A study of particleboards made from wood waste particles and common cane (A*rundo donax* L.) and urea formaldehyde adhesive.

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Abstract

19 particleboards of different thicknesses and humidity and composed of different proportions of recycled wood and reeds were made through a drying process. Test samples were then cut (longitudinal and transversal) with dimensions in accordance with UNE EN regulations for wood boards: 4 for flexion tests, 3 for water immersion tests and 2 for determining humidity and density.

Tests were carried out for density, humidity, thickness swelling after water immersion and flexure resistance, in accordance with UNE EN regulations for wood boards.

From the results obtained, it was noted that boards with a 75/25 ratio of reed particles and wood particles showed affinity and for this reason better quality boards are obtained than the wood boards made through the same process.

It was also demonstrated that it was not necessary to dry the material before making the board. Therefore, power costs are lower and also thickness swelling is less than for wood boards.

Keywords: particleboards, wood waste, *Arundo donax* L.

1. Background and objectives

A study was carried out on the possibilities of making particleboards with wood waste particles from carpenters' workshops and reed, which is an easily renewable resource and ideal for counteracting the high dependence on wood and board imports. The objective is to control a wild plant and obtain a product (particleboard).

2. Materials and methods

2.1. Materials

The materials used were:

- Giant reed particles (*Arundo donax* L.).
- Wood particles from the chipboard industry.
- Adhesive consisting of urea formaldehyde diluted in water and ammonium sulphate.

2.2. Methodology and work plan

The methodology followed was to make boards and evaluate them through thickness swelling tests after 24 hour water immersion and flexion tests, (obtaining the modulus of elasticity in flexure).

The SPSS 14.0 program for Windows was used for the statistical analysis of the data obtained.

2.2.1 Board manufacturing procedure

The drying process used for board manufacturing was the standard procedure for wood boards and the use of the traditional methodology of wood boards was adapted to reeds.

a) Leaf removal and cutting reeds.

b) Grinding the reed using a defibrator machine with horizontal blades with between 1.7 and 2.07 mm separation between the blades. As shown in figure 1.

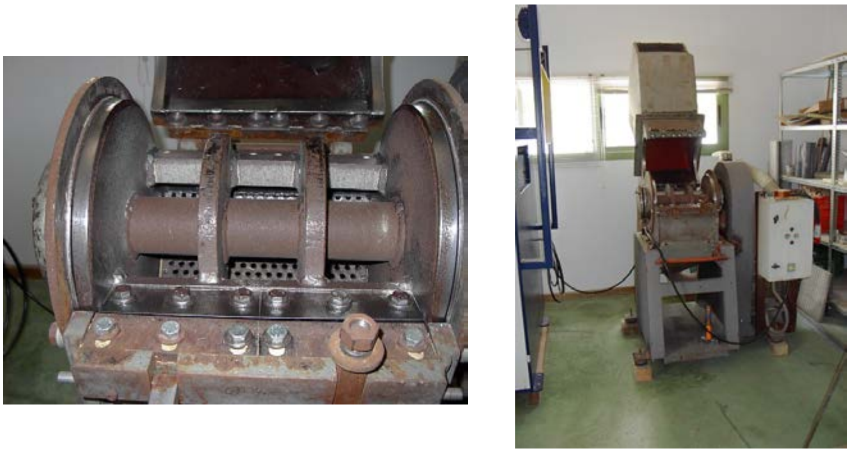

Figure 1. Defibrator machine*.*

c) Filtering the reed particles obtained from the defibrator machine, classifying them according to the filter they are retained in:

- Less than 0.25 mm. This particle size was rejected.
- Between 0.25 and 1 mm.
- Between 0.25 and 2 mm.
- Between 1 and 2 mm.
- Between 2 and 4 mm.
- Between 4 and 8 mm
- Between 8 and 10 mm.
- Bulk, as it comes out of the defibrator, without filtering.

d) Drying wood and reed particles to obtain an initial humidity of between 3 and 5%. Drying was not carried out on all boards during the manufacturing process; those boards that went through the drying process are called 'dry' and those that did not, with between 9% and 15% humidity, are called 'humid'.

e) Manually mixing the different proportions and particle sizes of reed and wood according to the board prototype.

f) Blending the reed and wood particles with adhesive (5.85% in weight of solid urea formaldehyde with respect to the weight of the particles) in a manual blender.

g) Forming the sheet in a 35 x 50 cm mould. For easy removal, the mould is previously protected with a film of polyethylene at a high temperature.

h) Manual pre-pressing for levelling the sheet.

i) Pressed in a hot plate press at a temperature of 120ºC for 6 minutes at a pressure of 80 bar.

j) Boards are cooled in the open air at a temperature of 20ºC and 65% atmosphere humidity, placed in a vertical position.

k) Measuring and weighing of boards.

l) Trimming the edges and cutting to obtain test samples of each type in accordance with the standardised measurements (UNE EN 325 regulation for wood boards, establishing test sample dimensions), for posterior testing and analysis of the boards.

19 particleboards of different proportions of recycled wood particles (0%, 25%, 50% and 75%) and reeds of different sizes and humidity levels were made. The different boards can be seen in Figure 2, and the different types manufactured and cut into samples of 50 x 50mm can be seen in figure 3.

Figure 2. Wood-reed boards (left dry particles, right humid particles)

Figure 3.Test samples of all the boards made.

2.2.2 Thickness swelling test.

Regulation EN 317: 1993 was applied in order to establish thickness swelling after water immersion.

The equipment used was a micrometer and a container for water immersion. Three square test samples from each board (50 ± 1) mm width were tested.

Operating procedure:

- Measurement of thickness. Thickness is measured for each test sample at the intersection point of the diagonals with 0.01 precision, in accordance with the EN 325 regulation.
- Immersion: The samples were submerged in a vertical position in clear, still water with a pH of 7±1 and a temperature of (20±1) º C. This temperature was maintained during the test. Immersion time was 24h.
- Measurement of thickness after immersion. When immersion time ended, the samples were taken out of the water, excess water was eliminated and thickness was measured.

Thickness swelling was calculated for each sample (Gt), expressed as a percentage of its initial thickness through the equation (1)

$$Gt = \frac{t_2 - t_1}{t_1} \cdot 100 \qquad (1)$$

where:

t_1 , thickness of test sample before immersion, in mm.

t_2 , thickness of test sample after immersion in mm.

Thickness swelling for a board was considered the arithmetical average of the results of all the test samples taken from the same board.

2.2.3. Flexion test.

Regulation UNE EN 310 1994 was applied in order to carry out the flexure test: “Wood based boards. Establishment of modulus of elasticity in flexure and flexure resistance”.

The measurement of the roller supports was fixed according to the thickness of the board t; ($L_1 = 20 \cdot t$), the length of the test sample ($L_2 = L_1 + 50$) and a fixed value of 50mm for the width. Flexure resistance f_m (in N/mm^2), of each test sample was calculated according to the following formula

$$f_m = \frac{3 \cdot F_{max.} \cdot L_1}{2 \cdot b \cdot t^2} \qquad (2)$$

where:

$F_{max.}$ is the maximum load in Newtons, which corresponds to the maximum value reached.

L_1 is the distance between the support axes in mm.

b is the width of the sample in mm.

t is the thickness of the sample in mm.

The modulus of elasticity E_m in N/mm^2, in accordance with the UNE regulation for testing flexure, is defined

$$E_m = \frac{\left[L_1^3 \cdot (F_2 - F_1)\right]}{\left[4 \cdot b \cdot t^3 (a_2 - a_1)\right]}, \qquad (3)$$

F_1 being the value of the load corresponding to approximately 10% of the value of the maximum load in Newton which corresponds to a deformation value of a_1 in mm.

F_2, corresponds to approximately 40% of the value of the maximum load and a_2 is the deformation value at that point.

According to the regulation UNE EN 1058:1995 for wood based boards (establishment of the characteristic values for mechanical and density properties) the typical resistance is defined as fifth percentile.

$$f_k = f_{05} \qquad (4)$$

Modulus of elasticity is also defined as fifth percentile or the average value, as the following equation indicates.

$$E_k = E_{0,5} = k_n \cdot m(E) \qquad (5)$$

k_n being a tabulated constant which depends on the number of tests.

3. Results and discussion

The percentage of thickness swelling of the board after water immersion is a quality which can define whether it is possible for the board to be used outside. In order to decrease thickness swelling of industrial boards, paraffin, asphalts or other types of substances are normally added. No type of additive was added to the reed-wood prototypes made.

Figure 5 shows how swelling can be observed in the three test samples of the 8 types of board in contrast to the three test samples to the left of each, which have not been submerged in water.

Figure 5. Comparison of samples before and after submersion in water for 24 hours.

Figure 6 shows the results obtained for the % of thickness swelling after 24 hours immersion in water according to the percentage of wood fibres. These results show that the greater the percentage of wood the greater thickness swelling is, however, it is not a totally determining factor, since it also depends on the reed particle size.

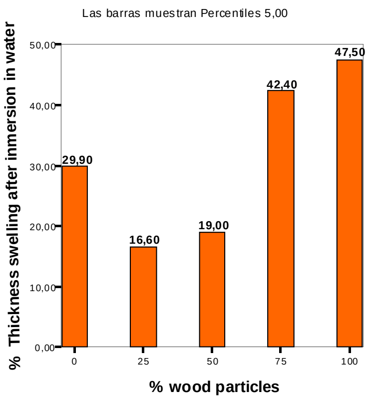

Figure 6. % Thickness swelling according to wood percentage of board.

The graphs in Figure 7 indicate the thickness swelling percentage after water immersion according to the size of the reed particles and the percentage of wood particles in the boards, by analysing these graphs, we can see that the reed as a material does not behave in the same way and swelling varies. In the boards made with small particles (0.25 to 2mm.) when the percentage of wood is increased, thickness swelling percentage decreases, however with bigger reed particles (2 to 8 mm), thickness swelling percentage increases when the proportion of wood is increased.

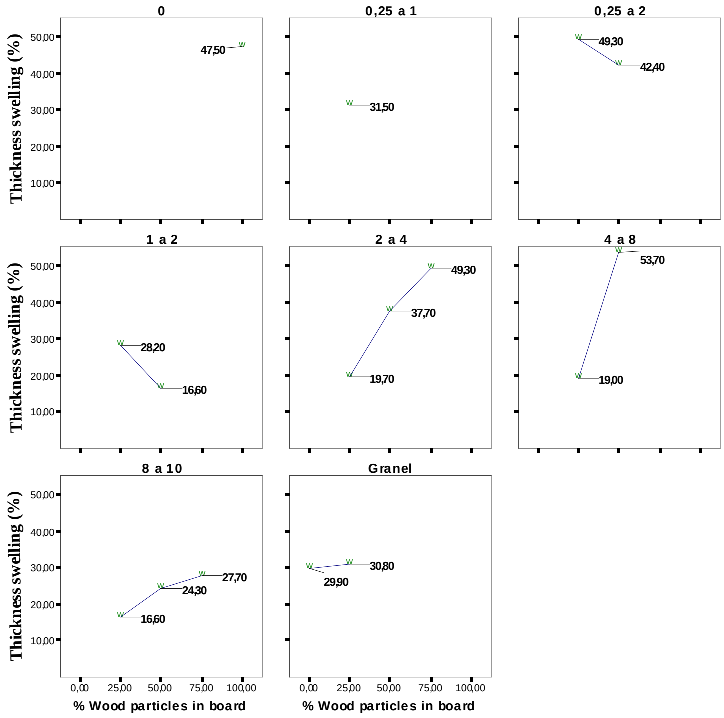

Figure7. % thickness swelling according to the % of the board's wood particles

Flexure tests were carried out on the 19 types of board made, on a P4 type industrial board and 1 board made with reed particles only, direct from the defibrator, which we call 'bulk'- 4 samples were cut from each of them (2 longitudinal and 2 transversal)..

When carrying out the tests more than 12 points of deformation and applied stress were noted for each sample, so the number of cases for each test N>12. For the test analysis, we only considered up to maximum tension and calculated the average values of load and instantaneous displacement on the points belonging to the curves of all the test samples in each test.

A diagram of tension dispersion to flexure-deflection was obtained for all 19 reed-wood boards, the industrial board (1M) and the reed only board (10H), through the computer program SPSS. Lineal regressions were obtained for each board as indicated in figure 8, which indicate that the tests were properly carried out and are significant for each type of board.

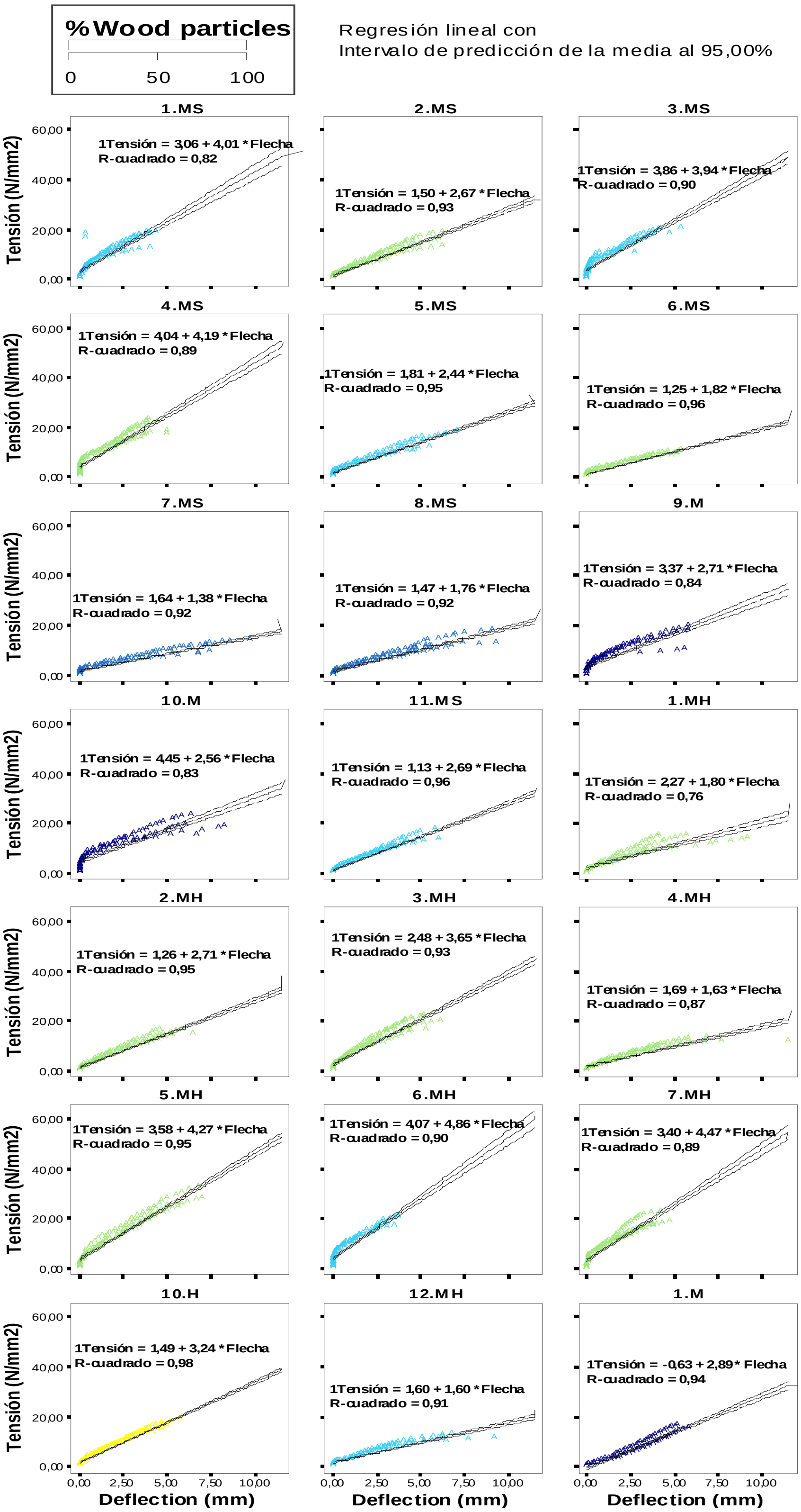

Figure 8.Lineal regressions tension to flexion-deformation of all boards.

Variance analysis of maximum values carried out according to the type of wood, percentage of wood and reed particle size as indicated in tables 1 and 2.

Table 1. Summary of case processing

	Cases					
	Included		Excluded		Total	
	N	Percentage	N	Percentage	N	Percentage
Max. deflection * Wood Type * % Wood * Reed size	82	3,9%	2033	96,1%	2115	100,0%
Max tension. * Wood type * % Wood * Reed size	82	3,9%	2033	96,1%	2115	100,0%

Table 2. ANOVA Table

			Total Number squares	gl	quadratic average	F	Sig.
Max deflection. * Wood type * % Wood * Reed size	Inter-groups	(Combined)	5,726	3	1,909	,684	,565
	Intra-groups		217,773	78	2,792		
	Total		223,499	81			
Max tension. * Wood type * %Wood * reed size	Inter-groups	(Combined)	32,863	3	10,954	,493	,688
	Intra-groups		1731,407	78	22,198		
	Total		1764,270	81			

We can observe that maximum tension of flexion and deflection depends on the type of wood, on the percentage of wood and on reed particle size which each board has been made with, and as each board has a different composition there is no relation between them.

To find out if the determining factor is the reed size, we analysed the tension to flexure-deflection curves according to reed particle size only and we obtained lineal regressions as observed in figure 9.

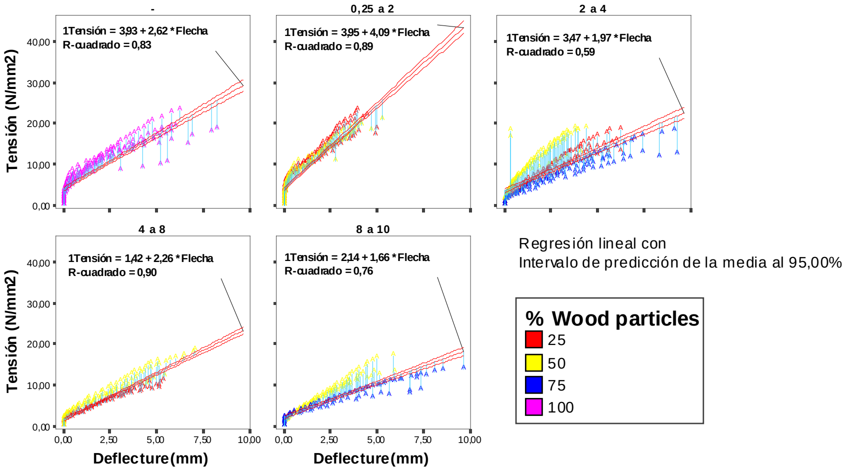

Figure 9.Lineal regressions of tension to flexion-deformation according to reed size.

We can see that in some reed particle sizes the lineal regression is not significant, so it does not depend totally on reed particle size.

If we obtain the characteristic tension of boards according to reed size and wood percentage, the results are as indicated in figure 10, noting (-) as wood board made in the laboratory and (0) as the industrial board tested.

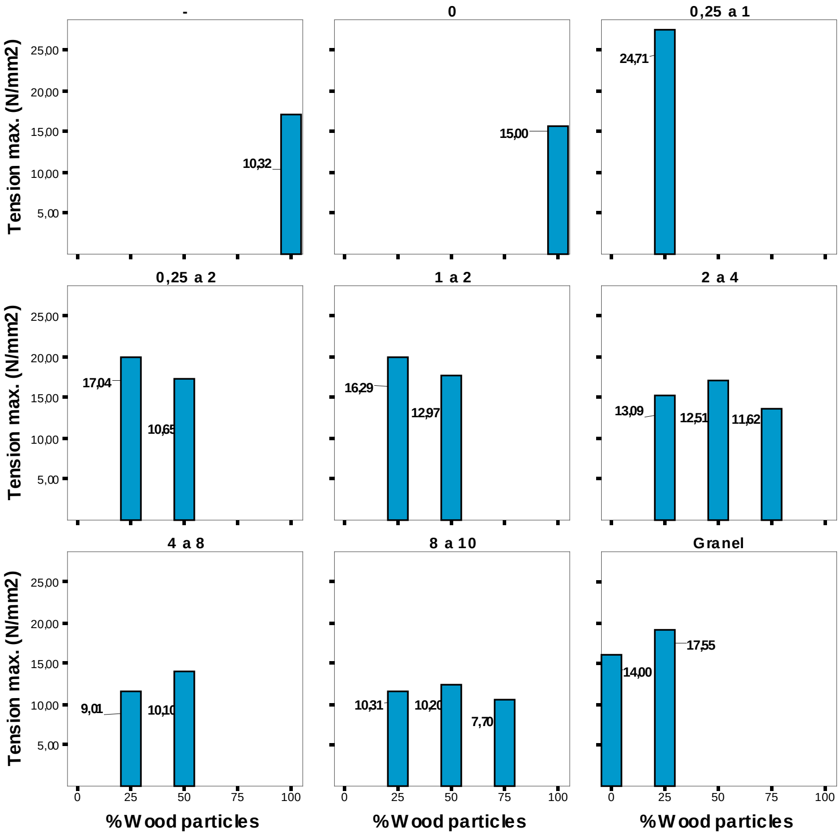

Figure 10.Characteristic resistance of boards according to reed size and wood percentage.

We can see that the typical resistance for the boards with 25% wood and reed particles of 0.25 to1 mm is very high (24.7 N/mm^2) in contrast to the industrial wood board (15.0 N/mm^2). Furthermore, as the size of reed particles increases, resistance decreases. Flexure force can also been seen to decrease with small reed particles and a higher proportion of wood. However, with large particles it increases up to 50% and then decreases. A significant fact is that without adding wood, the ‘bulk’ reed boards reach a typical resistance of 14 N/mm^2, and on adding 25% wood, 17,55 N/mm^2 resistance is obtained, which is greater than that of both materials separately.

If we analyse the characteristic Modulus of Elasticity in flexure according to reed size, wood percentage and humidity of fibres before manufacturing the board, (1) drying in oven and (2) without drying, we obtain the results indicated in figure 11.

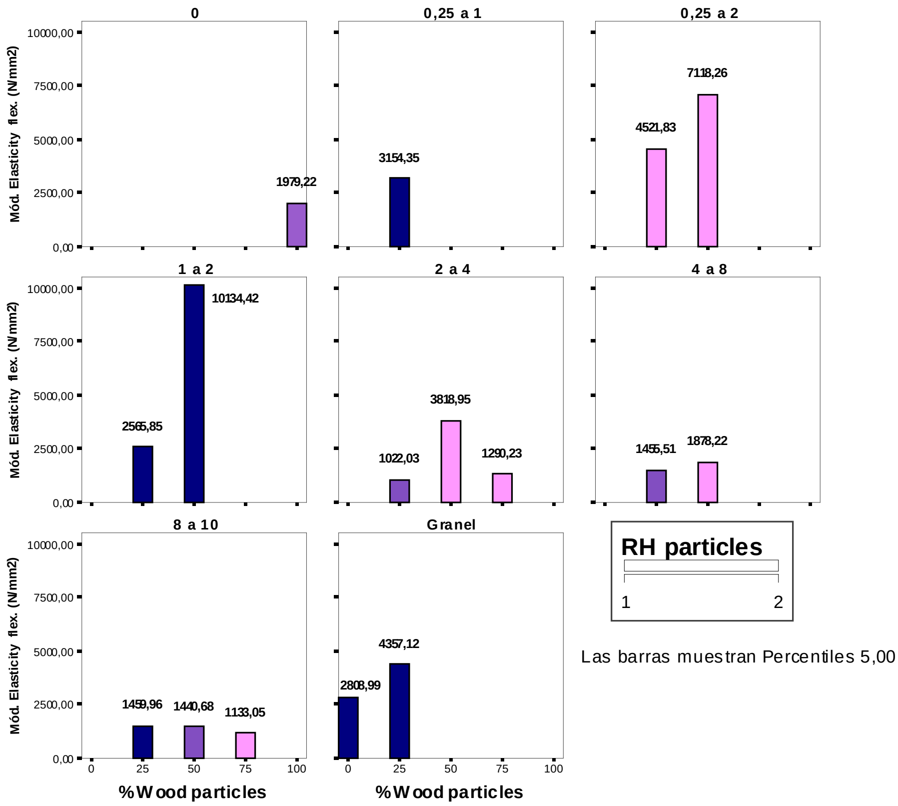

Figure 11.Characteristic Modulus of Elasticity f the boards according to reed particle size and wood %.

Boards with a reed particle size between 0.25 and 2mm combined with 25 and 50 percentage of any type of wood particles have a greater Modulus of Elasticity than the 100% wood boards, which indicates that they are good boards; even boards made with bulk reed increase the Modulus of Elasticity with 25% wood.

4. Conclusions

Reed particles and wood particles in a 75/25 ratio and thicknesses of 0.25 to 1 mm show affinity, obtaining a typical breakage load in flexure of 24.71 N/mm^2, wood particle boards made by the same process in the laboratory 10.32 N/mm^2 and industrial boards with 8% adhesive 16 N/mm^2. Therefore, boards with greater flexure resistance are obtained and they also have a lower percentage of thickness swelling.

Modulus of elasticity is greater with reed particles between 0.25 and 2 mm in 25/75 and 50/50 reed-wood ratios.

Reed is a vegetable fibre which combined with wood provides wood boards with improved properties.

5. References

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