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Evaluation of Mechanical Performance and Failure Modes of Sandwich Structures for Transport Industry

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Abstract: This paper deals with an evaluation of mechanical performance of specific sandwich constructions. Composition of prepared construction was chosen with respect to area of application – transport industry. In total, three plastic core materials were selected with different density and cell shape. Materials were tested in three-point bending configuration at room and elevated temperature. Conducted research provided useful information of flexural performance and showed specific failure modes for tested sandwich structures.

Keywords: Sandwich Construction; PP Honeycomb; Foam; Pre-Impregnated Material; Bending Test.

1 Introduction

Sandwich structures are well known materials used in aerospace, transport industry and also in civil engineering. Standard sandwich material consists of two thin, stiff and strength facings that are connected to thick, light and shear resistant core. Connection of individual parts can be achieved during manufacturing process (prepreg technology, vacuum infusion, RTM or hand lay-up), or individual materials are adhesively bonded together by foil adhesive and a joint is cured in over or autoclave. As was mentioned, many manufacturing technologies can be used for production of sandwich construction, where a choice is dependent on application of final product and number of produced parts [1, 2].

Material portfolio for individual parts of sandwich construction is very wide and a selection is also dependent on part application and cost. FRP composites, aluminum or steel sheets and plywood are conventional material used for facings and foams (aluminum or polymer), honeycombs (aluminum, polymer and paper) or natural materials as cork and balsa are selected as cores in sandwich constructions [1, 3, 11].

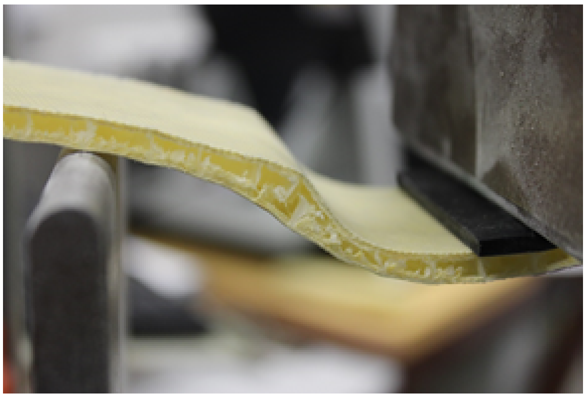
In many applications, for example in transport industry, where sandwich structures are used for outer and inner panels, bumpers and cabs, are increased demands on higher temperature stability and resistance. Moreover, materials have to satisfy requirements on fire-smoke-toxicity (FST) properties. In case of polymer core materials, mechanical properties are strongly dependent on temperature due to nonlinear and unstable behavior of these materials at elevated temperature leading in many cases to local decline of stiffness during three-point bending [4, 5]. Sandwich structures show specific failure modes during bending, namely core/facing interface debonding, indentation failure of facing due to concentrated loads and core shear failure or also wrinkling of compressed facing [9, 10]. Some failures can be minimized by increase of facing thickness [14].

Many researches have been already done on this problematic, however none of them have dealt with specific core materials used in transport industry [12]. This paper deals with experimental analysis of bending behavior at room and elevated temperature of sandwich constructions composed of specific materials used in rails and busses. Moreover, specific failure modes for tested structures caused by bending are noted.

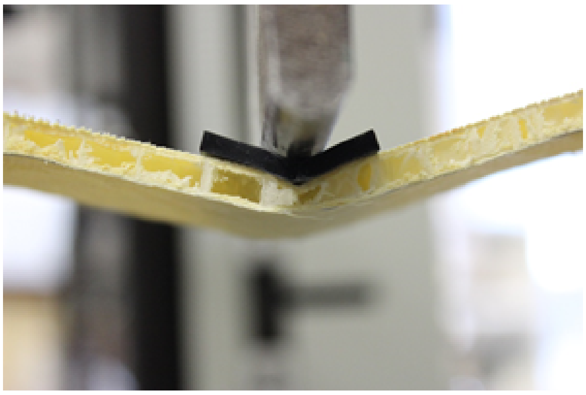
2 Experimental Analysis

Flexural properties were examined by three-point bending test at universal testing machine ZWICK 1456, where measurements at elevated temperature were conducted in temperature chamber. Value of elevated temperature was chosen according to requirements in transport industry. Totally, three types of core material in different thickness were used in presented research. These core materials differ in density, type and plastic material. Specifically, PET, PVC foam cores and PP honeycomb were chosen with thickness of 5 and 10 mm. E-glass prepreg impregnated by phenol resin was chosen as facing panel in two layers for each side of sandwich construction.

Sandwich constructions with foam core of lower thickness have higher values of flexural parameters, however deformations are much greater. During three-point bending, individual sandwich constructions exhibit different failure modes due to their inner structure, density and cell size. Following figure (Fig. 1) shows specific failures for structures with PP-honeycomb core. As can be seen, local failure of facing and compression of core (skin wrinkling) and core shear failure followed by interface delamination mainly occurred for all structures with this cores).



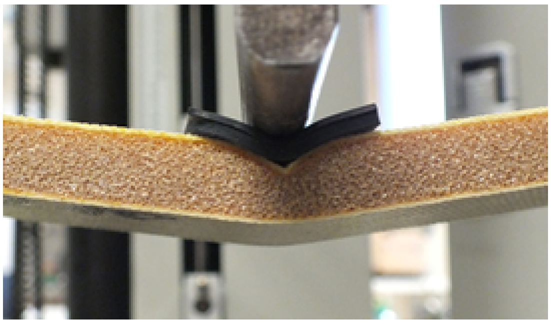
(a) shear deformation of PP-honeycomb core



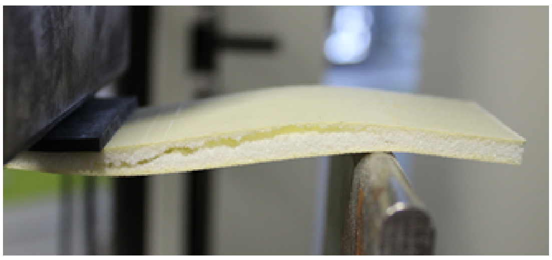
(b) local deformation of PP-honeycomb core

Fig. 1: Failures modes of PP-honeycomb core sandwich constructions in bending.

Sandwich structure with core of the lowest density (PVC core) failed only by skin wrinkling in all case of core thickness and layers (Fig. 2a). This was probably caused low compression resistance of core in combination with small thickness of facings. Similar behavior was reported for PET core. Only in case of core thickness of 5 mm, long shear failure from lower to upper facings was observed (Fig. 2b).



(a) skin wrinkling of thicker PVC core



(b) shear failure of 5 mm PET core

Fig. 2: Failures modes of foam core sandwich constructions in bending.

Bars in graph (Fig. 3) depict mean values of bending strength at two environmental temperatures with respect to core inside the sandwich construction. The highest values of parameter are shown for construction with PET core. However these materials exhibits deeper decline of strength at elevated temperature compared to ones with PVC core. Bending strength for structures with PET core of 10 mm thickness is only by 5.5 % higher compared to second foam core. Properties of PP honeycomb constructions are the most affected by temperature.

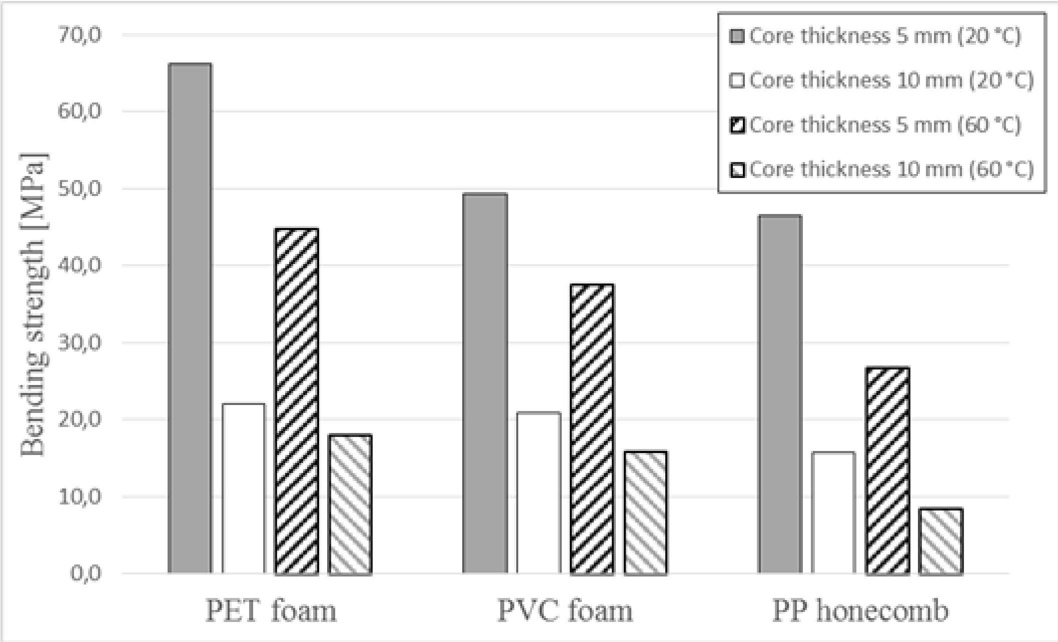


Fig. 3: Comparison of individual structures based on their core.

3 Conclusion

Flexural properties of plastic core sandwich constructions at room and elevated temperature have been experimentally examined. Obtained results showed that both modulus and strength of constructions with thinner cores are more effected (declined) by elevated temperature compared to thicker cores. Furthermore, plastic honeycombs still cannot achieve properties of foams in sandwich constructions. Decrease of their properties at elevated temperature is even more apparent. On the other hand, foam cores in sandwich structures are able to preserve about 70 % of their room temperature modulus and strength values.

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