Accepted Manuscript

Mechanical and impact characterization of hybrid composite laminates with carbon, basalt and flax fibres

E. Nisini, C. Santulli, A. Liverani

PII: S1359-8368(16)31089-7

DOI: [10.1016/j.compositesb.2016.06.071](http://dx.doi.org/10.1016/j.compositesb.2016.06.071)

Reference: JCOMB 4418

To appear in: *Composites Part B*

Received Date: 26 January 2016

Revised Date: 13 May 2016

Accepted Date: 20 June 2016

Please cite this article as: Nisini E, Santulli C, Liverani A, Mechanical and impact characterization of hybrid composite laminates with carbon, basalt and flax fibres, *Composites Part B* (2016), doi: 10.1016/j.compositesb.2016.06.071.

MECHANICAL AND IMPACT CHARACTERIZATION OF HYBRID COMPOSITE LAMINATES WITH CARBON, BASALT AND FLAX FIBRES

E. Nisini*, C. Santulli**, A. Liverani*

* Università degli Studi di Bologna, CIRI-MAM, viale Risorgimento 2, 40136 Bologna, Italy
** Università degli Studi di Camerino, School of Architecture and Design (SAAD), viale della Rimembranza, 63100 Ascoli Piceno, Italy

ABSTRACT

Ternary hybrids including carbon, basalt and flax fibres in an epoxy matrix have been fabricated by hand lay-up, then consolidated by vacuum bagging using two different stacking sequences. Both configurations involved the use of carbon fibres on the outside, whilst basalt and flax fibres were disposed internally either in a sandwich or in an intercalated sequence. They were subjected to tensile, flexural and interlaminar shear strength test, then to falling weight impact with three different energies, 12.8, 25.6 and 38.4 Joules, studying damage morphology and impact hysteresis cycles. Intercalation of basalt with flax layers proved beneficial for flexural and interlaminar strength. As regards impact performance, the differences between the two laminates were quite limited: however, the presence of a compact core of flax fibre laminate or else its intercalation with basalt fibre layers had a predominant effect on impact damage features, with intercalation increasing their complexity.

KEYWORDS

B. Impact behaviour; B. Mechanical properties; A. Hybrid; Flax

INTRODUCTION

During last decades, hybridisation, hence the introduction of layers of different fibre materials in composites has been often attempted. The first attempts involved glass/carbon hybrid composites, where it was found that performance is likely to exceed what would be expected from consideration of the rule of mixtures, which can be defined as a positive hybridisation effect [1]. In the specific case of traditional thermosetting composites, such as unsaturated polyester and epoxy, where the environmental advantage of hybridisation is not always obvious, this procedure may be perceived in different ways. A possibility is to consider hybridisation as an intermediate step for the substitution of traditional fibres, such as E-glass ones, with vegetable fibres, such as flax, hemp or jute, in composites, possibly with limited degradation in properties: this was mainly the approach of early studies [2-4]. Dealing with carbon fibre composites, the above mentioned approach comes somehow short, since the difference in properties with plant fibres is very considerable. On the other side, it has been suggested that the introduction of fibres with distinctly different properties would lead to a composite with properties more tailored on the requirements from service. This would compensate for some degree of complication involved in having different types of fibres. More specifically, carbon fibre composites, though outstanding in terms e.g., of tensile properties, suffer from limited toughness, which can be improved by their hybridisation with plant fibre composites [5], a characteristic found of interest for biomedical applications [6].
More recently, basalt fibres have been often considered as a suitable replacement for glass fibres, since they offer a lower environmental impact, in that their production does not involve the use of sizing agents, and they can effectively compete with glass in sectors, such as automotive, for example for the improved resistance to acid environment [7]. As a matter of fact, also hybrid laminates including carbon and basalt fibres have been produced, in which case the effect of the