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CORE CONFIGURATION EFFECT ON THE FLEXURAL BEHAVIOUR OF SANDWICH PANEL MADE OF ALUMINIUM SKIN AND SENGON WOOD CORE

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ABSTRACT

Among the many choices of composite sandwich panel cores, Balsa wood is one of the main alternatives of cores made of wood. However, the availability and price of Balsa wood are quite expensive, so it needs alternatives from other types of wood such as Sengon wood. The purpose of this study was to evaluate the feasibility of Sengon wood as a core of composite sandwich panels. Three variations of the Sengon wood layout had been prepared as the core of the sandwich panels with a skin made of aluminum. All specimens, including the control specimens made of whole Sengon wood, were prepared with a size of 550 x 50 x 24 mm for length, width, and depth, respectively. Each variation and also the control specimens were made of 3 pieces. Tests were carried out based on the ASTM C 393-94 standard under the three-point bending test scheme. The results showed that the sandwich panel with plain Sengon wood core has the highest capacity to carry a flexural load, which is approximately 177.391 MPa, followed by a sandwich panel with long and end grain Sengon board that possess flexural strength of 153.913 MPa and 79.101 MPa, respectively. The flexural strength of these sandwich panels is superior to solid Sengon wood. The sandwich panels showed a typical ductile material indicated by a non-linear curve without a distinct yielded point before reach the maximum failure load. Three sandwich panels with various Sengon wood cores collapsed under three types of failure mechanisms; face wrinkling, shearing of the core, and delamination between the interface of skin and core. In conclusion, Sengon wood has a great potential to be used as the core material for a composite sandwich panel.

Kata kunci : *sandwich panel, core, composite flexural strength*

1. INTRODUCTION

Wood is an alternative material for the core of the composite sandwich panel. Durable light wood is the perfect choice of core material and for a long time, Balsa wood has been recognized as the best core made of wood. Indonesia has a large variety of wood that meets the requirements to be used as the core, but not much has been further studied. One of them is Sengon wood which has good characteristics; lightweight, dimensionally stable, and quite

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durable. This article aims to discuss the flexural behavior of sandwich panels made of Sengon wood cores. The core was prepared using three types of Sengon wood configuration combined with Aluminum skins to form a sandwich panel structure.

Research related to the flexural behavior of sandwich panels has been widely reported. Edgars et al. (2017) reported the flexural behavior of sandwich panels made of plywood skin. The core of the sandwich panel was glass fiber reinforced polypropylene (GF/PP) and polyurethane (PU) foam. It was found that the average flexural strength of GF/PP was 26.1 MPa and 22.6 MPa for sandwich panels with PU core. Overall, they found that wood-based panels are a competitive substitute for solid wood materials. Srivarno et al. (2014) reported their study on using palm wood core sandwich panels with rubberwood veneer as the skins and the results showed that the developed sandwich panels had better performance compare to the commercial products with the same function. A new sandwich panel incorporating an intermediate layer made of natural fiber composite materials was developed by Fajrin et al. (Fajrin, Yan, et al., 2011; Fajrin, Zhuge, et al., 2011), and they found that employing an intermediate layer significantly improved the flexural behavior of sandwich panels. The theoretical concept of this new hybrid sandwich panel was comprehensively developed by Fajrin (2015). Further, Fajrin et al. (2016, 2017) experimentally investigated the suitability of the hybrid sandwich panels for structural applications and found that they can be applied for the structure under flexural or in-plane shear loading. Essentially, there are two main criteria in the selection of core materials used in sandwich panel structure; the design criteria and the specific application (Davies, 2008), hence all lightweight materials may be used for the core. Sandwich panels may collapse due to various failure mechanisms within the constituent materials or the interaction among the material such as face wrinkling, indentation, delamination, core shearing, or skins failure (Daniel & Abot, 2000). The incorporating Sengon wood as the core material of sandwich panel was studied by Diharjo (2009) where the sandwich panels made of Sengon core were compared to the solid Sengon and it was found that sandwich panels made of Sengon wood core performed better than its solid constituent materials.

Sandwich panels are commonly used in civil engineering applications as walls or floors that require a large size. Meanwhile, it is extremely difficult to find a wood-based core in such a large size. As a result, small pieces of wood are connected in such a way as to form a large area as a solution. In this case, the role of configuration or layout becomes so important to be further investigated. It is, therefore, the configuration of the Sengon wood core was proposed as the main parameter investigated in this research.

2. MATERIAL DAN METHOD

Sandwich panel samples were prepared using the manual pressing method. The samples were cut and formed into a span length of 400 mm with the size of 550 x 50 x 24 mm for the length, width, and thickness, respectively. Aluminum sheets were used as the skin and different layouts of Sengon wood, as shown in Figure 1, were employed as the core of the sandwich panel. The constituent materials were glued together using epoxy resin glue and clamped for 24 hours before the specimens were ready for the test. The basic properties of Sengon wood were also tested for further analysis. All the laboratory tests were conducted in the laboratory of structure and material, Faculty of Engineering, Mataram University. The detail of the arrangement of the sample is presented in **Table 1**.

Table 1. Experimental arrangements for flexural testing

Sample Groups	Skin Material	Skin Thickness (mm)	Core Material	Core Thickness (mm)	Core Layout	Number of Samples
SCA	Aluminum	1	Sengon	22	Long grain plain	3
SCB	Aluminum	1	Sengon	22	Long grain board	3
SCC	Aluminum	1	Sengon	22	End grain board	3
SW	-	-		24	Solid	3

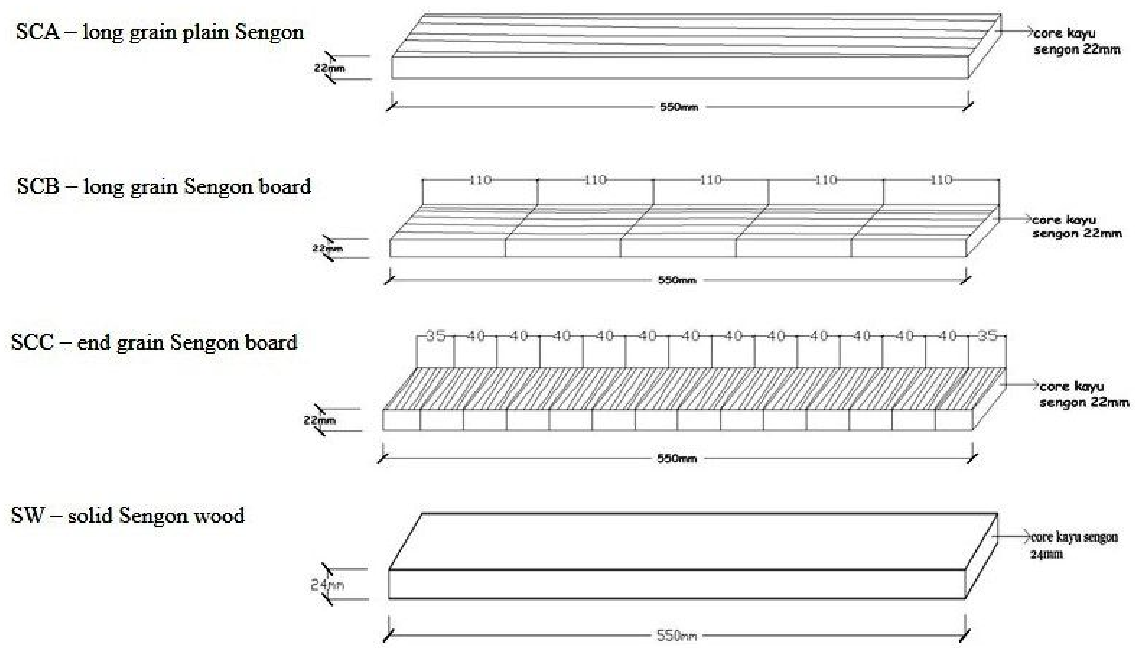

Figure 1. The layout of Sengon wood as the core of the sandwich panel

Static flexural testing, as depicted in **Figure 2**, was conducted under one point load scheme as per ASTM C393-2000 (ASTM, 2000). The load was applied at the center of the span length. The testing was performed using a flexural testing machine. Steel plates were placed under the loading point and between specimen and support to prevent early failure mechanism. The test was terminated once a visible collapse mechanism was observed, and the specimens did not carry any increase in load.

3. RESULTS AND DISCUSSIONS

3.1. Ultimate load and deflection

The comparison of ultimate load carrying capacity is presented in Figure 3 (A). It is seen that the sandwich panel with long-grain plain Sengon wood core (SCA panels) possesses a higher load-carrying capacity than the others. With the average load of 2040 N, it is 15.25% and 124% higher than a sandwich panel with a long-grain Sengon board core (SCB panels) and end-grain Sengon board core (SCC panels), respectively. It is also superior to the load-carrying capacity of solid Sengon wood (SW) which is only carrying a maximum average flexural load of 1407.6 N. Figure 3 (A) also showed that SCA and SCB panels supported higher load than SW, while on the other hand, SCC carried lower load than SW. It may indicate that the end grain configuration for Sengon is undesirable for sandwich panels carrying flexural loads.

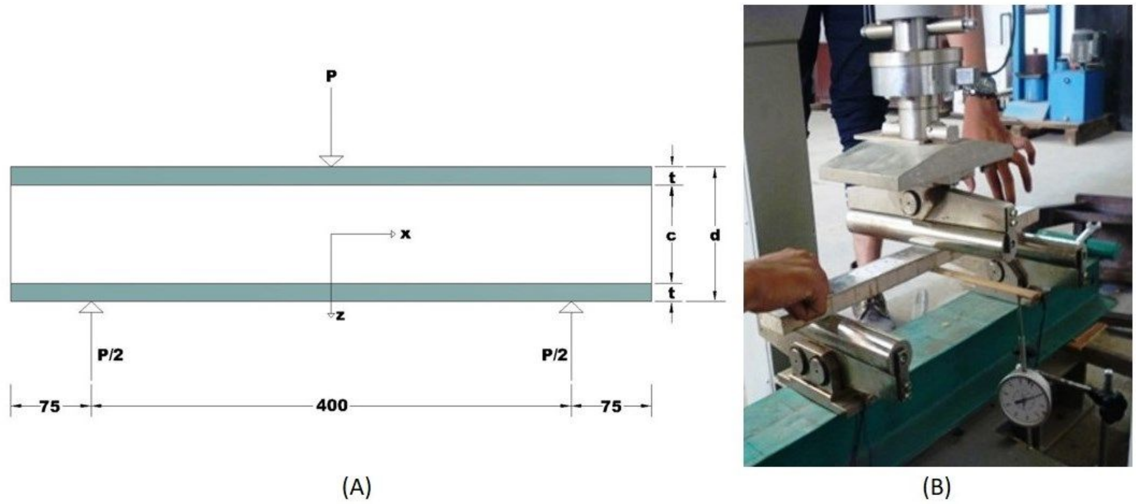

Figure 2. Setting (A) and actual (B) set up for flexural testing

In terms of deflection under a maximum given load, as seen in **Figure 3** (B), the SCA panel experienced the largest deflection, which is 6.43 mm under a maximum average load of 2040 N. SCB and SCC deflected slightly less, which is 5.26 mm and 4.30 mm, respectively. However, if stiffness of a material is technically defined as the force (load) per unit deformation (deflection), then the above data infer that SCA and SCB are much stiffer than SCC and SW.

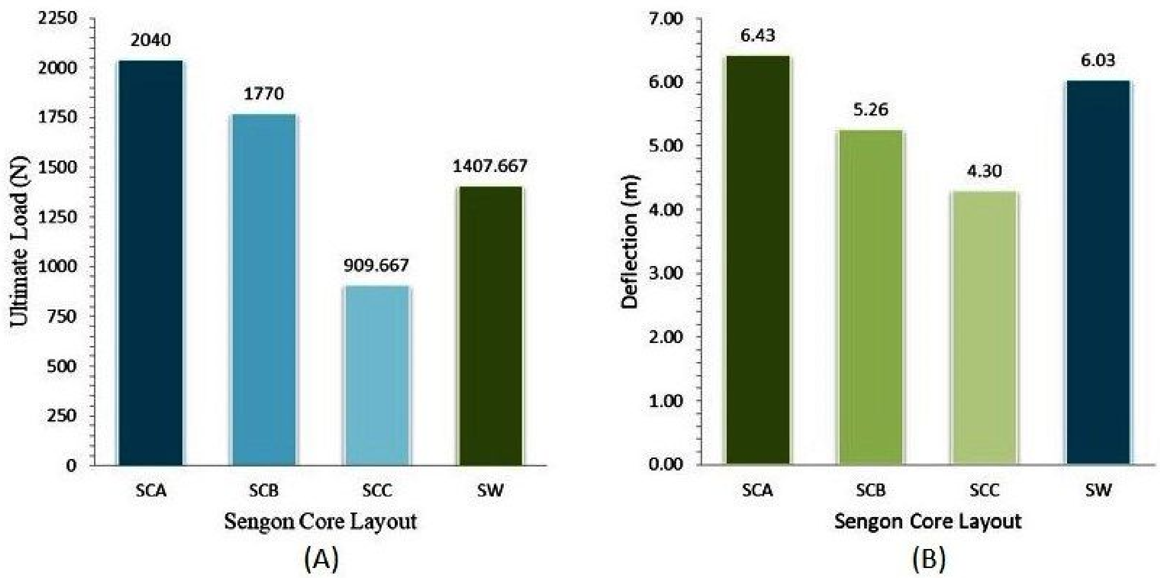

Figure 3. Ultimate load carrying capacity (A) and deflection (B) of sandwich panel with different

3.2. Flexural strength and core shear strength

Figure 4 (A) shows the average flexural strength of sandwich panels with different. It is clearly shown that sandwich panels with plain Sengon board core (SCA) possess the highest flexural strength, which is approximately 177.391 MPa. The flexural strength of sandwich panel with long grain Sengon board (SCB) is 153.913 MPa which is about 13.23% less than SCA. While the sandwich panel with end grain Sengon board (SCC) has the maximum average flexural strength of 79.101 MPa which is approximately 55.4% and 48.6% less than SCA and SCB, respectively. It is also clearly seen that sandwich panels with various types of Sengon core provide higher flexural strength than solid Sengon wood (SW) that only has a flexural strength of 29.326 MPa.

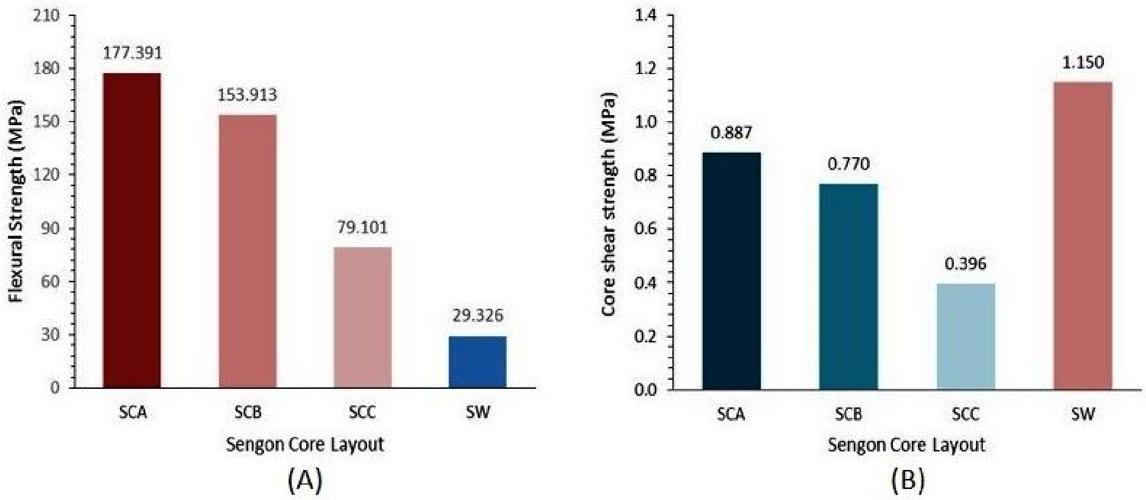

Figure 4. Flexural and core shear strength of sandwich panel with different

Likewise, the flexural strength, the core shear strength of SCA is also superior to SCB and SCC as depicted in Figure 4 (B). The core shear strength of SCA, SCB, and SCC is 0.887 MPA, 0.77 MPa, and 0.396 MPa, respectively. In contrast with flexural strength, however, the shear strength of the sandwich panel is less than solid Sengon wood which has an average shear strength of 1.15 MPa.

3.3. Load-deflection behavior

The relation between load and deflection for all tested samples is given in **Figure 5**. It can be observed that the graphs for SCA and SCC panels appear more consistent than SCB and SW, which may indicate that samples are well prepared. Sandwich panels are made up of two thin skin layers separated by a thick core. The skin is designed to withstand normal and flexural loads, while the core is intended to withstand shear and compressive loads. However, because the core is quite thick, there is a portion of the core that carrying tensile and flexural loads when subjected to bending. As a result, the role of core configuration becomes extremely important in this situation as the core must be able to withstand some portion of tensile and flexural loads existed below the neutral axis. In the SCA configuration, the solid wood core provides support through the long continuous fibers that run parallel to the loading direction. This increases the ability of SCA to withstand tensile and flexural loads over SCB and SCC. While the SCB and SCC configurations also provide the same support, but the fibers are discontinued at certain distances along the length of wood pieces, so the load capacity is directly proportional to the length of the cut. The load-bearing ability of solid Sengon wood (SW) is higher than that of SCC but lower than that of SCA and SCB, most likely due to the absence of the skin's role in carrying the load.

The presence of a glue line at the end of grain between adjacent pieces of wood causes SCB panels to appear slightly inconsistent when compared to SCA. While for SCC panels the glue lines were attached parallel to the grain which creates a better connection between the adjacent wood. In the case of SW, the inconsistency of performance under load may be attributed to the nature of wood as a biological material. One of the drawbacks of wood is that its quality varies even when it comes from the same tree. The micro-composition of a piece of wood determines how it will react when subjected to a load. All SW samples may appear similar, but they have different microstructures, which cause them to react differently under load.

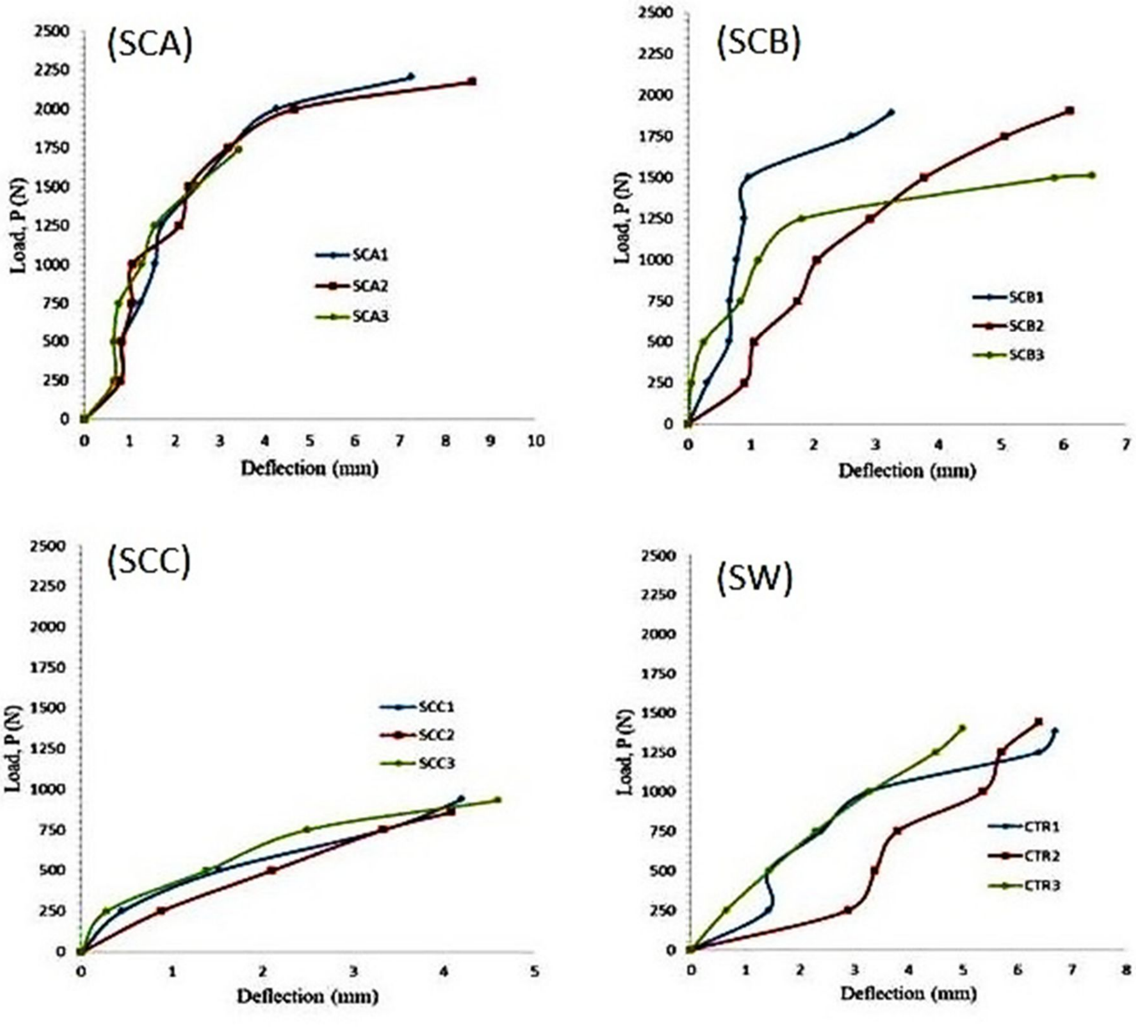

Figure 5. Load-deflection graphs of sandwich panel with various configurations of Sengon wood as the core material

To provide a more reasonable comparison among the fourth-panel types, a single graph was selected from each panel type and then plotted in a comparison graph as seen in Figure 6. It is seen that all graphs related to sandwich panels showed a typical ductile material indicated by a non-linear curve without a distinct yielded point before reach the maximum failure load.

Structures made of ductile material are less likely to fail catastrophically and are therefore preferred for public buildings (Fajrin et al., 2016; Somayaji, 1995). While the solid Sengon wood has a long linear curve up to the failure load. For the sandwich panel specimens, the initial part of the curves was linear and then gradually diverged as the load increased and terminated at the maximum failure load.

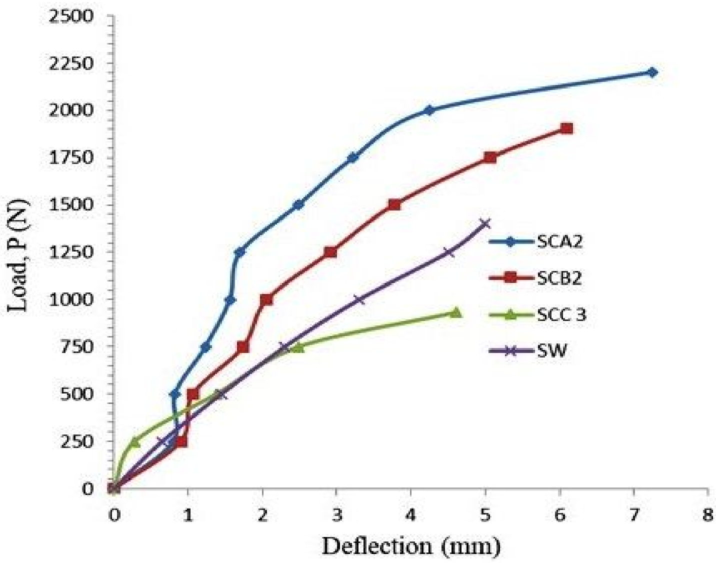

Figure 6. Load-deflection graphs of representative specimens for all groups

3.4. Failure mechanism

Figure 7. Failure pattern of the tested sandwich panels

The typical failure modes of sandwich panel with a different configuration of Sengon wood core is shown in **Figure 7**. It was observed that mostly SCA sandwich panels collapsed due to the shearing of the core and propagated to the lower part resulting in a tensile failure at the bottom face. The failure mechanism of the SCB was dominantly triggering by delamination at the interface of the upper face and the core near the loading point. While SCC sandwich panels were collapsed immediately due to wrinkling of the upper face near the loading point. All the failure mechanisms observed in this study were corresponding to those reported in previous studies (Daniel & Abot, 2000; Fajrin et al., 2016).

4. CONCLUSIONS

The main conclusion drawn from this study is that Sengon wood is feasible to be used as the core material of sandwich panels. More specific findings are as follows:

1. Sandwich panel with plain Sengon wood core has the highest capacity to carry a flexural load, which is approximately 177.391 MPa, followed by a sandwich panel with long and end grain Sengon board that possesses flexural strength of 153.913 and 79.101 MPa, respectively. The flexural strength of these sandwich panels is superior to solid Sengon wood.
2. The sandwich panels made of Aluminum skin and Sengon wood core showed a typical ductile material indicated by a non-linear curve without a distinct yielded point before reach the maximum failure load. This made the structures are less likely to fail catastrophically and preferred for public buildings
3. The sandwich panels with various Sengon wood cores collapsed under three types of failure mechanisms: face wrinkling, shearing of the core, and delamination between the interface of skin and core which is corresponding to those reported in previous studies.

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