details which are suitable for construction technique in Thailand, could be analyzed from the design of the installation guidelines as present in Figure 4:

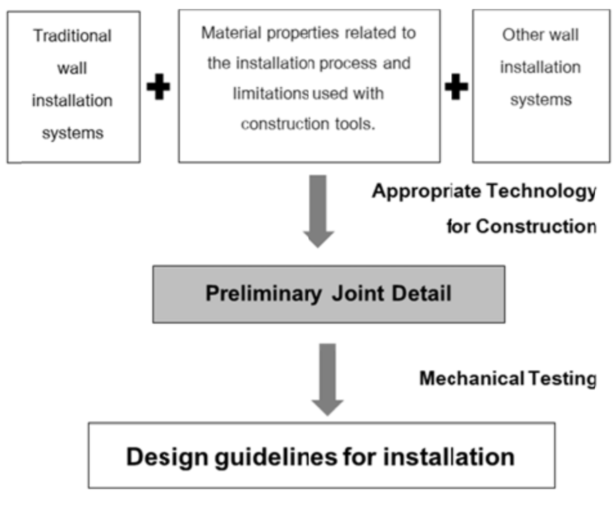

Figure 4 Design guideline used to analyze the installation systems of SIP

Installation Joint Detail and Testing Methods

In this research, the solid wall with two different types of joint (Type 1: panel-to-panel and Type 2: panel-to-exiting floor) was used to analyze. The panel-to-panel joint strength of prototype SIP was done in accordance with ISO 3349:1975 [9], as present in Figure 6, while, the panel-to-exiting floor joint strength was performed with some modification standard, as present Figure 7. Finally, the two joint strengths were compared with drywall mock up manufactured from fiber-cement board on galvanized U-stud number 24@40cm.

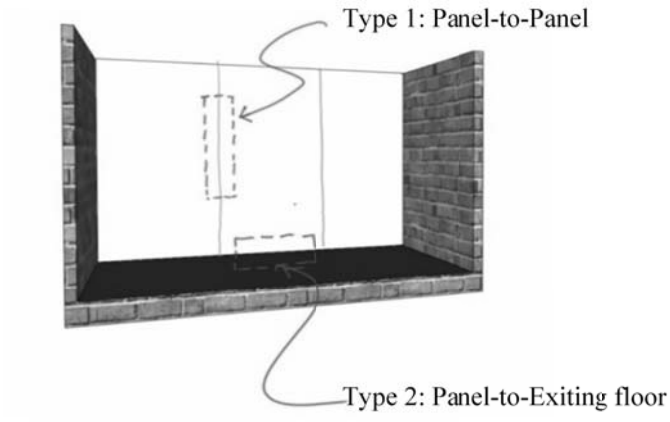

Figure 5 Model of two joint systems used in the experiment.

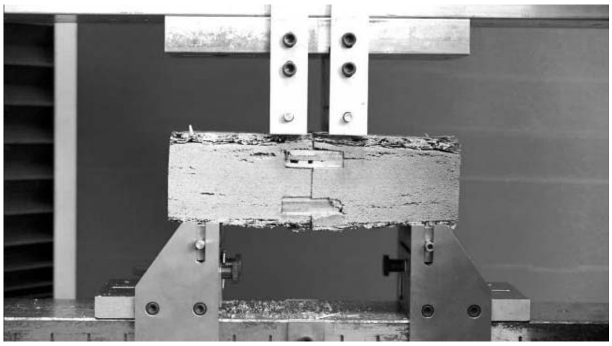

Figure 6 Testing of joint strength for panel-to-Panel.

Figure 7 Testing of joint strength for panel-to-exiting wall or floor.

Results

The Critical Buckling Load of SIP

The result indicates that prototype SIP has the average MOE value of surface and core layer of 5,000 ± 120 MPa and 5 ± 0.5 MPa, respectively.

Figure 8 shows the increasing critical buckling load with increasing core layer thickness. On the other hand, with increased in SIP height, the critical buckling load decreased. According to the design standard of wood structures for two-story buildings in USA and Canada, the minimum requirement of critical uniform load on edgewise of SIP is 13.13 kN/m. The comparison of the critical uniform load on edgewise required by APA and the calculated critical buckling load caused SIP failure when the wall height is 2.8 m, is shown in figure 8.

The result indicates that calculated critical buckling load at all thickness of SIP is greater value than the critical uniform load required by APA design standard. It is reasonable to hypothesize that SIP with the height of 2.8 m can withstand uniform load without buckling. Consequently, the maximum thickness of SIP has the potential to be used as a two-storey building wall with a height of 2.8 m without the failure caused by buckling.

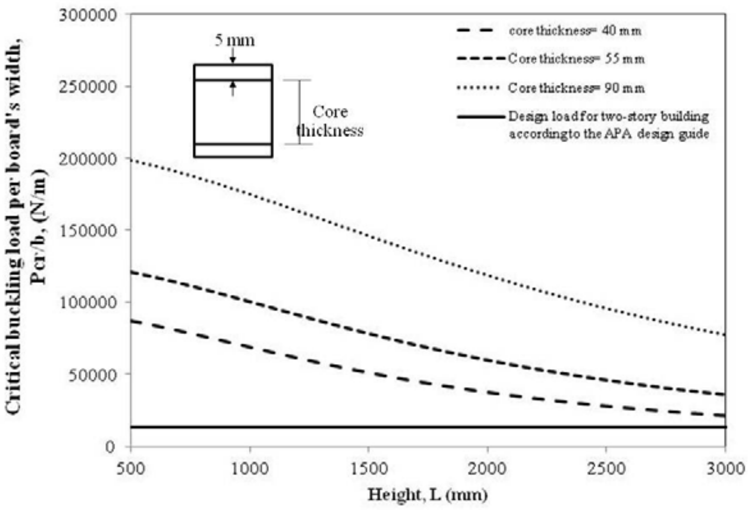

Figure 8 The critical buckling load caused failure of SIP with a thickness of 5 mm at different height and thickness of core layer

Design of Joint Detail

Based on design guideline analysis, there are four-typical joints consisting of tongue and groove for panel-to-panel joint (Type 1), as illustrated in Figure 9. For panel-to-existing joint (Type 2), the galvanized steel frame and screw as a plate fastener are suitable to be used with the prototype SIP, as shown in Figure 10.

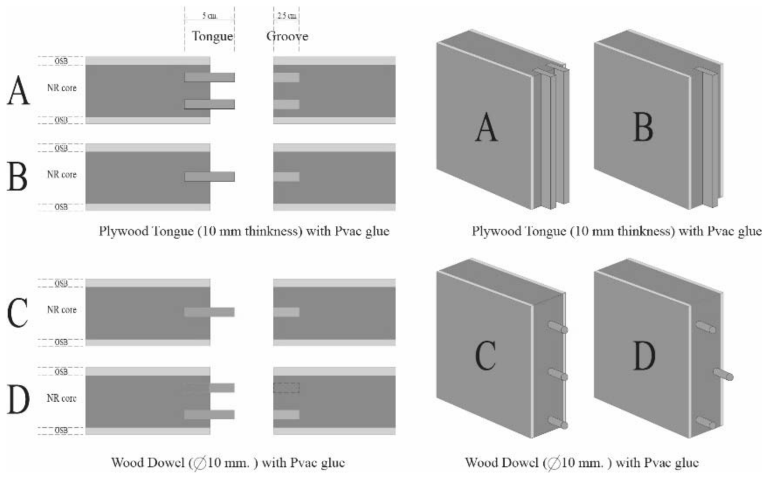

Figure 9 Four-typical joints for panel-to-panel jointing

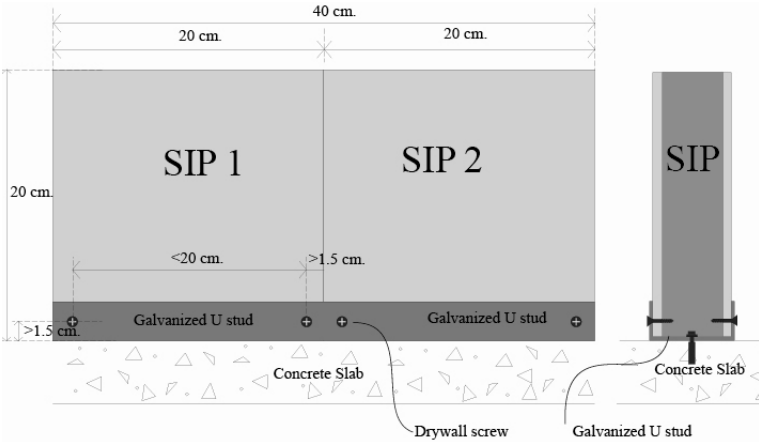

Figure 10 Four-typical joints for panel-to-panel jointing

Joint Strength

The results suggest that the maximum load resistance of all joints varies in the range of 1,133.39-1,467.11 N. The comparison of joint strength for four types of panel-to-panel jointing and non-jointing panel is shown in table 2. It should be noted that maximum load of all joints is approximately 40-50% lower than non-jointing panel. Based on the suitability and simplicity, joint type B might be suitable as panel-to-panel jointing for prototype SIP.

Table 2 The joint strength of panel-to-panel jointing

Panel-to-Panel Jointing	Maximum Load (N)
A	1,467.11 ± 81.32
B	1,324.76 ± 51.62
C	1,133.39 ± 78.49
D	688.71 ± 72.12
Non-jointing	3,892.23 ± 131.52

For panel-to-floor jointing, the galvanized steel frame could carry 80.30–90.35 Kg of load equal to 700 N/m^2. The result shows that the designed joint could resist the lower load capacity than the requirement of TISI 863-2532 which the load capacity of stud is in the range of 240-480 N/m^2.

However, screw type is a critical factor because the strength of installation depends on the laceration between the panel wall and those screws. From the practical point of view, the drywall screw is suitable to be used with the prototype SIP.

Conclusion

Based on the analysis of critical buckling load, the prototype SIP has potential to be used as the self-containing panel in building construction. Therefore, it can be used as a two-story building wall with a height of 2.6 m without the failure caused by buckling. Then, the suitable proportion of SIP to be used as a precast wall is 1.20 m width and 2.8 m height. Moreover, this proportion of SIP is compatible with the modular system.

Based on design guideline analysis, there are four-typical joints consisting of tongue and groove for panel-to-panel joint. The galvanized steel frame and screw as a plate fastener are suitable to be used with the prototype SIP for panel-to-existing joint**.**

A panel thicker than 6.5 cm would provide more options for installation detail appropriate for construction in Thailand.

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