ABSTRACT

Many researchers are striving to implement lightweight materials in their applications to achieve energy savings. Composite sandwiches are becoming more and more popular in structural and non-structural applications, mainly due to their lightweight and uncompromising performance. Most of the composite sandwich structures nowadays are made of non-renewable resources, which need extensive amounts of energy for production generating excessive amounts of carbon dioxide which impacts the environment. End life disposal is also a hindrance due to their non-biodegradable nature. These aspects have led the material experts to explore the possibilities of using natural materials as constituents in composite sandwiches which has benefits in terms of natural availability, biodegradability, and cost. Hence, a green composite sandwich might be the material of the future which will satisfy both the performance and environmental concerns.

The objective of this research work is to investigate mechanical, thermal, sound absorption, vibration damping and biodegradable behaviour of the newly developed green composite sandwich made of flax and agglomerated cork. In this work, flax fibre in woven form is used as skin reinforcement and agglomerated cork with three different densities (240, 280, & 340 kg/m^3) is used as a core in the green composite sandwich. Along with this, glass and flax/glass skin reinforced composite sandwiches are also manufactured for comparison purpose. The composite sandwiches are manufactured by vacuum bag moulding due to their benefit of getting higher volume fraction of fibre, and improved adhesion between layers compared to hand lay-up method.

In order to understand the mechanical behaviour of composite sandwich, flatwise tensile test, flatwise compressive test, edgewise compressive test, flexural test and drop weight impact test were carried out as per the ASTM standards and the strength of each sample was recorded. The test results revealed that the flax fibre reinforced composite sandwich (FEC) with core density 340 kg/m^3 has higher specific flatwise tensile strength, specific flatwise compressive strength, and specific flexural strength than glass fibre reinforced composite sandwich (GEC) with core density 340 kg/m^3. But in the edgewise compressive test and drop weight impact test, FEC has a slight decrease in the specific edgewise compressive strength and perforation energy. Effect of water absorption on the mechanical properties was also determined by exposing the samples in a humid environment. The presence of moisture content in the samples decreases the specific flexural strength of FEC by 27-42 % in contrast to a mild impact in GEC by 14-33 % due to the existence of natural fibre in the FEC.

A detailed experimental procedure was adopted to find out the thermal conductivity, thermal expansion, flammability, and thermal stability of composite sandwiches and the results revealed that the FEC with cork core density of 240 kg/m^3 has the lowest thermal conductivity of 0.03 W/mK. In contrast, FEC having a cork core density of 340 kg/m^3, has 19 % higher thermal conductivity, and GEC has nearly 50 % higher thermal conductivity. The lowest thermal expansion of 29.2×10^{-5} /°C has been obtained for GEC having cork core density of 340 kg/m^3. The thermal expansion of FEC does not vary much and is in the range of 4-11 % higher than that of GEC. In the flammability test, FEC with a cork core density of 340 kg/m^3 takes more time to ignite (12 s) when compared to GEC of the same core density (4-8 s). The propagation rate is also minimum for FEC having a cork core density of 340 kg/m^3. FEC having a cork core density of 340 kg/m^3 has got better flame resistance property than its counterparts. The degradation temperature of the glass/epoxy skin and flax/epoxy skin also not vary much and cork core with a density of 240 kg/m^3 has better thermal stability than the other two densities of cork core.

Sound absorption and vibration suppression are also to be considered while designing the automobile and construction applications in which composite sandwiches are used. In this work, sound absorption coefficient (α) was found by using impedance tube test, while the vibration-damping ratio was determined by using the cantilever beam free vibration test. The results revealed that FEC with core density 240 kg/m^3 has maximum α of 0.53 among all samples because of the multiscale and cellular structure of the fibre and core materials respectively, which is 96 % higher than GEC of same core density. It also shows that FEC with core density 240 kg/m^3 has higher damping ratio of 0.049 among all samples due to higher friction in the cell wall, friction in the yarn and fibre, cellular structure of the cork and intergranular friction in the cork, which is 32 % higher than GEC with core density 240 kg/m^3.

Exploring the biodegradability of composite sandwiches was performed by soil burial test and verified by using Scanning Electron Microscope (SEM) and Fourier Transform Infrared Spectroscopy (FTIR) analyses. The results conclude that the percentage of weight loss in all the samples increase with burial time. The results depict that the FEC with cork core density 340 kg/m^3 has a weight loss of 11.46 %, whereas GEC with cork core density 340 kg/m^3 has about 6.31 % after 100 days of soil burial. This shows FEC sample has 82 % higher degradation than GEC sample. SEM images add to the evidence that the flax fibre and cork core have lost its fibrous structure and cell wall texture in FEC samples. But in the GEC samples, only cork core has lost its structure and glass fibre still intact. FTIR clearly indicates the changes in the peak intensity attributed to the alkane C-H stretching vibration and carbonyl (C=O) stretching vibration in FEC, which shows degradation. But in GFEC and GEC, a change in intensity of OH stretching vibrations were observed, which is insignificant.

This study recommends that, the green composite sandwich could be an environmentally friendly alternative for automobile and construction applications, where mechanical as well as secondary characteristics like thermal, sound absorption, vibration damping and biodegradability are essential.