# IMPACT BEHAVIOR OF WOOD-BASED SANDWICH STRUCTURES

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## INTRODUCTION

Low carbon impact is a shared goal of all transportation industry. One way to match this expectation consist in the introduction of lightweight materials with high specific properties such as composites materials. Wood based materials combined with fibre reinforced composites appear as good candidates if we introduce safety considerations and energy absorption capabilities [1]. Properties of wood such as fire resistance or thermal and acoustic insulation are also essential for many applications and could lead to a new interest for this old material. Wood is also a totally renewable material which guarantees sustainability with much lower costs compared to honeycomb or foam cores. Balsa wood is currently used for the design of naval sandwich structures. Some results highlight its advantages for impact applications [2, 3]. Very few applications of wood based sandwich structures were found in automotive [5] and naval structures [4- 6]. Nevertheless, in the sixties a “Le Mans” race car designed by the famous English engineer Frank Costin was all plywood made for the structure with a total mass of only 450 kg (see Fig; 1). Until the 90s, the french acrobatic aircraft Mudry CAP 10 was fully made of plywood.


*Fig. 1: Costin-Nathan Le Mans 1967*

In the final purpose to promote such materials by combining it with “modern” materials, sandwich structure using lightweight plywood core and different skins were manufactured. In this paper, only the response of such structures under low-velocity, low energy impact will be considered.

## EXPERIMENTAL PROCEDURE

Specimens are handmade. Two types of plywood are used: Allin [6] and homemade (IUT). Both are made by stacking of okoume and poplar plies at 0° and 90° (see Fig. 2). Skins are made with aluminum alloy, carbon, glass or flax fabrics and made by thermo-compression or liquid resin infusion. The plywoods are 10 mm thick. The size of the specimen is 100 x 150 mm$^2$ which is the normalized size for composite specimens according to Airbus or Boeing standards. These specimens will also be used for Compression After Impact tests then a tomography analysis is performed. Typical specimens are shown figure 3.

| Wood | Orientation | Thickness |
|---|---|---|
| Okoumé | 0 | 0.69 |
| Okoumé | 90 | 0.94 |
| Poplar | 0 | 1.94 |
| Poplar | 90 | 2.05 |
| Peuplier | 0 | 1.94 |
| Okoumé | 90 | 0.94 |
| Okoumé | 0 | 0.69 |

(a) ***Allin Plywood***

| Wood | Orientation | Thickness |
|---|---|---|
| Okoumé | 0 | 1 |
| Poplar | 90 | 3 |
| Okoumé | 0 | 2 |
| Poplar | 90 | 3 |
| Okoumé | 0 | 1 |

***(b) IUT Plywood***

***Fig. 3: Plywoods stackings.***

***Fig. 3: Allin plywood with aluminium skins.***

These structures are impacted using a classical drop weight apparatus. The impacts energies are 5J, 10J and 15J. In order to explore the impact response of these structures, the dispersion on three identical samples was studied only for one plywood structure and one sandwich structure with aluminum skins (Table 1).

***Table 1: Summary of Specimens manufactured and tests made***

| Tests Made | | Impact | | | Total (No. of samples) |
|---|---|---|---|---|---|
| | | 5 J | 10 J | 15J | |
| Plywood (Allin) | | 1 | 1 | 1 | 3 |
| Plywood (Iut) | | 3 | 3 | 3 | 9 |
| Plywood(Allin)/Aluminium | | 3 | 3 | 3 | 9 |
| Vacuum Moulding | Allin (Pw)/Glass | 1 | 1 | 1 | 3 |
| | Allin (Pw)/Carbon | 1 | 1 | 1 | 3 |
| Thermo-compression | IUT(Pw)/Flax | 1 | 1 | 1 | 3 |
| | IUT(Pw)/Carbon | 1 | 1 | 1 | 3 |
| | IUT(Pw)/Glass | 1 | 1 | 1 | 3 |

## RESULTS AND DISCUSSION

In this paper, the response of plywood alone and sandwiches with aluminum skins will be only considered. Force vs displacement responses are shown hereafter (Fig. 4):

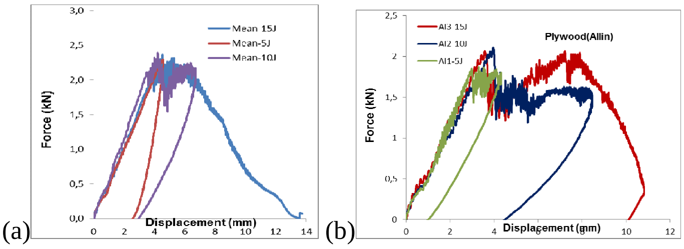
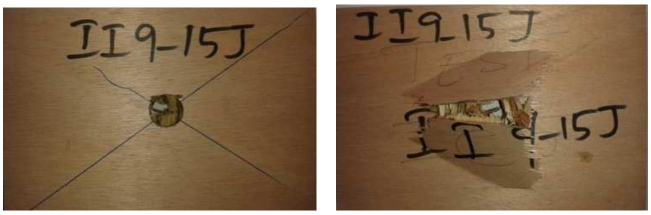



***Fig. 4: Plywood impact force/displacement curves (a): IUT, (b): Allin.***

The response of the IUT plywood to impact exhibit a first peak, a sudden drop and then an immediate densification without a plateau. The impactor remained blocked inside the plywood for the 15J test and a perforation occurred for all the tests at this energy level. The bottom of the plywood is showed Figure 5. Thus, for this test it is not possible to evaluate the real absorbed energy.



(a***) Impacted side*** ***(b) Bottom plywood***

***Fig. 5: Failure patterns of IUT Plywood specimen impact at 15J.***

The ratio of energy absorbed is about 68% for 5J and 10J. The Allin plywood exhibits clearly a better behavior under impact. The response is globally the same as honeycomb [7] and a plateau appears. The impactor was also blocked for the 15J test. The ratio of energy absorbed was 49.5 % for 5J and 80.7% for 10J. The difference of behavior can be explained by the stacking of the two plywoods. The thickness of the ply is thicker for the IUT and there are more interfaces in the Allin one. Thus, the second plywood is able to dissipate more energy. The plywood alone seems to behave as laminates. This remark is interesting because it means that optimizations are possible in order to enhance the energy absorption capability.

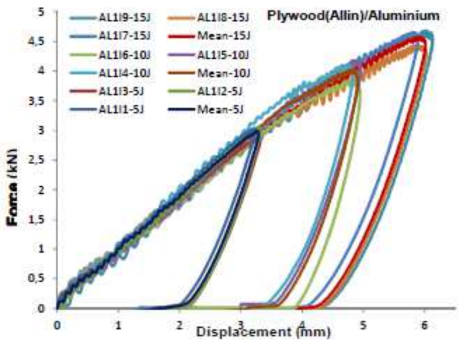



***Fig. 5: Allin plywood with aluminium skins.***

The figure 5 shows the response of sandwiches with an allin plywood core and aluminum skins. A very low discrepancy is observed. The ratios of energy absorbed are respectively 72%, 85% and 80%. There is no perforation for those specimens and the failure patterns can be showed in the following figure. The dents are respectively 1.58, 2.89 and 3.54 mm. The lower face is pristine for 5J and 10J.

***Fig. 6: Plywood with aluminum skins impact pattern.***

A tomography analysis was performed and a view for the 15J test is shown figure 7. This view shows that the plywood is almost crushed. Only some large vertical crack at the tip of the dent and some other 45° cracks are visible. Delaminations between plies of wood were not found. This analysis shows that the plywood has a behavior closer to honeycomb or foams than laminates from this point of view. It is simply crushed under the impact.

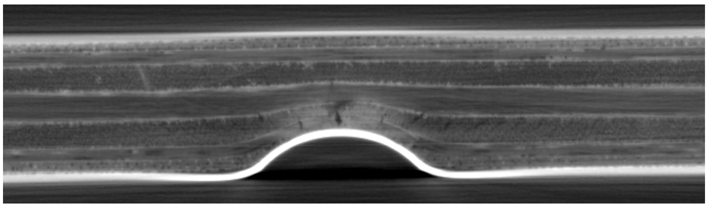


***Fig. 7: Tomography of a 15J impact.***

## CONCLUSIONS

Low velocity/low energy impact tests were conducted on wood-based eco-structure sandwiches with a plywood core. The plywood alone seems to have a behavior similar to laminate. In a sandwich, it is almost crushed under the impactor which enhances the energy absorption. Due to their low mass and their low cost, this kind of material may be good candidates for the design of light-weight structures for transportation.

## REFERENCES

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