ECOFRIENDLY SANDWICH PANELS USING RECYCLABLE/BIODEGRADABLE MATERIALS

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Introduction

Hollow core sandwich panels find broad applications in weight sensitive areas. Most of the conventional hollow core sandwich panels consist of metallic, paper or polymeric core with polymeric or fibre reinforced faceplates, but due the high cost involved in manufacturing, the application has been somewhat limited to high end products such as in aerospace industries. To overcome this, researchers have used low-cost thermoplastic materials to produce cores for sandwich panels and in the recent years patents [1,2] on such manufacturing processes have been filed. Though they are cost effective and recyclable, their performance as structural members is somewhat questionable. Hence, with the idea of improving the structural properties of polymeric honeycombs while retaining their functional properties, hollow cores with their cell walls reinforced with short natural fibres, have been manufactured in this study and have been shown to possess superior properties. Examples are also given on the use of commercially available veneers as novel sandwich materials, Fig. 1.

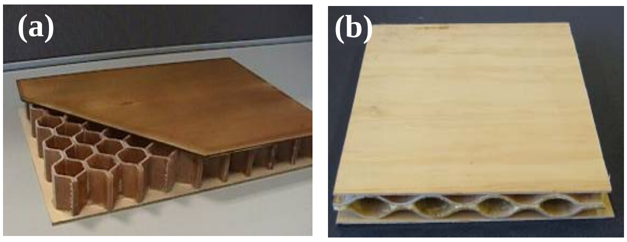

Fig.1 Hollow core panels (a) Woodfibre-PP core (b) Double corrugation wood veneer core

Experimental Details

Manufacturing and structural testing

The components (fibres, talc and polypropylene) were dry blended and then extruded in a TC35 Cincinnati Milacron extruder through a die of rectangular cross-section. The sheets were calendered to obtain thin (1.5mm) continuous rolls of wood or sisal fibre-PP composites. As the manufacturing of composites through a continuous extrusion process is influenced by many factors, a full factorial design of experiments based on Taguchi method was used to select the best manufacturing parameters, and the details of the analysis can be found elsewhere [3]. The reinforced composites exhibited and increase of >10% increase in tensile strength, >15% increase in impact strength and >100% increase in tensile modulus compared to those of the base polymer. Following the analysis, the composites were mechanically pelletised and reprocessed to check for any change in properties. As the recycled composites exhibited only marginal changes, the recycled sheets were thermoformed into half hexagonal and sinusoidal profiles after their formability and manufacturing window were experimentally determined, using vee-bending tests and differential scanning calorimetry technique, respectively. The corrugated sheets were cut to required heights and ultrasonically bonded to form hollow cores. Wood veneers were used as facings and the compressive and flexural properties were experimentally determined. The results reveal an increase (100% - 200%) in specific compressive and shear properties, with the reinforcement.

Very good mechanical performance could also be obtained with 3-ply (0/90/0 w.r.t. grain direction) Radiata Pine wood veneer hollow cores (single/double corrugations or honeycomb) because of the lower overall densities of the sandwich panels. In fact, it is possible to optimise the core geometry, depending on the material (composites or veneer) and the core pattern [4]. The results establish viability of the manufacturing process and its applicability to different materials, thus reducing the required tooling costs. To examine the possibility of continuous or semi-continuous manufacturing of this

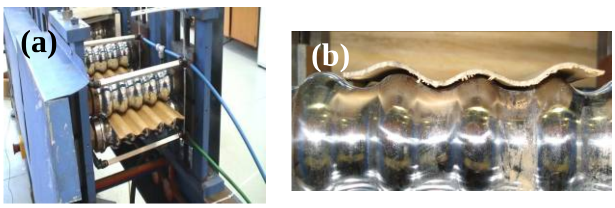

Fig.2 Continuous rollforming of corrugations (a) Woodfibre-PP (b) Wood veneer

kind of hollow cores and hence the possibility of automation, roll forming technique was also tried successfully. Composite sheets from continuous rolls or lengths of multiple-ply veneers were fed into a modified roll former to obtain the desired profiles, Fig. 2, which were then used to manufacture the sandwich panels.

Functional property evaluation

In certain cases the honeycomb cores may not be used in structural members only, but in addition, may require good functional properties. Hence, in the view of examining some functional properties while maintaining a panel's structural integrity, the acoustic performance, vibration damping and energy absorption aspects of the woodfibre-PP sandwich panels were determined. The hollow core panels were tested in a Brüel & Kjaer standing wave apparatus to determine the sound absorption coefficients. The measurements were taken at 1/3 Octave from 200Hz - 4kHz. The tests were conducted on hollow cores, polyurethane foam filled cores and medium density wood fibre filled cores, Fig.3, with the sound wave incident on the core (in-plane) and on the faceplate (out-of-plane). It was observed that the panels were good sound absorbers at mid and high frequencies, when the sound waves were incident on the woodfibre filled cores (out-of-plane but without facings) and at 1-1.25kHz for the sound waves incident out-of-plane (with facings), thus making them applicable as resonant panels.

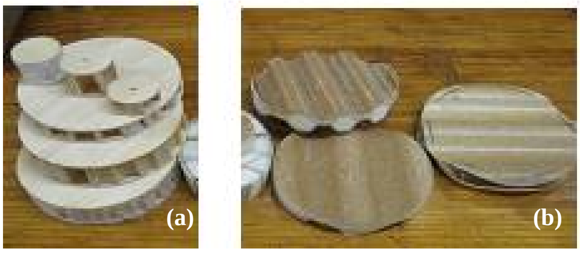

Fig.3 Sandwich panel specimens for impedance tube test (a) Out-of-plane scheme (b) In-plane scheme

As most engineering materials and structures experience vibrations to some degree, their design requires the consideration of their vibrational characteristics. At each one of the natural frequencies a deformation pattern, resulting when the excitation coincides with one of the natural frequencies of the system, may exist and are referred to as the mode shapes. When the system is forced to vibrate, there is a possibility of resonance which may result in failure of the structure. Hence in the view of designing the panels against failing catastrophically, natural frequencies of the panels have been determined between 0-800Hz and the structural damping coefficient has been calculated at the first mode using single degree of freedom method. It was observed that the first natural frequency of the un-reinforced and reinforced core appear at similar frequencies (50-55Hz) but the second natural frequency of the reinforced core appeared to have shifted from 269Hz to 294Hz. The damping coefficient (calculated at the first natural frequency) of the reinforced core was 0.07 as compared to un-reinforced core (0.02). The energy absorption capability of the cores and hence the panels were experimentally determined by subjecting the panels to quasi-static compressive loads. The total energy absorbed was calculated as the area under the stress-strain curve. The results revealed that the reinforced cores could absorb >100% more energy compared to its un-reinforced counterpart.

Conclusions

Ecofriendly sandwich panels comprising of natural fibre-PP and wood veneer cores with wood veneer facings have been successfully produced. Both matched-die and roll forming processes can be used to manufacture the core materials, either in corrugated or in honeycomb form. The short fibre reinforcement of the cell walls not only enhances the structural properties but also improves the functional properties of the panels. Woodfibre filled honeycomb core panels exhibit absorption coefficients of ~0.9 at mid and high frequencies (1-4.0kHz); however, the panels could be designed with different core configurations to have efficient sound absorption at required frequencies. The vibration experiments also reveal that the reinforced cores are highly damped and a natural frequency shift could be achieved. Double-corrugation veneer panels also show core shear strengths to increase although the compressive strength might slightly decrease, which can be overcome by using foam filling. One big advantage of these cores is that the properties could be manipulated by selecting the right geometry and grain direction. The high energy absorption ability displayed by the panels make them suitable for packaging and automobile/aircraft interior panelling.

Acknowledgements

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