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EFFECT OF DIVIDED CORE ON THE BENDING PERFORMANCES OF TEXTILE REINFORCED FOAM CORE SANDWICH COMPOSITES

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Abstract: *Sandwich composites are generally used in marine applications, wind turbines, space and aircraft vehicles due to their high bending rigidities in addition to their lighter weights. The objective of this study is to investigate the effect of divided foam core and interlayer sheet of glass fabric on the bending performances of sandwich composites which are manufactured with glass fabrics as the facesheets/interlayer sheets and PVC foam as the core material. Sandwich composites with single and divided core are manufactured and compared in terms of flexural behavious via three point bending tests. It is found that the bending performance is enhanced with the use of divided core and using divided core does not affect the behaviour of the sandwich composite against bending deformations. In the case of the plain core sandwich composite, dividing the core is advised for certain applications rather than perforating the core to increase the bending stiffness and strength of the textile reinforced sandwich composites because it is possible to purchase core with any thickness and there is no need for additional process such as perforation. The proposed application could enhance the bending performances without altering the weight and cost of the sandwich composites, which are preferred due to their higher bending rigidities in relation to their lighter weights.*

Key words: *sandwich composite, glass, fabric, flexural, PVC foam*

1. INTRODUCTION

Sandwich composites are manufactured by using facesheets and core material in-between the facesheets. Facesheets are expected to be rigid and stronger; textile reinforcements are popularly preferred. Core materials are expected to be lighter but thicker and with lower strength than the facesheets; foam cores are popularly preferred. Sandwich composites are generally used in marine applications, wind turbines, space and aircraft vehicles due to their high bending rigidities in addition to their lighter weights. The properties of the facesheet, stiffness and strength properties of the core and the strength of core-to-facesheet bonding determine the characteristics of the sandwich composites.

Enhancement studies on the flexural stiffness and strength of sandwich composites have been achieved with the use of z-pinned cores [1], perforated core [2], stitched foam core [3], pin reinforced foam core [4], and foam cores with different design parameters [5]. Thus studies on the improvement of such properties of the sandwich composites have been and are still being done.

In this study the effect of "dividing the core materal" and "addition of an interlayer facesheet of textile reinforcement" on the bending performances of sandwich composites composed of glass fabrics as the facesheet and foam core are investigated. With this aim; 3 point bending tests are performed, plain, perforated and divided core specimens with interlayer sheet are compared.

2. EXPERIMENTAL

2.1 Materials

The sandwich composites were manufactured using unidirectional 300 g/m^2 E - glass fabrics as the sheet material, 0.06 g/cm^3 PVC foam as the core and epoxy resin.

As the first type of specimen standard sandwich composite was manufactured as reference specimen and coded as R20 with the stacking sequence of $[+45/-45/(0/90)_2/C_{20}/(90/0)_2/-45/+45]$. For the second type of specimen (P20), core material was perforated to have holes and during vacuum infusion these holes were filled with epoxy resin, which behave as a column and these specimens have the same stacking sequence with the reference specimens. As the next two types of specimen, core material was divided for both the reference (coded as R10/10) and perforated specimen (coded as P10/10) with the aim to examine the effect of dividing the core; both types of these specimen have the stacking sequence of $[+45/-45/0/90/C_{10}/(90/0)_s/\ C_{10}/90/0/-45/+45]$. Perforated core panels were drilled (prior to composite manufacture) with areal density of 0.5 hole/cm^2 by CNC milling machine with 2.5 mm diameter holes. For single core specimens the core thickness is 20 mm and for divided core specimens the core thickness is 10 mm.

Sandwich composites were manufactured by vacuum-assisted resin infusion process as given schematically in Fig. 1. Specimens were cured initially at room temperature for 24 hours, and then all of them were post-cured at 80 ºC for 15 hours. The nominal thicknesses of all of the samples are 23 mm. The reference specimen and specimen with perforated divided core can be seen in Fig. 2.

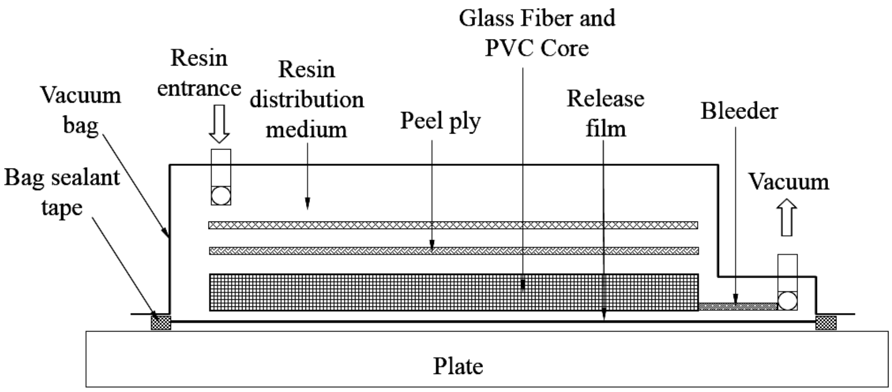


Fig.1: *Vacuum-assisted resin infusion process*

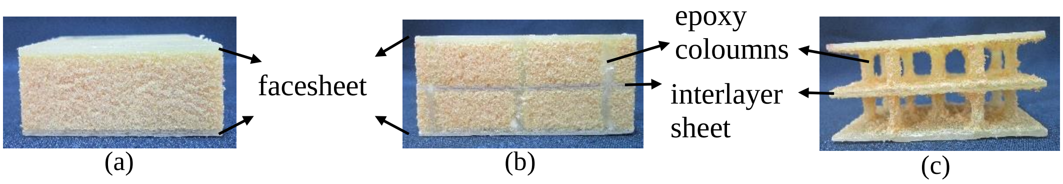


Fig. 2: *Images of the specimens (a) Reference specimen (R20) with nonperforated single core, (b) perforated specimen with divided core (P10/10), (c) columns in perforated specimen with divided core (P10/10) after the core is removed mechanically for presentation purpose*

2.2 Bending Tests

Three point bending tests were performed to determine flexural performance of the sandwich composites. The dimensions of the specimens were selected according to the recommendations of the ASTM C393/393M standard [6]. The span length, total length and width were 150 mm, 200 mm and 50 mm, respectively. The thickness of the specimen was 23 mm. Bending test apparatus (Fig. 3) was connected to Shimazdu AG-X 100kN testing machine. All of the tests were performed at constant crosshead displacement of 4 mm/min.

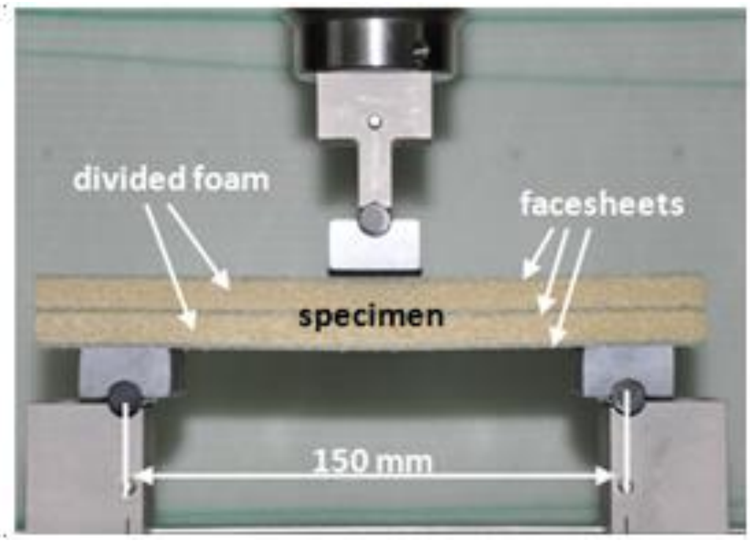


Fig. 3: *Three point bending test setup*

3. RESULTS AND DISCUSSION

Force-deflection behaviors of the specimens are given in Fig. 4; linear ascending trend between force and deflection values can be observed for all types of specimen. A distinction difference can be observed between the nonperforated and perforated specimens after the maximum force values are reached by the specimens and specimens with divided core behave similiarly with their single core counterparts.

As the nonperforated specimen R20 and its divided core counterpart R10/10 have reached its maximum, applied force is observed to descend and damage is seen after relatively higher deflection (Fig. 5a&b). In the meantime for the perforated specimens P20 and P10/10, damage can be observed right after the specimens have reached its maximum force without further deflection (Fig. 5c&d).

This difference can be explained with the damage mechanism taking place during the bending of the non-perforated specimens; specimens act as a “one-piece system” with the start of the bending but after the maximum force values the core has crushed and the top facesheet has cracked while there is no damage in the bottom facesheet of the sandwich composite. For the perforated specimens the sandwich composite also starts as a “one-piece system” and continues to maintain its integrity better than the non-perforated specimens because the applied force is transferred to the bottom sheet via the holes (filled with epoxy for perforated) in the core by acting like bonding columns between the facesheets. And as a result for all of the perforated specimens the damage is observed in only the core and no visual damage is observed in the top or bottom facesheets.

It can be clearly indicated that maximum force values of perforated specimens are significantly higher with a weight increase of 9% for undivided core and 12% for divided core sandwich specimen (Table 1) in comparison to their unperforated counterparts. Perforated specimens are found to be stiffer than the non-perforated specimen. For divided core specimens, the maximum force values and bending stiffness values are higher than their undivided core counterparts with a weight increase of 5% for nonperforated and 7% for perforated core sandwich specimen (Table 1).

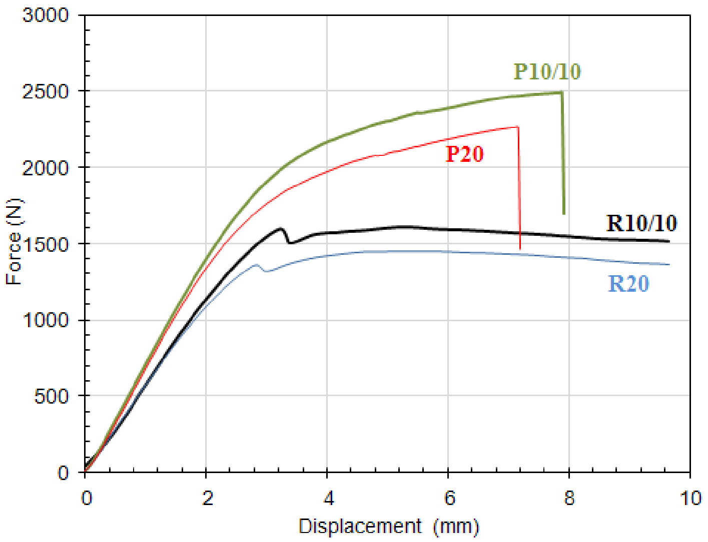
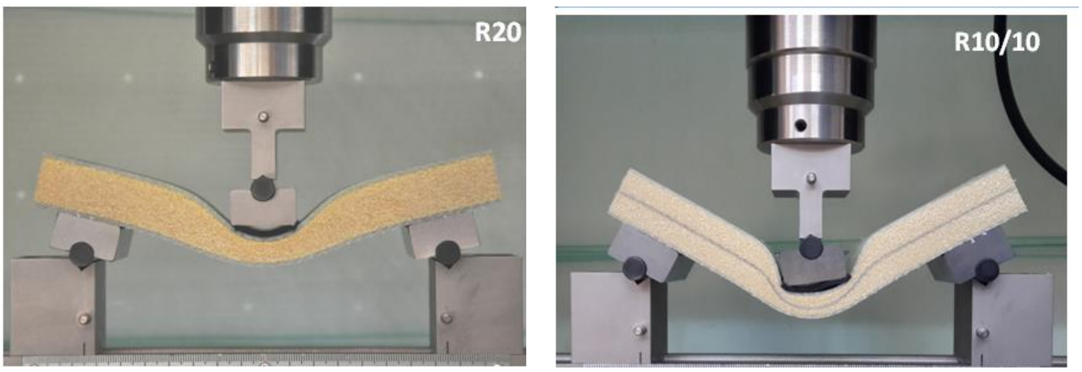


***Fig. 4**: Force-deflection behaviors of the specimens against bending*



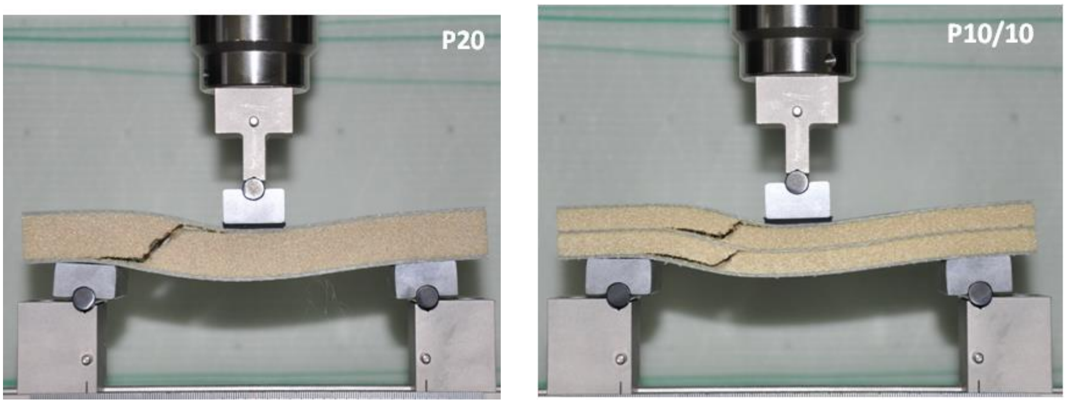


Fig. 5: *Bending failure of the specimens*

Table 1: *Sandwich composite specimens in terms of weight, bending stiffness and maximum force values*

Specimens	Bending Stiffness (N/mm)	Maximum force (N)	Weight (g/m^2)
R20	560	1359	7261
P20	699	2260	7911
R10/10	605	1591	7597
P10/10	747	2502	8481

4. CONCLUSION

The comparisons were performed between reference (R20), perforated (P20), reference divided core (R10/10) and perforated divided core (P10/10) sandwich composites in terms of three point bending performances.

It is seen that perforating the foam core highly affects the bending strength and stiffness of the sandwich composites. It can be indicated that perforation determines the damage mode in bending; causing higher stiffness. It is possible to obtain enhanced bending performance with the use of divided core and using divided core does not affect the behaviour of the sandwich composite against bending deformations.

In the case of the plain core sandwich composite, dividing the core can be advised for certain applications rather than perforating the core as it does not add on to the cost as an additional process (as perforating might) besides being less laborious (it is possible to purchase core material with any thickness) using divided core shall be preferred to increase the bending stiffness and strength of the textile reinforced sandwich composites.

As the future work, it is planned to continue investigating the shear, impact and compression after impact properties of the sandwich composites with such cores.

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