GLASS-FIBRE WOOD
THE COMPOSIT MATERIALS USED ON THE REDUCTION OF WOOD IN THE WOOD LAMINATED INDUSTRY

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SUMMARY

The actual world faces a big environmental problem: the climatical changes, due to the increasing of the greenhouse effect in association with the diminution of the green areas, are changing the entire globe.

To reduce the quantity of wood used in a wood laminate, a new technology based in composite materials, has been developed in a partnership between the Department of Mechanical Engineering and Industrial Management of the Engineering Faculty of Oporto University and the Institute of Mechanical Engineering and Industrial Management.

This technology creates a new material called GLASS FIBRE WOOD (GFW).

The GFW it's a thermoset matrix laminate without the impregnation in the wood exterior layer, very similar tactile and visually with the usual wood laminates such as Medium-Density Fibreboard (MDF).
Meanwhile, the similarities are not much more, because the mechanical behaviour of the GFW is higher, the environmental impact is lower and the wood and energy consumes are also much lower than the MDF.

This article presents the GFW and is comparison with one of GFW's bigger competitor – - the MDF.

INTRODUCTION

Since the beginning of Time, Man used the natural resources for the production of forms and objects. The use of the stone, first splintery and later polishing, for the production of utensils

was probably the first indication of this use.

In the present, the use of these resources is in such exaggerated way that the Humanity feels the need of rationalize this use and preserving these resources that start to be rare.

In these resources we find the wood – used since fuel for heating until structural ends.

To minimize the use of natural resources, the wood industry has developed technologies and products that intended the substitution of the wood for other wood base materials such as MDF.

However, even so these technologies and products allow the reutilization of wood or of its wastefulnesses, they continue consuming great resources – material and energetic.

These raised consumptions of wood lead to a reduction of the green zone, that associates to the biggest fire number, lead to a bigger effect of greenhouse with an increase of the globe temperature and a bigger concentration of carbon dioxide with a lesser global capacity of photosynthesis.

The GFW that will be presented in this article is a composite answer for two of the problems of the actuality that have a big impact in the greenhouse effect: The wood waste and the massive consumption of energy to produce wood laminates.

ENVIRONMENTAL ASPECTS

Polystyrene

One of the GFW raw materials is the polystyrene (PS).
The PS is a non-biodegradable thermoplastic with an increasing of use due is good properties as we can see in Figure 1.

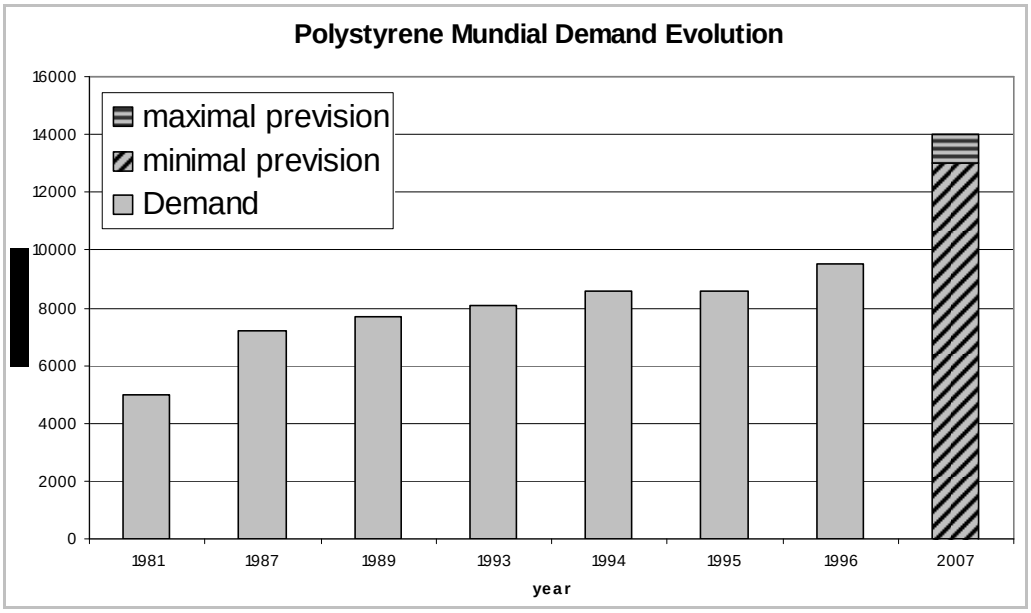

Figure 1: Polystyrene Mundial Demand Evolution. (*Source: Brasilian Ministery of Development, Industry and Exterior Trade)*

For applications that not require much mechanical capability, it's possible to re-use the PS.

That's a mechanical process, indicated in figure 2, composed for five different steps.

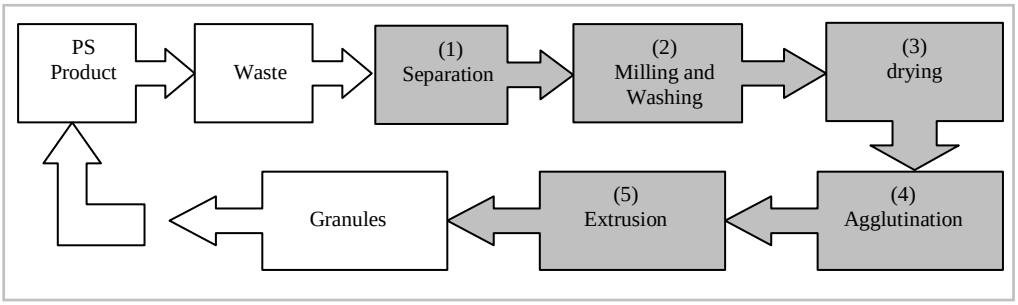

Figure 2: Mechanical process for re-utilization of the polystyrene

After the separation (1) of all parts that are not PS, the PS is washed and miller (2). After that enters in a hot chamber to reduce the water quantity (3) and goes to an agglutination system (4). To finalize de cycle the PS is extruded and cuted in granules (5) that will be the raw material for another PS product.

Wood

The relation between wood and climatical changes is well known of the entire globe. In Portugal all the possible climatical scenarios say that the country will increase temperature and hot waves intensity. The previsions say that the interior of Portugal will have a temperature increase of 7ºC and the sea-side area an increase of 3ºC.

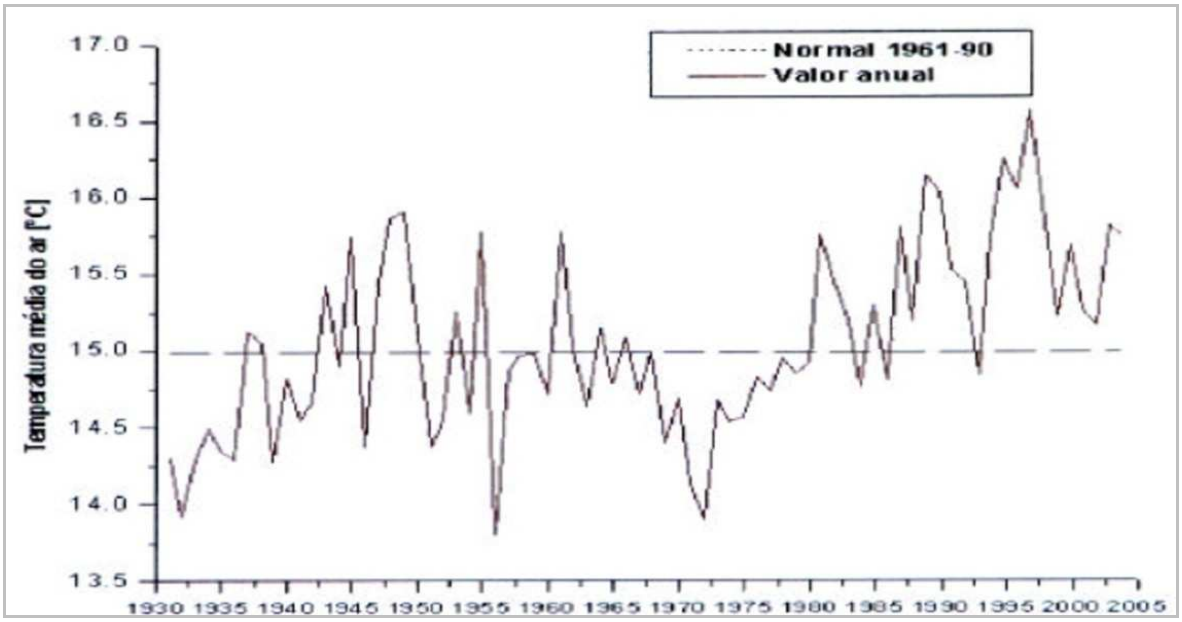

Figure 3: Evolution of the annual medium temperature. (y axis – Medium temperature; x axis – Year) (*Source: Portuguese Directorate General of Forestry Resources – 2006)*

On the other side, the forestry fires decreases the wood available for the industry and increases the soil temperature.
All this factors together take us to a climatical state that increases the desert areas and decreases the rain quantity and the quantity of water in the soil, as we can observe in figure 4 which represents the susceptibility to desertification of Portugal.

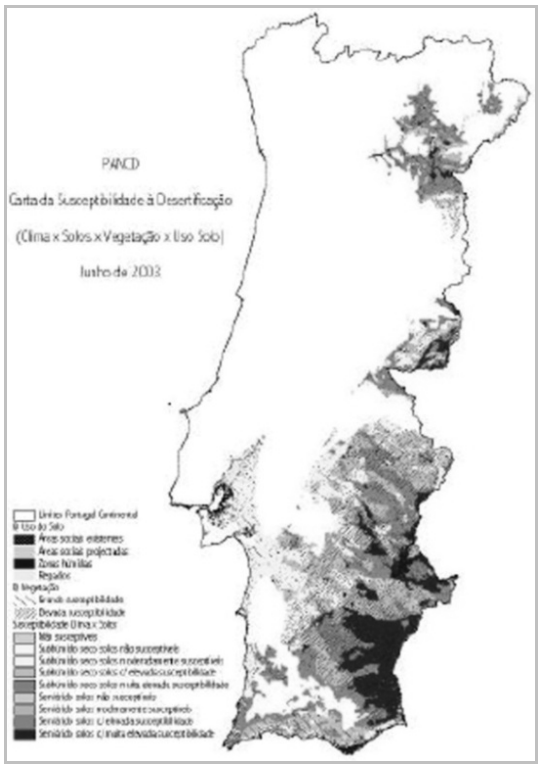

Figure 4: susceptibility to desertification Map (*Source: Portuguese Directorate General of Forestry Resources – 2006)*

GLASS-FIBRE WOOD – TECHNICAL DETAILS

To reduce the quantity of wood used in the wood laminate products, the GFW uses only a wood veneer. This reduction of the quantity of wood used in the production of the wood laminate products will decrease the need of wood and consequentially the diminution of the destruction of the green areas.

The Glass-Fibre Wood is a composite material produce by a technological method of composite materials fabrication named Resin Transfer Moulding (RTM).

In a RTM system is necessary to have a closed mould. In that mould we put the several layers that will made the final material. After that we close the mould and, under pressure, we inject the resin that will agglutinate all the layers. When the mould is full of resin, and the resin's cure reaction ends, we open the mould and the material is produce.

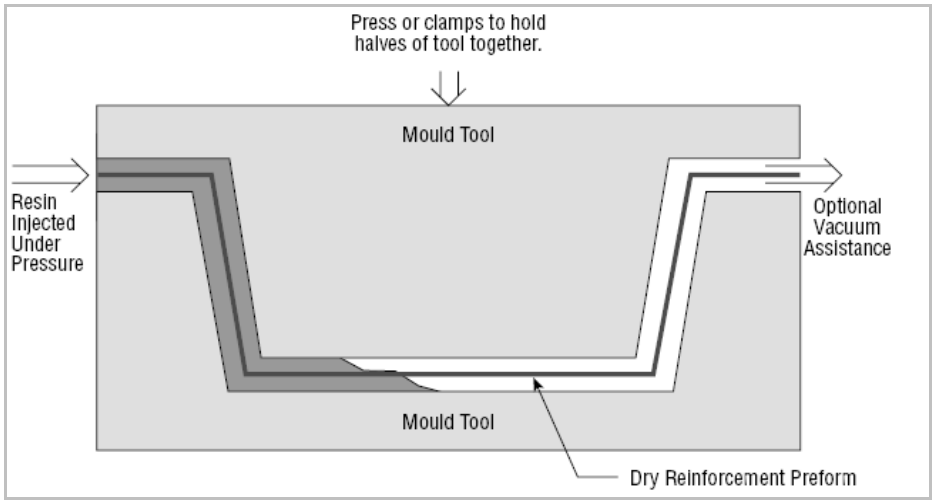

Figure 5: RTM system

For the fabrication of GFW we use the next layers:

- Pre-composed wenge *(Millettia Stuhlmannii*) veneer with 0,5mm of thickness
- Polystyrene sheet with 0,25mm of thickness
- RTM's Glass-fibre - Rovicore® 450/B5/450

and we use, also, an epoxy resin SR8100 / SD8824 from SICOMIN EPOXY SYSTEMS

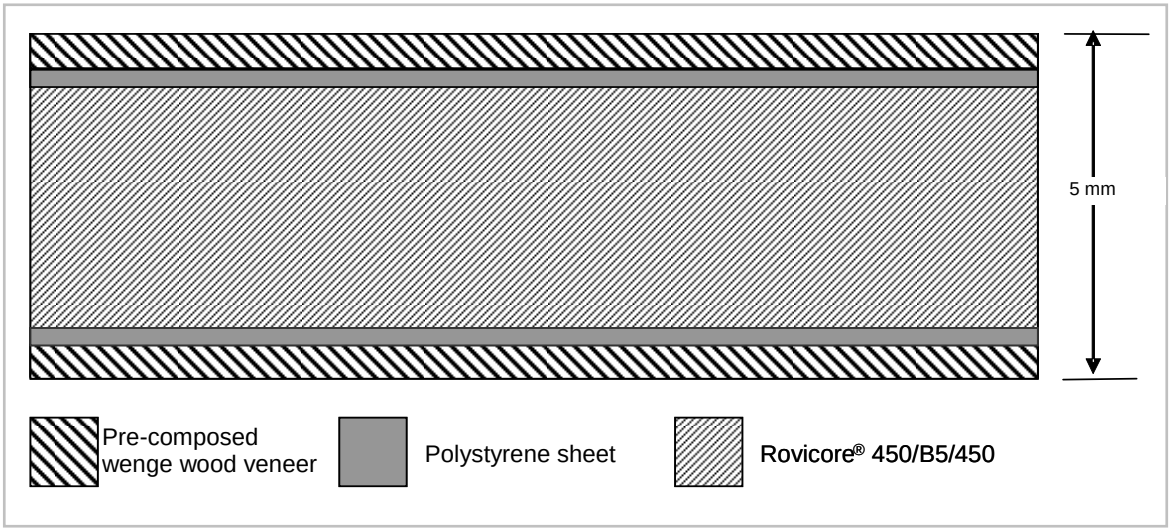

Figure 6: GFW's layers scheme

The polystyrene sheet gives isolation between the epoxy resin from the Rovicore core and the wood veneer. For this reason the original mechanical and fisical properties of the wood are preserved.

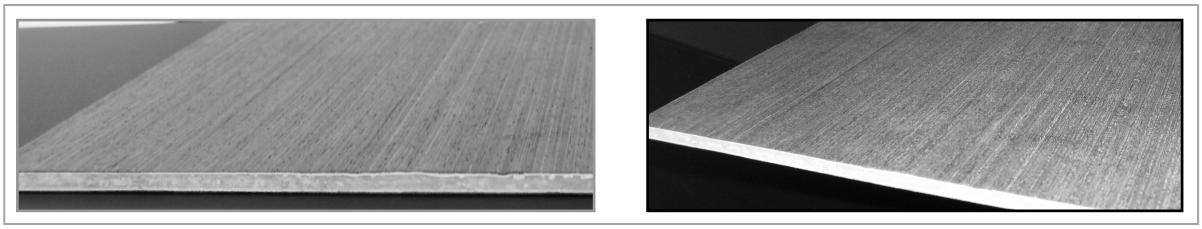

Figure 7: Details of GFW Laminate

The temperature inside the mould in the RTM process is register by a thermopar and the results are express in the graphic of the figure 7. The reason of the increasing of the temperature is only the heat of the exothermal cure reaction of the epoxy resin.

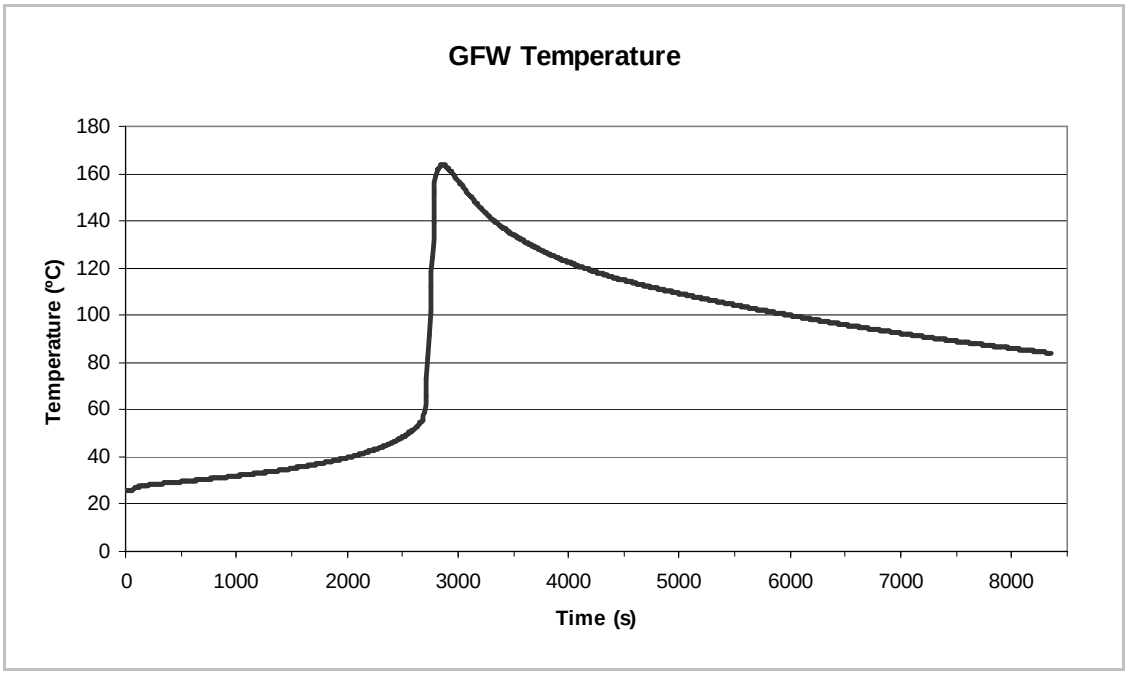

Figure 8: Temperature inside the RTM mould

With this range of temperature the polystyrene starts to be viscous and "glues" the wood-sheet to the fibre-glass core.

COMPARATION OF GFW WITH MDF

Because MDF veneers have a very similar layer structure to GFW, we have made a comparison between those two products.

We studied the mechanical behaviour and the environmental impact of those two products.

To study the mechanical behaviour we have made:

- Tensile Tests according the ISO 527 standards
- Bending Tests according the ISO 178 standards
- Determination of density
- Microscopic analysis of the joint area

To study the environmental impact, we have used the "Design for Environment- toolkit" (DfE) developed by the Minnesota Office of Environmental Assistance [3].

MECHANICAL TESTS RESULTS

The results obtain in the mechanical tests are describe in the next figures and tables.

Density

Material	Density	Standard Deviation
MDF	**0,87**	**1,15 %**
GFW	**1,16**	**0,50 %**

Table 1: Experimental density results

Tensile

Since we already know from other composite materials that the orientation of the exterior fibres could interferer with the mechanical properties, for both materials, we test two different series. The serie "PAR" that have the fibres orientated parallel to the major side of the specimen and the serie "PER" that have the fibres orientated perpendicular to the major side of the specimen.

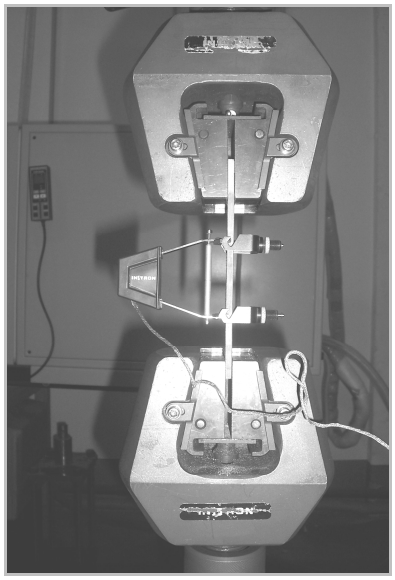

Figure 9: tensile specimen being tested

Material	Serie	Ultimate strength		Young's Modulus	
		(MPa)	Standard Deviation	(MPa)	Standard Deviation
MDF	**PAR**	**34,92**	**2,49 %**	**4817**	**7,08 %**
	PER	**22,77**	**5,99 %**	**3622**	**6,06%**
GFW	**PAR**	**54,87**	**28,08 %**	**4796**	**27,19 %**
	PER	**40,29**	**9,74 %**	**2714**	**2,64 %**

Table 2: Experimental results of the tensile test

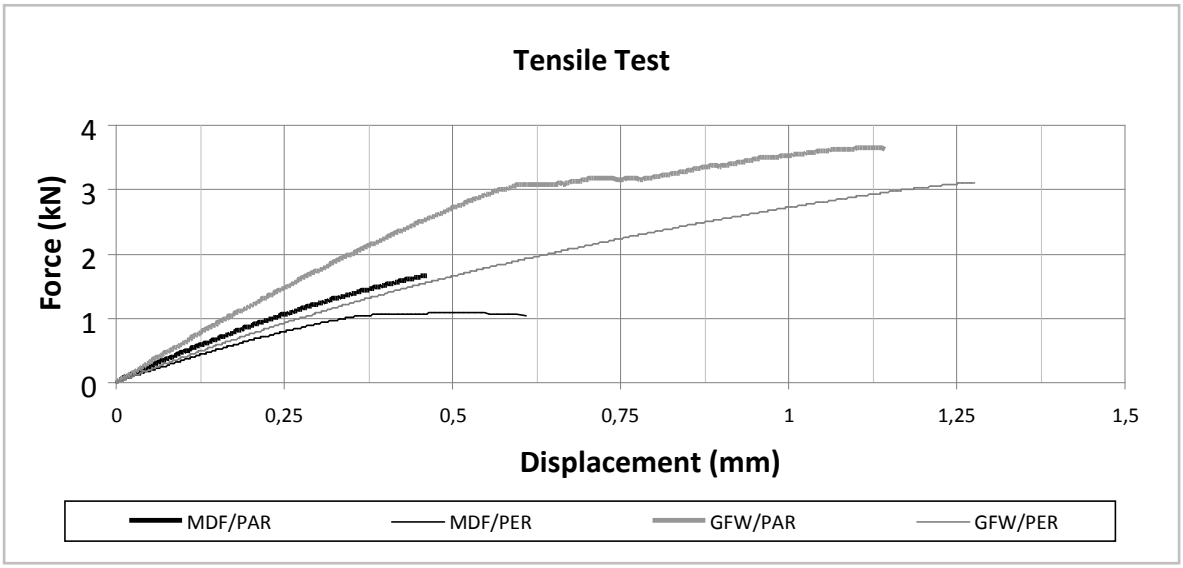

Figure 10: Experimental graphics of the tensile test

Bending

To maintain a uniform method of comparison, in the bending test we also use the two series alignment that we used in the tensile test.

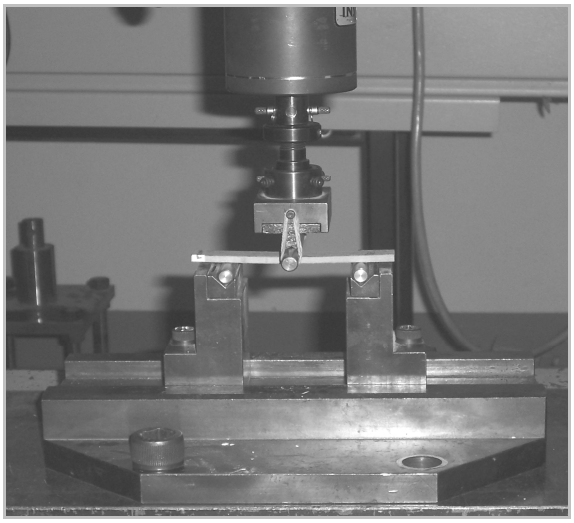

Figure 11: bending specimen being tested

Material	Serie	Ultimate strength		Young's Modulus	
		(MPa)	Standard Deviation	(MPa)	Standard Deviation
MDF	PAR	68,12	4,28 %	5157	4,05 %
	PER	41,72	6, 09 %	3024	2,96 %
GFW	PAR	88,94	4,23 %	3574	12,34 %
	PER	88,03	3,54 %	2322	5,97 %

Table 3: Experimental results of the bending test

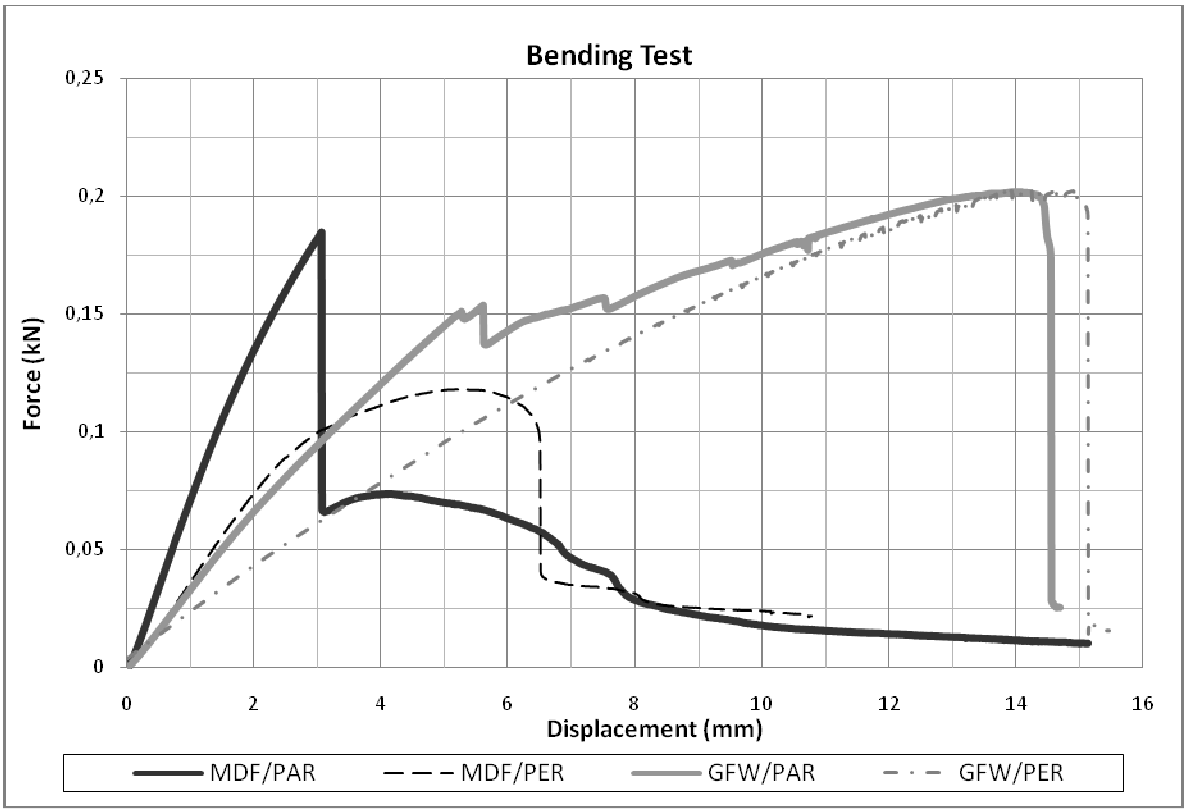

Figure 12: Experimental graphics of the bending test

Microscopic analysis

We have submitted the two materials to a visualization of its structure into a microscope.

As you can see in the next figures the GFW and the MDF have a different process of fix the exterior layer.

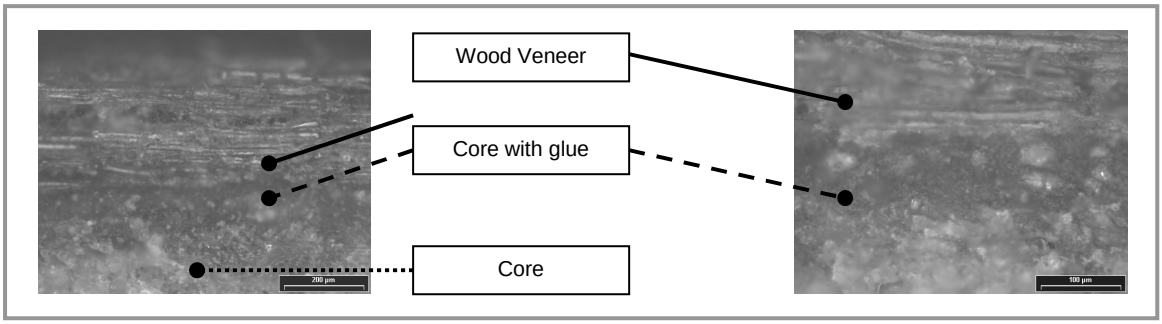

Figure 13: Microscopic view of the MDF structure. Magnification of 10x (left) and 20x (right)

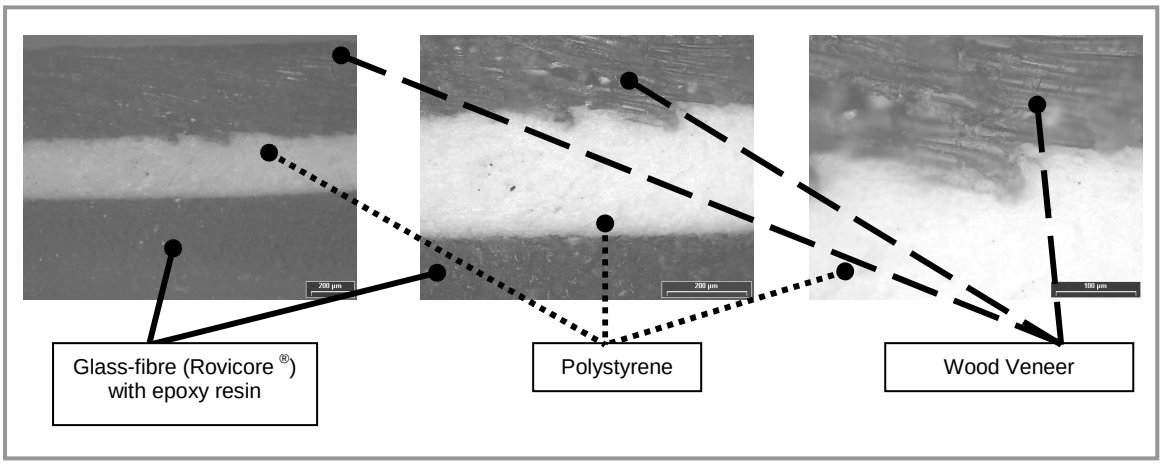

Figure 14: Microscopic view of the GFW structure. Magnification of 5x (left), 10x (center) and 20x (right)

In the MDF we can see that the glue that it's use is almost absorbed by the core. On the other hand, in the GFW, the polystyrene "glues" to the core by chemical bounds and fixes the exterior layer by wrapping the wood filaments.

ENVIRONMENTAL COMPARISON

For the environmental comparison we use the toolkit developed by the Minnesota Office of Environmental Assistance. This method of comparison is based in an Environmental Indices (EI).
The EI is calculated in an environmental matrix that analyses all the life-time of a product, since is raw-material until his waste and recyclability.

	Environmental Concern					
LIFE STAGE	1 Materials	2 Energy Use	3 Solid Residue	4 Liquid Residue	5 Gaseous Residue	Total
A Premanufacture	(A.1)	(A.2)	(A.3)	(A.4)	(A.5)	
B Product manufacture	(B.1)	(B.2)	(B.3)	(B.4)	(B.5)	
C Distribution, packaging	(C.1)	(C.2)	(C.3)	(C.4)	(C.5)	
D Product use, maintenance	(D.1)	(D.2)	(D.3)	(D.4)	(D.5)	
E End of life	(E.1)	(E.2)	(E.3)	(E.4)	(E.5)	
Total						

Figure 15: Environmental matrix according to the DfE.

Using this methodology the results of the environmental impact of GFW and MDF are those indicated in figure 16.

NOT AVAIABLE					
5	5	4	5	5	24
1	0	2	5	5	13
0	2	1	5	5	13
3	5	2	5	5	20
9	12	9	20	20	70

NOT AVAIABLE					
3	0	3	6	2	14
0	0	2	5	5	12
1	2	3	5	5	16
4	5	2	5	4	20
8	7	19	21	16	62

Figure 16: Environmental matrix and Environmental Index for the GFW (left) and MDF (right)

CONCLUSIONS

After analyses of the values obtained by the experimental method we can conclude that the GFW presents better mechanical properties. That is visible in the increasing of tensile capability about 60%. It's possible to verify that in GFW the contribution of the exterior layer is minor that in MDF. That allows using GFW without taken care of the orientation of the fibres.

We also can conclude that the GFW has a minor environmental impact than the MDF. This reduction is caused by the utilization of the heat of the chemical reaction to produce the GFW without any external source of heating.

We verify also that the GFW is around 33% heavier that the MDF.

To finalize we can conclude that the GFW is a valid option to substitute MDF, because GFW uses less wood, less energy and presents better mechanical properties and less environmental impact.

ACKNOWLEDGMENTS

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