Experimental Investigation on the Mechanical Behaviour of Natural Fibre Sandwich Panels with Posidonia Core

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Abstract. In this work, the mechanical behaviour of natural composite fibre sandwich panels is experimentally investigated. The composite sandwich panels are composed of a natural core made of Posidonia dried leaves reinforced with aluminium skins. The introduced material system is characterized by good structural behaviour (due to the aluminium skins) combined with the good thermal and acoustical insulation provided by the Posidonia core.

Flexural and impact tests, characterized by different impact energies, have been performed on specimens with and without the aluminium skins, to preliminary assess the influence of the Posidonia core densities on the natural fibre sandwich mechanical behaviour.

Introduction

The continuous demanding requirements on the reduction of the weight, the cost, and the environmental impact of the materials used in the plastic industry are driving the attention on alternatives to glass and carbon fibres in fibre reinforced plastic (FRP) materials. Indeed, natural fibres have been found to be an interesting alternative, being able to satisfy almost all the aforementioned requirements [1,2].

Among the others, one of the most interesting application of natural fibre composites is related to the manufacturing of sandwich panels with an improvement in terms of weight saving as well as in mechanical properties and functional capabilities, such as vibration control, heat and energy dissipations [3,4]. Posidonia leaves, in particular, are characterized by excellent thermal and acoustical insulation capability, due to their high porosity. Moreover, being composed of a high content of silicon, they have an excellent self-extinguishing behaviour and excellent fireproof properties [5,6].

In this work, the mechanical behaviour of sandwich panels, composed of a natural core made of Posidonia dried leaves reinforced with aluminium skins, is experimentally investigated. A three-point bending test has been performed to preliminary assess the mechanical behaviour of the core by considering different Posidonia densities. Then, the dynamic behaviour of the sandwich panels is investigated by means of low velocity impact tests.

Three-Point Bending Test

The aim of the three-point bending test is to determine the influence of the Posidonia core density on the mechanical behaviour of the natural fibre composite. Therefore, three different fibre densities have been considered: Low Density (LD), Medium Density (MD), and High Density (HD). To
better appreciate the differences between the analysed specimens, Figure 1 reports the sections of the Low, Medium, and High Density specimens. The experimental set-up is shown in Figure 1 as well.

![Experimental set-up](image)

**Figure 1:** a) Experimental set-up; b) Low Density (LD), Medium Density (MD) and High Density (HD) specimens

The experimental test has been performed according to the ASTM D 790. The results of the three-point bending test are shown in Figure 2, in terms of load as a function of the applied flexural displacement.

![Load vs Displacement](image)

**Figure 2:** Three-point bending test results: Low, Medium, and High Density core – Load vs applied displacement; Failure loads.

According to Figure 2, the core density strongly influences the mechanical response of the natural fibre panel, in terms of stiffness and maximum attained load. In particular, the configuration characterized by the lowest density core is able to reach a failure load equal to 5.6 N. Increasing the
core density makes the core more compact thus increasing the flexural response. Indeed, the failure loads of MD and HD configurations have been found equal to 15.36 N and 48.26 N, respectively.

Impact Test

In this section, the results of the experimental impact tests are reported. Following the results of the Three-Point Bending test, only the Medium and High Density core have been selected in this stage. Moreover, for each core density, two configurations have been analysed: unskinned specimens (Posidonia core only), and skinned specimens (Posidonia core reinforced with aluminium skins). Hence, the analysed configurations are unskinned medium density core (MD-C), skinned medium density core (MD-S), unskinned high density core (HD-C), and skinned high density core (HD-S). The impact test has been performed according to the ASTM D 7136/D 7136M-7. Figure 3 reports the results of the HD-C specimens subjected to 1 J and 2 J impacts.

High Density – No skin – 1 J and 2 J impacts

Figure 3: 1 J and 2 J impact test results: unskinned high density specimens – Energy, Force, Displacement, and Velocity as a function of the Time.

According to the results shown in Figure 3, the unskinned high density core configurations are not able to sustain a 2 J impact, since penetration has occurred. Hence, in the subsequent analyses, only 1 J impacts have been considered.

In the following Figures 4-7, the results of the 1 J impacts are reported. In particular, Figure 4 compares the results of the skinned and unskinned high density specimens. In Figure 5, the skinned medium and high densities configurations are reported, while the results of the skinned and unskinned medium density core specimens are shown in Figure 6. Finally, Figure 7 compares the experimental results of the unskinned medium and high density core configurations.
High Density – No skin and with skin – 1 J impact

Figure 4: 1 J impact test results: skinned and unskinned high density specimens – Energy, Force, Displacement, and Velocity as a function of the Time.

Medium and High Densities – With skin – 1 J impact

Figure 5: 1 J impact test results: skinned medium and high densities specimens – Energy, Force, Displacement, and Velocity as a function of the Time.
Medium Density – No skin and with skin – 1 J impact

Figure 6: 1 J impact test results: unskinned medium and medium densities specimens – Energy, Force, Displacement, and Velocity as a function of the Time.

Medium and High Densities – No skin – 1 J impact

Figure 7: 1 J impact test results: unskinned medium and high densities specimens – Energy, Force, Displacement, and Velocity as a function of the Time.
Indeed, Figure 4 (HD-C vs HD-S) demonstrates that the skinned specimens experienced an increase of the peak force compared to the unskinned ones. Moreover, a full penetration has been observed in two of the three unskinned specimens.

According to Figure 5 (MD-S vs HD-S), an increase of the peak force of the skinned specimen with higher density can be appreciated. Moreover, the impact duration of the skinned medium density specimens increases. Hence, the medium density specimens seem to be more suitable for energy absorption applications.

Figure 6 (MD-C vs MD-S) shows an increase in peak force for skinned specimen. Moreover, a full penetration has been observed in the specimens without skins. The lower density specimen without skin are not able to sustain the impact without penetration.

Finally, according to Figure 7 (MD-C vs HD-C), the peak force for specimen with medium density core increases. However, a full penetration has been observed in all the specimens. The higher density specimen without skin seems to be more suitable to energy absorption application with respect to medium specimen without skin.

As a result of this preliminary impact experimental campaign, the tested configurations have been found very weak to impact. Further improvements in the manufacturing process are needed in order to reach an acceptable level of impact resistance even with protecting skins.

Conclusions

In this work, the mechanical behaviour of natural fibre sandwich panels with a Posidonia dried leaves core has been experimentally investigated. The mechanical behaviour of the core, as a function of Posidonia density, has been preliminary assessed by means of three-point bending tests. Then, impact tests have been performed on skinned and unskinned configurations with different core densities, to assess the dynamic response of the natural fibre sandwich panels. According to the presented results, the investigated unskinned specimens are not able to sustain low velocity impacts, since penetration has occurred in all the unskinned specimens. On the other side, a limited energy absorption can be observed in the skinned specimens with a medium density core. Indeed, the Posidonia leaves sandwich panels are not suitable to replace the traditional carbon and glass fibres in FRP materials as primary structures. However, the good thermal and acoustical insulation capabilities, combined with the good energy absorption capability when combined with aluminium skins, make them particularly suitable in the field of the secondary structures, as internal fire-resistant panels and overhead luggage compartments. Further improvements in the manufacturing process are needed in order to reach an acceptable level of impact resistance even with protecting skins.

References