Marine: a new experimental ground for green composites

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Bio-sourced sandwich materials for marine applications

This paper describes a series of investigations specifically designed to evaluate commercially-available bio-sourced sandwich materials combining thermoset-based resin matrices, natural fibres and cork cores, intended for marine structures. The aim was, first, to evaluate the properties of these materials with respect to currently-used marine composites in order to examine equivalent dimensions for different boat structures, and then to assess a number of aspects affecting durability such as wet ageing and impact damage. Examples of structures are given.

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There is currently considerable interest in biocomposite materials, which can offer an environmentally-attractive alternative to traditional composites [1]. Kaïros, an SME set up in 2007 and headed by skipper Roland Jourdain and Sophie Vercelletto, not only manages sailing activities but also works on the development of biomaterials for nautical applications.

Since 2009, Kairos and Ifremer have been collaborating to characterize commercially-available bio-sourced

Fig. 1: Flax fibres tested in mat, woven and unidirectional reinforcement forms

polymers, composites and sandwich cores, performing ten test campaigns since then. They decided to focus on thermoset resins, even though most of these are still only available as partially bio-sourced resins and cannot be recycled, but are easily processed by infusion. Other groups in Brittany are concentrating on fully bio-sourced thermoplastics such as PLA, and developments in this area were described in a recent JEC Composites Magazine article [2].

The reinforcements tested include flax, hemp, jute and cellulose from various suppliers, in unidirectional, woven and mat forms. Cork was also studied in detail as a bio-sandwich core. In all these tests, particular attention was paid to the comparison with traditional boat-building materials, so glass-reinforced polyester and epoxy specimens produced using similar manufacturing methods were tested systematically along with the bio-composites. All the samples were produced in the Kaïros workshops. Early tests revealed considerable variability and poor properties but more recent campaigns have shown that the quality of reinforcements has improved as suppliers adapt their manufacturing methods to these natural fibres. New resins have also become available and have been integrated in the test programme.

The first results with bio-composites show that more material is usually needed to achieve equivalent stiffness and strength to traditional marine laminates, although this can be compensated by their lower density. When a cork core is added to produce a bio-sandwich, the resin tends to infiltrate the core, making resin selection a critical step. For example, two core sandwich materials with the same flax fibre reinforcements and cork cores but different matrix resins, produced using the same infusion technique, showed a 15% difference in overall weight.

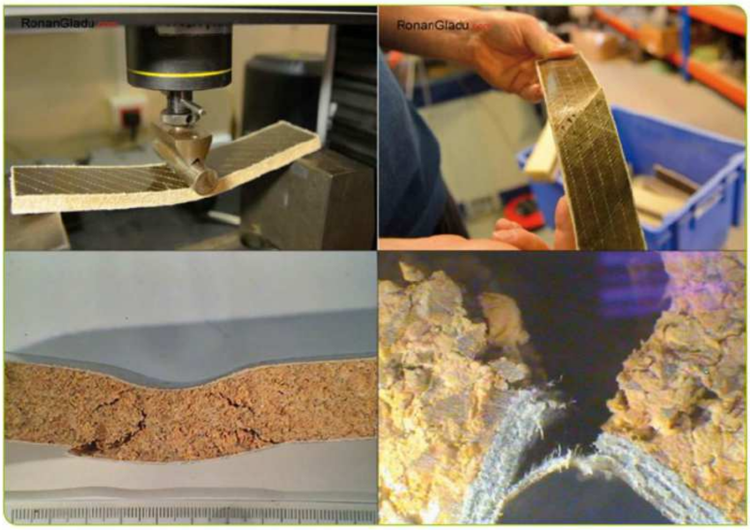

Fig. 2: Evaluation of bio-sandwich materials by extensive testing – here, flax fibre-reinforced facings on cork cores, showing different failure mechanisms (Photos: R. Gladu)

Durability

The behaviour of bio-composites in marine environments also needs to be characterized, and already published studies [3] have highlighted the sensitivity of natural fibres to water. Water diffusion is controlled by the matrix resin, and the use of partially bio-sourced epoxy resins offers a number of benefits as these resins are not very sensitive to water and can protect the fibres.

The figure below shows the results of tensile tests performed on traditional glass/epoxy and cellulose-reinforced epoxy composites after various ageing periods of up to 18 months fully-immersed in natural sea water at 40°C. This is a very severe test since the higher temperature accelerates degradation while the immersion of tensile test specimens with unprotected edges and no gel-coat results in much faster water ingress than in a real boat structure. The two composites had the same weight content of reinforcement fibres and were infused with the same resin. After ageing, break load decreases in a similar way for both materials but their stiffness, although initially similar, drops more rapidly for the cellulose composites, with an increase in failure strain.

A second important aspect of the long-term behaviour of these materials is their damage tolerance. Few data are available to make compari-

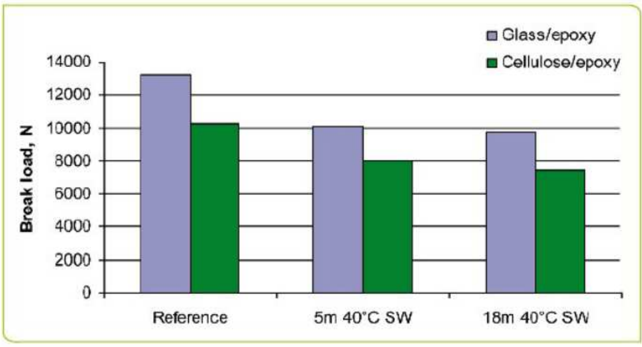

Fig. 3: Seawater ageing, 0/90° infused composites

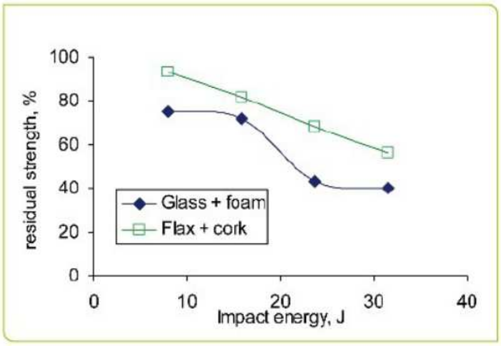

Fig. 4: Residual flexural strength after impact

sons, so a series of tests was performed. Drop weight impact tests were performed at increasing energy levels to compare the damage introduced in traditional sandwich materials made of glass/epoxy facings and a foam core with that produced in a bio-composite sandwich with a flax fibre-reinforced cork core. In the example below, residual flexural strength after impact is compared for two such materials. The impacted face was placed on the lower (tensile) side of the sample for residual strength tests.

In this particular example, where the criterion was the replacement of a foam core panel with a cork and flax alternative with similar overall thickness and static properties, the resulting solution behaved at least as well as the original panel under impact, but with a weight penalty. Such comparisons provide a first indication of the potential of these materials but further investigation is required to optimise the durability of bio-sourced solutions.

Fig. 6: The Glaz surf board (Photo R. Gladu)

Larger structures

Some larger structures were manufactured by Kaïros to determine how these materials can be transformed (see figures 5 & 6).

Future work

Kaïros is involved in various projects in order to take these laboratory studies forward and integrate bio-composites in commercial boat structures. For example, a day-boat prototype will integrate flax fibres, cork and bio-based resin as the main sandwich for the hull. The challenges are not just in the materials but also in the process adaptation, as boat-builders like the infusion process, and in removing psychological barriers such as the reluctance to use natural fibre reinforcements in marine applications. ■

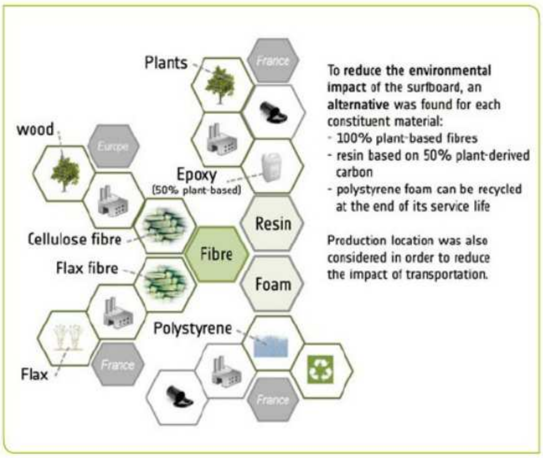

Fig. 5: The Glaz surf board

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References

1. CELC/JEC Technical book: Flax and hemp fibres: a natural solution for the composite industry, (2012)
2. Bourcois, D., Baley C. et al: Environmentally friendly composites for marine applications: The NAVECOMAT project, JEC Magazine No 67, August-September (2011), p.35
3. Le Duigou A., Davies P., Baley C.: Seawater aging of flax/PLLA biocomposites, Polymer Degradation and Stability, 94, 1151-62 (2009)