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Geometry Strength of Honeycomb Sandwich Panel

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Abstract: The geometry strength of honeycomb sandwich panel with several types of core were investigated. There are four types of sandwich panels; Rectangular Core Sandwich Panel (RCSP), Horizontal Core Sandwich Panel (HCSP), Triangular Core Sandwich Panel (TCSP) and Symmetrical Core Sandwich Panel (SCSP). For all types of panel, the upper and bottom layers and the inner core made from the plywood with different thickness. The performance of the honeycomb sandwich panel subjected to four-point bending test and punching shear test were investigated. The results of flexural test showed that RCSP that having the rectangular core has the highest maximum load of 9.79 kN compared to HCSP and TCSP. The maximum load of RCSP in the punching shear test achieved 34.35 kN which was higher than SCSP. All the specimens having the core shear failure.

Keywords: Keywords: plywood sandwich panel, inner core, four-point bending test

1. Introduction

Sandwich panel is a structure is made of three layers, comprises the upper and bottom layer with a low density corrugated-core inserted in between two relatively the two layers. Based on European Recommendations for Sandwich Panel, structural sandwich panel is defined as a panel that has been designed for use as an external wall or roof element with subject to the usual requirement for wind load, snow load and also to meet the quality assurance. The sandwich panels propose a wide range of advantages over the conventional monolithic materials. Fig.1 show the basic concept of sandwich panel composite which consists of two faces and mix with core in between.

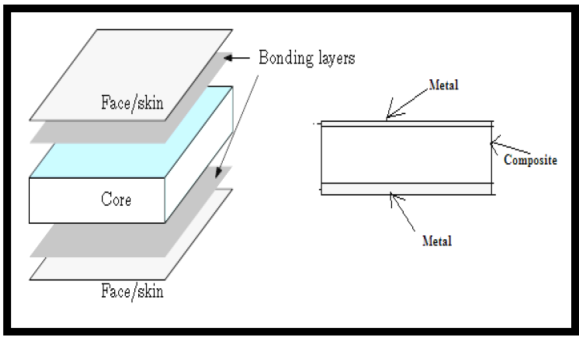


Fig. 1 Structure of a Sandwich Panel Composite [1]

Generally, the purpose of building a sandwich panel is to have lighter weight structure along with the ability to cater the compression load. The accurate combination of varying core and skin material agrees in merging the best expedient properties of each fundamental material and even remove some of their undesirable properties [2]. The material used in building a sandwich panel is normally low density, stiff and high strength. According to [3], the sandwich panels consists of a thick core with low density between two thin density of faces that made of many possible combination of materials. The usual core layer that frequently used is made of structured foams like polyurethane (PUR), polystyrene (PS) or of mineral wool (MW). Fig. 2 show types of sandwich panel.

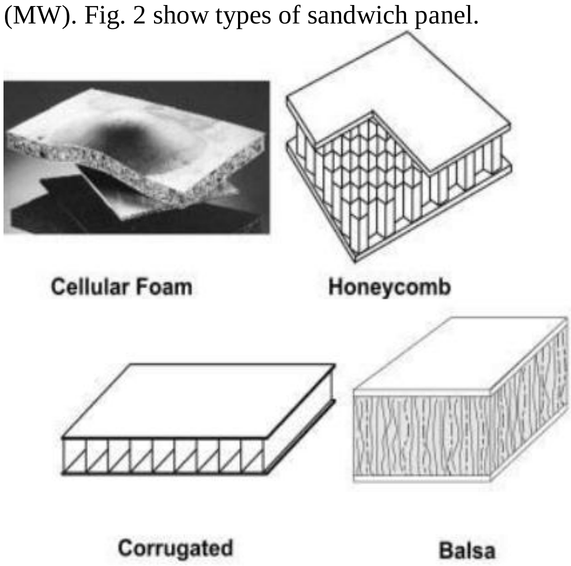


Fig. 2 Types of sandwich panel [4]

Previous researcher [5], states that the sandwich panel construction has increasingly been used in aerospace, automotive and marine industries because of their strategic function over other structural material in improved stability, better stiffness and strength to weight ratio. There are many types of the sandwich panel that can be determined by the shapes of its core arrangement.

2. Design and theories of sandwich panel

The calculations for sandwich panel must be considered the additional loads like temperature differences between external and internal metal faces or creep of the core [2]. The high load bearing capacity of sandwich panels is the effect of a rigid connection between the material of core and the skin layers. The two faces and core layers have two different functions. The faces of the sandwich panel received the bending moment and the shear forces are distributed to the core layer.

Optimization of load bearing on the sandwich panel has been made through two main assumptions. The first assumption is all the mechanical properties of sandwich panel shall be adjusted in such way that the biggest potential span can be achieved. The second theory is all the mechanical properties shall be mostly utilized. The optimizations of a sandwich panel become a complicated process when the combination of these two assumptions with some statical systems and various load cases that might possibly occurred. Based on the sandwich panel theory, the background of the optimization calculations is influenced by the calculation method for sandwich panels [2].

The design of sandwich panel enables complete structure to act as a single thick plate. Based on research done by Deshpande et al, corrugated cores tested in longitudinal direction give shear strengths which are comparable with square honeycomb and slightly greater than the results from diamond cores and other traditional foam cores. According to [4], among all the sandwich panel systems, the corrugated core sandwich is one of the most promising alternatives which plays increasingly important role in civil engineering areas especially in reducing the structure to have light weight with the ability to cater compression load or punching shear force.

The failures of sandwich panel may occur on three (3) main elements which is on the surface, core and bond. The failure at surface may be yielding and wrinkling while at core may be shear and fracture. The failure at bond is called bond failure. Fig. 3 show summary of failure at Face, Core and Bond.

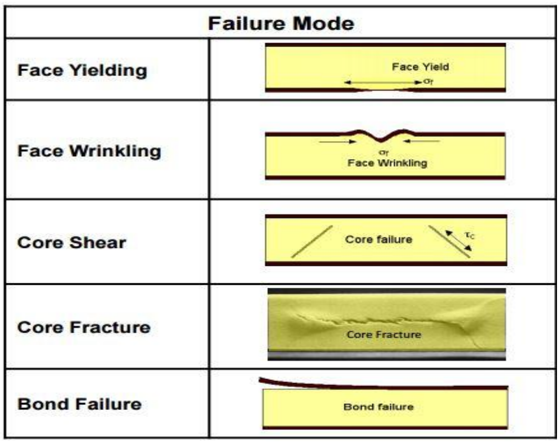


Fig.3 Summary of failure at Face, Core and Bond [5]

A sandwich panel has numerous mode of failure due to load bearing capacity [6]. Load bearing is depending on material, dimension and structural geometry of sandwich panel. Fig. 4 show the theory and mode of failure of Sandwich Panel.

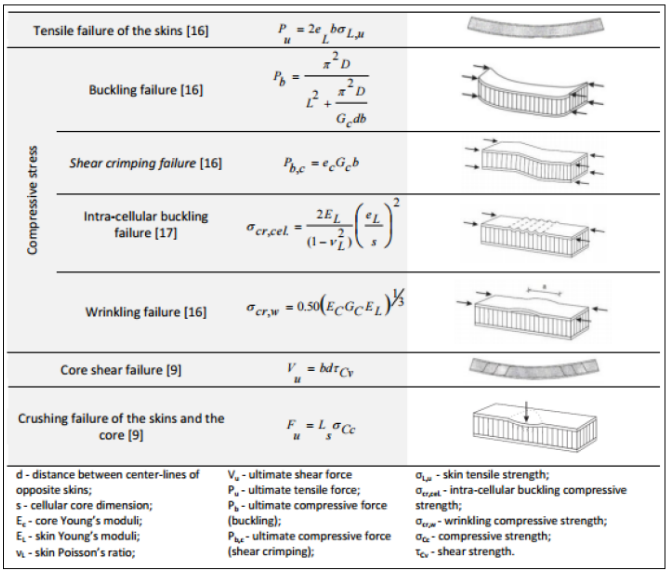


Fig 4 Mode of Failures of Sandwich Panel [6]

In this paper study on geometry strength of honeycomb sandwich panel with several types of core will be conducted.

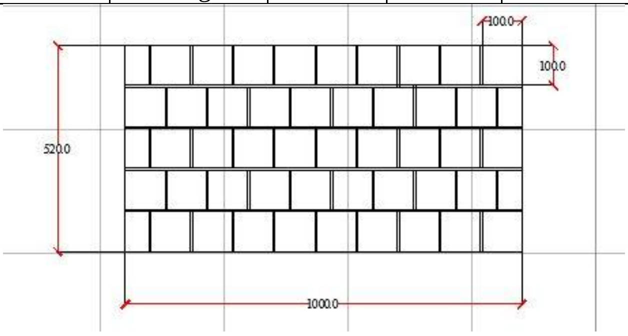
3. Experimental Model

3.1 Arrangement of core

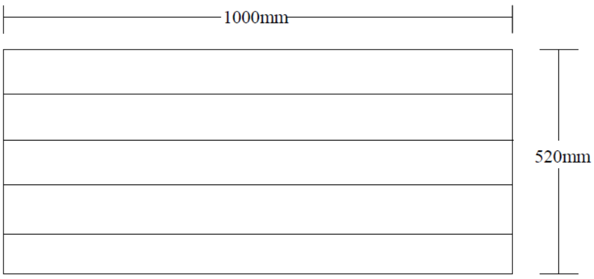
In the presence study, four samples have been fabricated which are Rectangular Core Sandwich Panel (RCSP), Horizontal Core Sandwich Panel (HCSP), Triangular Core Sandwich Panel (TCSP) and Symmetrical Core Sandwich Panel (SCSP). The dimension of all samples was 1000 x 520 x 120 mm with different types of inner core. The height of the inner core was 100mm. HCSP has the horizontal arrangement of core in between the two layers while TCSP has the triangular inner core. There are two different thickness of the plywood used to differentiate the components of the model. The thickness of the skin layer was 9mm and thickness of the core layer was 4.5mm. The skin layer was proposed to be thicker to ensure the core of the sandwich panel can be observed for any type of damage or failure without damaging the outer layer. Table 1 tabulated the details of each sample. Fig. 5 shows the dimensions (3D) of the models.

Table 1 Details of each sample

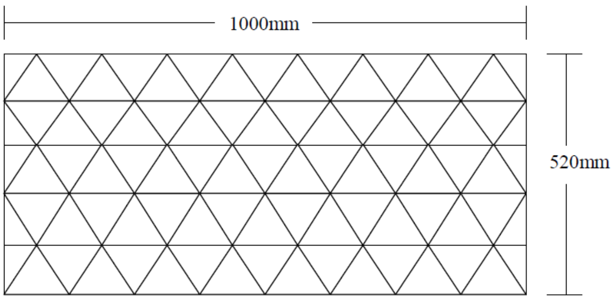
Sample	Types of Core	Length (mm)	Width (mm)	Thickness (mm)
RCSP	Rectangular	1000	550	120/100
HCSP	Horizontal	1000	550	120
TCSP	Triangle	1000	550	120
SCSP	Rectangular	1000	550	100



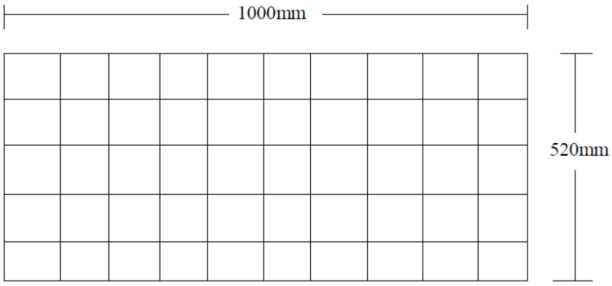
Rectangular Core Sandwich Panel (RCSP)



Horizontal Core Sandwich Panel (HCSP)



Triangular Core Sandwich Panel (TCSP)



Running Bond Sandwich Panel (RBSP)

Fig. 5 Dimensions of the models

3.2 Assembling of the samples

The procedures are continued with assembling process of the plywoods using the latex glue that is suitable for the work required to hold the panel together in forming the arrangement proposed for the study. The assembling process took 24 hours to make sure the plywood pieces are sticking to each other. Fig. 6 - Fig. 9 show the arrangement of each models after assembled.


Fig. 6 Plan view of RCSP (top), side view of RSCP (bottom)

Fig. 7 Plan view of HCSP (top), side view of HSCP (bottom)

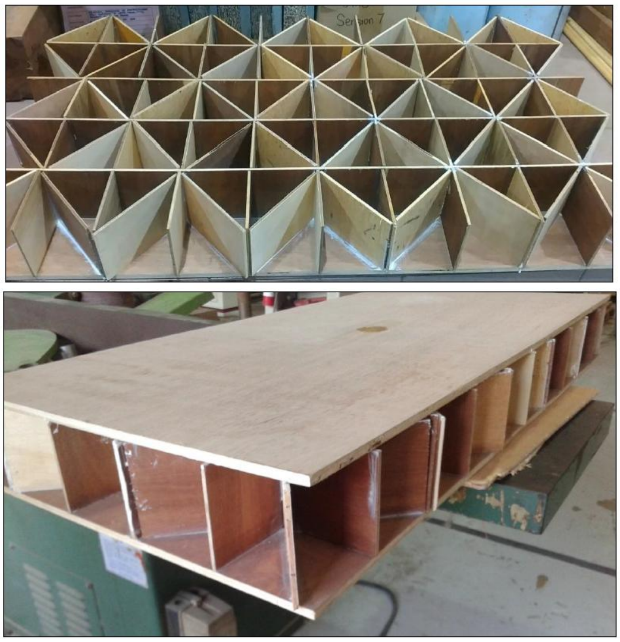


Fig. 8 Plan view of TCSP (top), side view of TSCP (bottom)

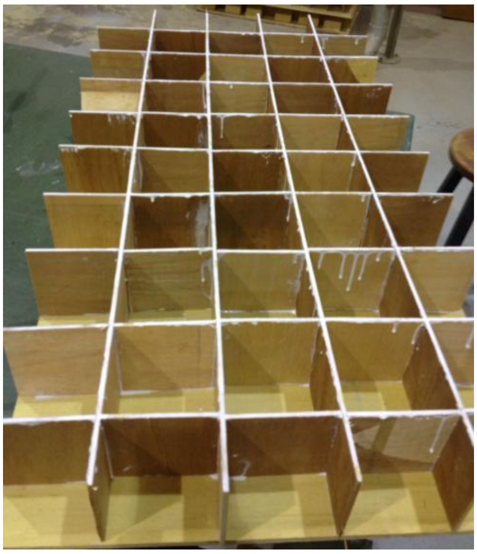


Fig. 9 Plan view of SCSP

3.3 Flexural test

The entire sample in this study has been tested under four-point bending test that follows the ASTM D7250 standards. The four-point bending test is the static flexural test which the load is applied with the distance of 300mm on the panel. Three Linear Variable Differential Transformers (LVDTs) was mounted at three locations beneath the specimen. The LVDTs are placed with the distance of 150mm from each other parallel with the load applied. LVDTs are installed during the testing to plot the load-displacement curves. The test set up as shown in Fig. 10. All the data is recorded and the analysis is done in tabulation and graphical method.

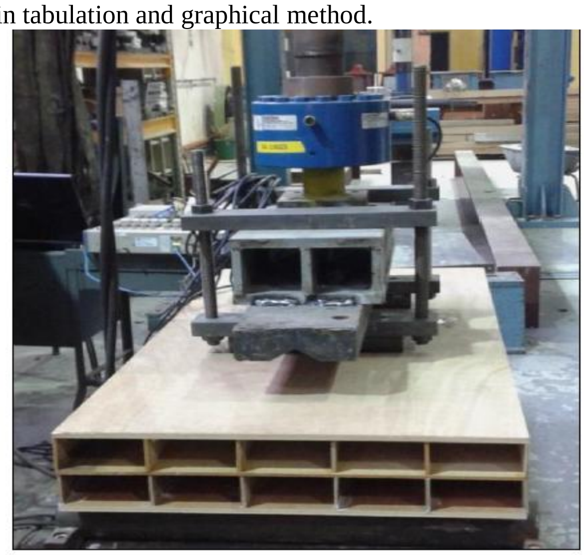


Fig 10 Flexural test arrangement

3.4 Punching shear test

The punching shear test require setup arrangement referring to 3-point bending test but with supports all along the edge of the panel to ensure the slab is not in bending test condition thus allow the load to punch through the honeycomb sandwich panel. A metal rectangular support having width of 50mm is as shown in the Fig. 11.

Fig. 11 Metal rectangular support for the honeycomb sandwich panel

The complete arrangement is to allow the load to be exerted at the middle of the sandwich panel. The Linear Variable Differential Transformers(LVDT) is also placed to record the deflection data of the sandwich panel. The setup is as in the Fig. 12.

Fig. 12 Complete setup arrangement for the punching shear test

4. Results and Discussion

The flexural performance of the three specimens was evaluated by a four-point bending test under simply supported condition to achieve the objectives of this study. From the test that had been conducted, the load-displacement behaviour of the sandwich panel can be analyzed. Fig. 13 indicates the load-displacement relationship of all samples.

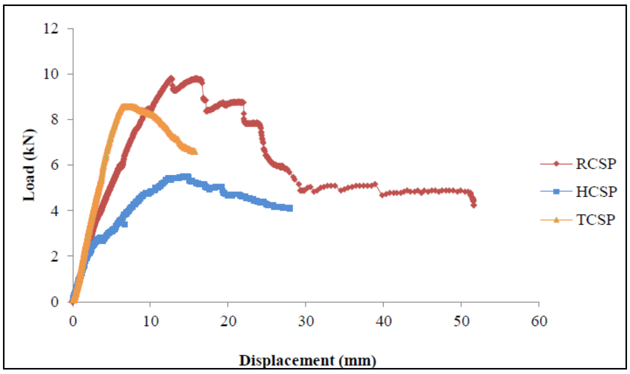


Fig. 13 Load -Displacement of sandwich panel in flexural test

From the graph, the maximum load that applied on the RCSP was 9.79 KN with the displacement at the mid span was 12.76mm. It is obviously that RCSP has the highest maximum load capacity compared to HCSP and TCSP. The curves for all samples showed a non-linear behaviour where they respond to the capacity applied until they reach the maximum load of the panel. However, the curves for each sample show a drop after their maximum point in the last stage of load carrying behaviour. The behaviour is due to the initiation of failure of the panel that was core shear cracks, core tension cracks, flexural cracking of the core and compressive failure of the top skin [7]. Summary of the flexural test results are shown in Table 2.

Table 2 Summary of Flexural test

Sample	Max. load (kN)	Strain tension (µm/m)	Strain compression (µm/m)	Displacement 1 (mm)	Displacement 2 (mm)	Displacement 3 (mm)
RCSP	9.79	113	752	12.12	12.76	9.77
HCSP	5.51	468	1190	13.11	14.31	11.88
TCSP	8.56	500	614	6.42	7.16	6.24

Fig. 14 shows the bar chart that represents the maximum load of each sample with the percentage different between the samples. From the figure, it obviously shows that RCSP has the highest maximum load compared to the other two samples. The maximum capacity of RCSP was 9.79 kN while TCSP has the least maximum load which was 5.51 kN and TCSP has the maximum load of 8.56 kN. The percentage difference between RCSP and HCSP was 43.2% which was nearly to 50% HCSP lower than the RCSP. While the maximum capacity of TCSP was 12.56% lower than RCSP. Maximum capacity of HCSP was also has 35.63% lower than TCSP. Based on the results, the rectangular inner core was the strongest to sustain the load. Practically, the number of inner core of RCSP was higher compared to the number of core of HCSP. The highest number of inner core, the strongest the sandwich can perform.

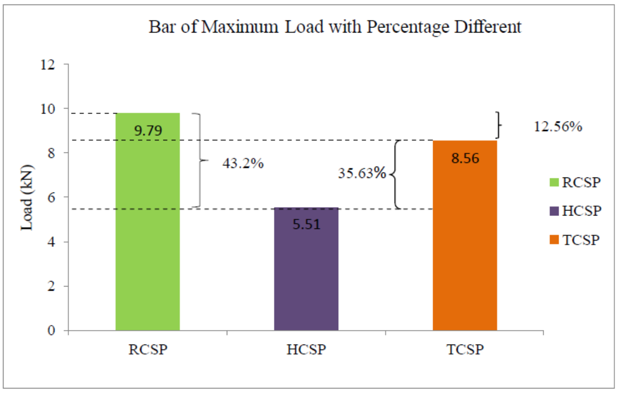


Fig. 14 Percentage different of each sample

Furthermore, Fig. 15 show the result punching shear test of samples RCSP and RBSP. The thickness for both were 100 mm. The result shows the RBSP has steeper slope compared to the SCSP. This prove that RBSP deflect less that the SCSP. The maximum load of RBSP and SCSP is 32.7 kN and 34.35 kN respectively. The curve also shows that the RBSP fails earlier than the SCSP but it can still sustain a considerable amount of loading ranging from 25 kN to 30 kN within displacement range of 20 mm to 35 mm. On the other hand, the SCSP are able to hold more load at 17 mm to 24 mm displacement and same range of load with RBSP until 30 mm only. The difference of maximum load for both sample is only 1.65%.

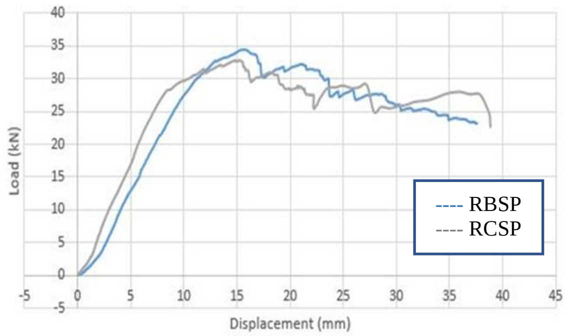
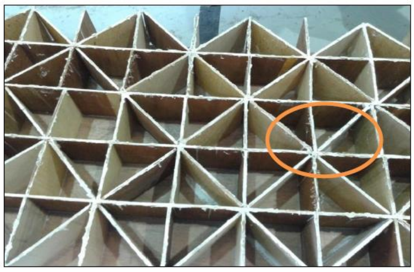


Fig. 15 Load Displacement of sandwich panel in punching shear test

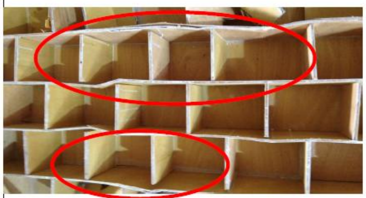
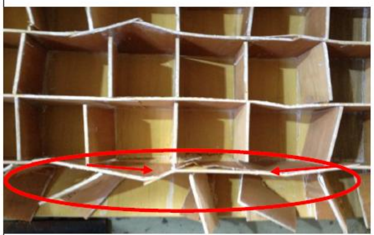
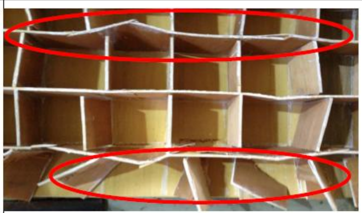
The plywood sandwich panels in this experimental study were recorded having the core shear failure. The panel bent due to the inner core fail to support the compression applied on the top skin. As a result, the samples were bending downwards. Core failures were observed in sandwich panel under four-point bending test. Primarily, the inner core carries the applied shear loading. Table 3 shows mode of failures in flexural test.

Table 3 Mode of failures in flexural test

Sample no.	Types of Failure	Figure of Sample
1	Core shear failure	
2	Core shear failure	
3	Core shear failure	

By comparing the figure above to the recorded condition of sandwich panel after the punching shear test completed, the bottom skin layer has found to be fracture while most of the core panel has core shear, general buckling and fracture. The core failure mostly occur at the longitudinal core which in between the spacing of the smaller core. At the edge of the sandwich panel, the core tend to break into two because of the high compression strength receive during the loading distribution. The core fracture also occurs at the core that is in contact with the upper skin layer which causes the edge of core to split or debonded. Additionally, some core was oriented during the tesing because of the displacement of the slab when subjected to the punching shear test. Table 4 summarizes the mode of failure for the honeycomb sandwich panel subjected to the punching shear.

Table 4 Mode of failure in punching shear test

Sample	Type of failure	Figure of sample
RCSP	Face yielding; mildly cracked along the length of the longitudinal core.	
RCSP	Core shear failure at the edge core; The core was severely crushed and split at both side of the sandwich panel.	
RCSP	Shear crimping; The longitudinal core fail in shear crimping and bond failure.	
RBSP	Face yielding; The skin layer failed severely until it can be seen through and the edge of the core has bended permanently along the longitudinal core panel.	
RBSP	Core shearing; The edge core sheared on both side of the sandwich panel.	
RBSP	Shear crimping; Longitudinal core of the sandwich panel fail in shear and fracture along with tearing.	

5. Conclusion and recommendation

The strength capacity of the structure depends on the material, dimension and structural geometry of honeycomb sandwich panel.

- From the Four-Point Bending Test, the specimens which were RCSP, HCSP and TCSP have been analysed to have core shear failure subjected bending where it has failed to sustain the bending loading from the top skin layer and initiate the panel to fail.
- The different types of inner core give the different in flexural strength of the PHSC where the rectangular core gives the higher strength to the panel compared to the sandwich panel that use horizontal and rectangle of core.

In conclusion, it is concluded that square shaped core with different arrangement pattern of RCSP and RBSP does not become a big impact in the design based on the experimental work on the punching shear test.

From the research conducted, there are some recommendations made to improve the quality of the research and get a better outcome:

- Develop at least three models for each sample to obtain the average maximum load and get the accurate results.
- Minimize the size of the core for each sample to have larger number of cores and decrease the space of the empty cell
- To enhance the de-bonding resistance of the sandwich panel, the honeycomb cell can be filled with foam.
- Reduce the manufacturing defects during the bonding process between the core cell and the face sheets to avoid the core shear failure.

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