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MECHANICAL PROPERTIES OF A CELLULAR COMPOSITE: COMPARISON WITH OTHER STRUCTURES[1)]

WŁASNOŚCI MECHANICZNE KOMPOZYTU KOMÓRKOWEGO: PORÓWNANIE Z INNYMI STRUKTURAMI

Bending and crash properties of an original cellular composite based on polystyren cells ***BOXcell*** are compared with a polypropylene honeycomb and a thermoplastic foam panel. The panels are covered with different walls.

Keywords: Composite, short fibres, sandwich structures, crash, bending, foam, honeycomb

Przedmiotem pracy jest porównanie własności takich jak giętkość i łamliwość oryginalnego kompozytu komórkowego na bazie komórek poliestyrenu ***BOXcell*** z polipropylenem typy plaster miodu i płytą termoplatycznej piany. Porównywane płyty pokryto różnorodnymi powłokami.

1. Introduction

In a common research and development work between BOX Industrie and the≪Solides Complexes≫ group of the University of Metz a large range of cellular composites has been explored. In nature cellular structures can be found in plants and bird bones. Such structures have been reproduced so closely as possible to the natural ones. The basic principle for the production of such a material is the association of a sophisticated system of stiff-walled, three-dimensional cells with a short-fibred composite material. Results of bending and crash test are compared to those obtained with honeycomb and foam structures aiming at increasing the mechanical properties of industrial cellular panels.

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1) invited lecture

2. Basic rheological results

At an initial stage of this work, a particular attention is directed to the control of the viscosity of different epoxyde matrices. Beside commercial resins, a certain number has been produced on demand with specific physical properties [1–4].

A mixture based on very short carbon or glass fibres and the previous resins is realized to bond the cell cavities which are achieved by means of lightweight polystyrene (and in the future cork) spheres, polypropylene honeycomb or foam.

The rheological behavior of mixtures (epoxy resins and milled carbon fibres as reinforcing particles) ranging from 0 to 30% volumic fraction of filers, has been explored [2, 4]. The properties of the resins and a possible addition of glassy microspheres [1] make it possible to obtain mixtures with a viscosity lower than those of the matrix alone. For many polymeric materials the gain in fluidity can be of 20 to 25% with size and concentration of thoroughly chosen microspheres. Now, fillers concentrations up to 35% are conveniently reached [4]. A convenient viscosity then allows to have a good wettability of the cell cavities. The final blend (epoxyde + fibres+ cells) can also be used to reinforce specific hollow structures with a significant increase of the mechanical properties (to be published). On the other hand, the same mixture is the basic core material for different sandwich panels. The properties of the sandwich panels based on this cellular composite may be adjusted by varying wall characteristics (matrix modulus, fibre type, volume fraction), the compacting rate during the forming step, or the short fibres/lightweight spheres ratio of the composite. By a convenient adjustment of these different parameters, it is also possible to obtain the density and stiffness of the cellular composite as a function of the desired application.

3. Mechanical tests

A four-point bending test allows us to deduce the bending and shear rigidity of sandwich structures later submitted to the impact test. The bending test is done with respect to the NF T 54-606 norm using an INSTRON BE209 machine (figure 1).

TABLE 1

Mechanical properties of the cores

	Shear stress (N/mm^2)	Shear modulus (N/mm^2)	Density (kg/m^3)
Polypropylen honeycomb	0.5	8	80
AIREX R63 thermoplastic foam	1.85	37	63
BOXcell polystyren cells	0.5	20	100

The load displacement is constant during the test. The dimensions of the sandwich samples are : L = 300 mm, l = 20 mm with a global thickness close to 10 mm. To obtain acceptable values, the tests are performed over 500 samples. A specific cellular composite ***BOXcell*** based on a composite material and low density spherical cells is

TABLE 2

Mechanical properties of the walls

	Tensile modulus (N/mm^2)	Tensile stress (N/mm^2)
Prepreg carbon/polyester	17 897	1421
Roving T300	13 406	384
T800/M300	6385	321

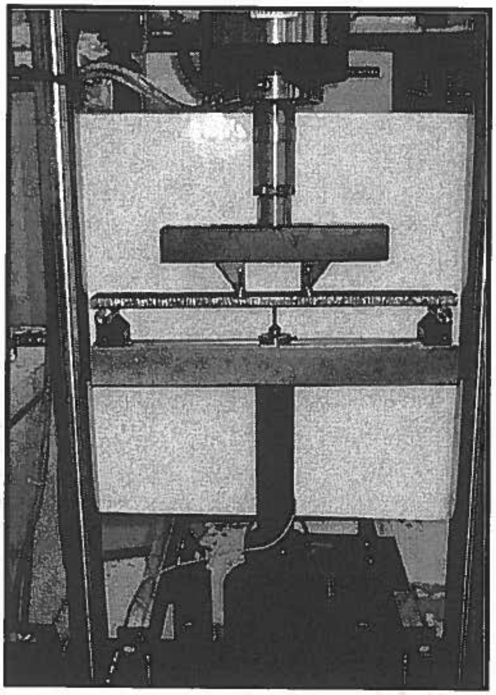

Fig. 1. INSTRON BE209 machine used for the bending test. Distance between the supports: 250 mm. Loading displacement: 10 mm/mn

compared to a set of panels with different cores. The mechanical properties of the basic materials are summed up in tables 1 and 2.

For the crash test a specific apparatus has been developed (figure 2). The impactor is a system with interchangeable masses (from 440 g to 4 kg) with a steel sphere of 10 mm diameter as block profile, the drop height varying from 10 to 85 cm. Impact energies up to 30 J can be developed with this system.

Samples have been cut out in different areas of the panels to verify the mechanical homogeneity and the efficiency of the production conditions.

Figure 3, summarizes the results obtained with a ***BOXcell*** core covered with different walls. The influence of the orientation of the wall fibres is clearly observed with a significant increase of the bending in comparison with polypropylene wall.

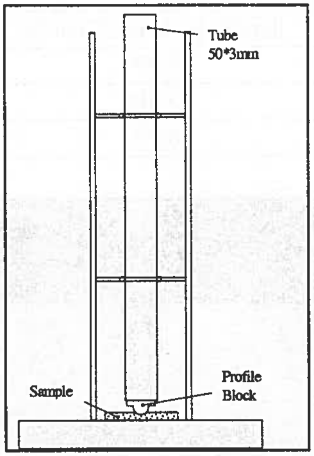

Fig. 2. crash machine

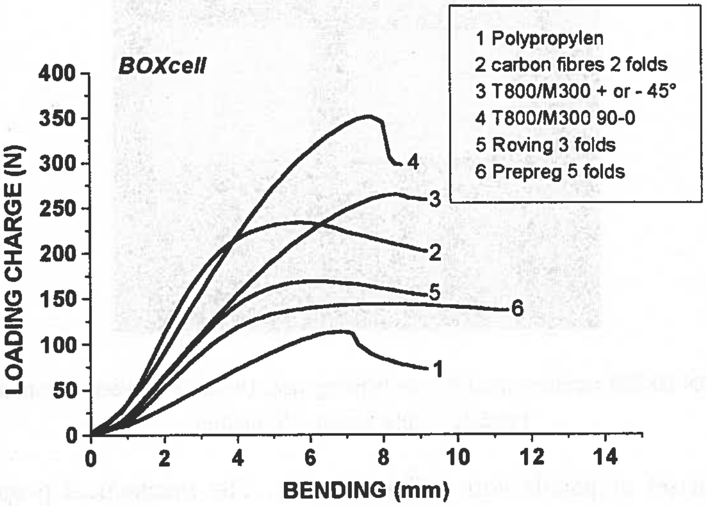

Fig. 3. Bending comparison of ***BOXcell*** core with several walls

Results with prepreg manifolds layers show no significant difference in the bending modulus. Over a certain thickness of the wall, the ridigity does not vary anymore. For the three lower curves the walls are stuck on the cores. For the other ones, the walls are impregnated with the same resin as used to prepare the composite mixture. The complete panel polymerizes in the same time and leads to quite a monolithic structure. If the production proceedings are not fulfilled a pilling mechanism of the walls cannot be avoided.

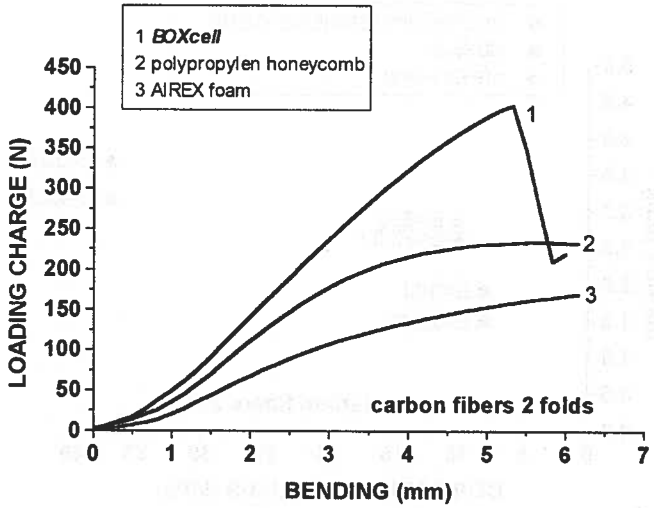

Fig. 4. Bending comparison of the cores with a carbon 2 folds wall

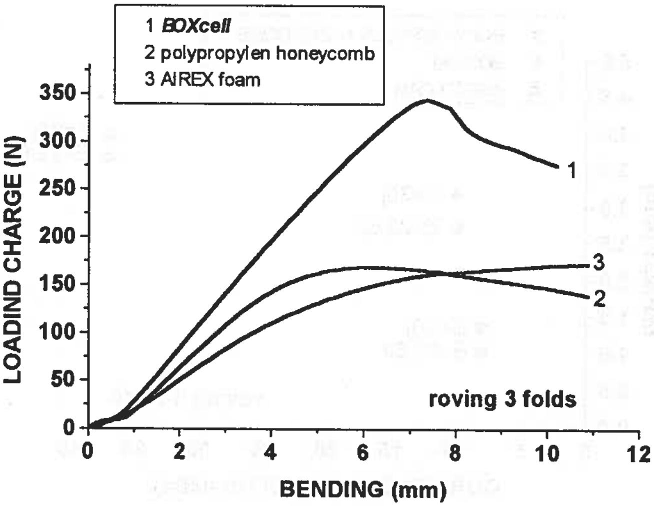

Fig. 5. Bending comparison of the cores with a Roving 3 folds wall

Figures 4 and 5 represent the three retained cores with two different walls. If the general behaviour appears to be the same, the ratio loading/bending and then the bending resistance are different. The higher the elastic modulus is, the higher bending we found for the studied sandwich structures. In the same way, figures 6 and 7 illustrate the behavior of the core with the same walls during a crash test.

In addition to the different figures presented in this paper, panels have been produced to study the influence of fibres additions in the epoxyde matrix (20% of glass fibres, 4% of carbon fibres — 500 μm length).

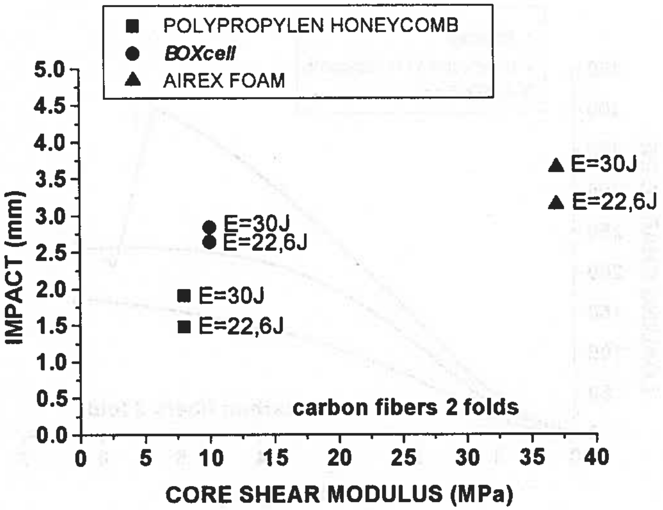

Fig. 6. Crash test — comparison of the cores with a carbon 2 folds wall

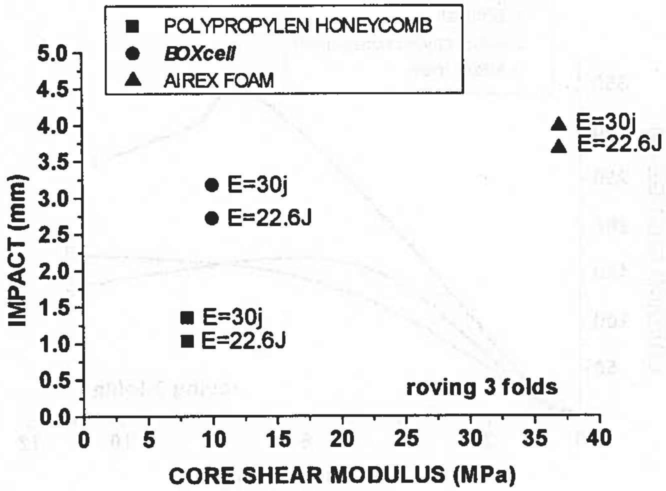

Fig. 7. Crash test — comparison of the cores with a Roving 3 folds wall

4. Conclusions

Adding glass or carbon fibres allows to strongly increase the loading charge maximum. The wished performances (***BOXcell*** better than the other composites) are not always reached. The bending properties are higher for the different walls. The crash energies are lower than those measured for the thermoplastic foam. ***BOXcell*** has performances close to or better than AIREX foam with T800/M300 90-0 walls. The rigidity of the cellular composite is better than that of the honeycomb structures.

Increasing the loading charge of ***BOXcell*** from 350 N to 400 N must be achieved by adjustment of the proceeding conditions. Properties of ***BOXcell*** still can be increased if are avoided non homogeneous mixtures between the matrix or/and formation of fibre aggregates not impregnated with the resins.

The results concerning a composite material based on cork spheres have to complete this previous comparison. Finite elements calculations based on different mechanical models should be compared with the available set of experimental data.

Chemical safety boxes, phone and military shelters, furnishing panels, IPN for ultra-light planes are still produced with the cellular composite and certificated.

Acknowledgements

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