



Modular panel with wood and particleboards of sugarcane bagasse for cattle handling facilities

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ABSTRACT. This work aimed at the construction and structural evaluation of modular panel with reforested wood, particleboards of sugarcane bagasse and a bi-component resin based on castor oil, for use in lateral closing for construction of crowding pens and chutes for cattle handling facilities. The quality of the particleboards was evaluated considering the requirements of NBR 14810 (ABNT, 2006) and A208.1 (ANSI, 1999). The structural performance of the modular panel was evaluated by the soft body impact testing. The results indicate that the particleboards have physical and mechanical properties that meet the minimum recommendations of the normative documents for structural use. The modular panel shows structural performance suitable to withstand impact loads equivalent to conditions of use, and can be used in cattle handling facilities.

Keywords: zootechnical facilities, waste, working chute, crowding pen.

Painel modular em madeira e chapas de partículas de bagaço de cana-de-açúcar para curral de bovinos

RESUMO. Este trabalho teve como objetivo a construção e avaliação estrutural de um painel modular em madeira de reflorestamento, chapas de partículas de bagaço de cana-de-açúcar e resina poliuretana bicomponente à base de óleo de mamona para aplicação em fechamento lateral de seringa e tronco coletivo (brete) de centro de manejo para bovinos. A qualidade das chapas de partículas de bagaço de cana-de-açúcar foi avaliada com base nas prescrições dos documentos normativos NBR 14810 (ABNT, 2006) e A208.1 (ANSI, 1999). O painel modular teve seu desempenho estrutural avaliado por meio de ensaio de impacto de corpo-mole. Os resultados obtidos indicam que as chapas de partículas possuem propriedades físico-mecânicas que atendem as recomendações mínimas dos documentos normativos para uso estrutural. O painel modular apresentou desempenho estrutural adequado para resistir às cargas de impacto equivalentes as de condições de uso, sendo possível indicá-lo com alternativa para fechamento lateral de centro de manejo para bovinos.

Palavras-chave: instalação zootécnica, resíduo, brete, seringa.

Introduction

Brazil is the largest commercial producer of cattle in the world, with 176.6 million head (ANUALPEC, 2010), being one of the most important economic activities in the agroindustrial sector, accounting for a substantial portion of the GDP and generating more than nine million jobs, directly and indirectly. From the 90's, with the effects of globalization, the livestock sector (beef cattle) has shown a significant need for advances to increase its productivity and economic competitiveness. Brazil, the largest exporter of beef, has been gaining more and more markets around the world.

Initially, the production of beef cattle does not require much technology. In general it is pasture-

based, requiring more area than for milk production. The production is annual and demand less care when compared to dairy production. The herd covers a greater number and requires higher initial capital, despite using simpler facilities, usually for cattle handling facilities and pasture (SOUZA et al., 2003).

According to Bicudo et al. (2002), cattle handling facilities comprise a group of structures necessary to manage the beef cattle, including holding pens, working chutes, squeeze chutes, balances and loading chutes. The facility is used to safely and efficiently confine cattle for observation, sanitary handling and routine handling procedures.

The working chute leads the animals from the crowding pen to the holding pens or squeeze chute.

Its purpose is to keep the animals in a single row so that they can be transported for treatment or loading area. The working chute must be at least 6 meters long, regardless of the size of the herd. The sides of the working chute shall be closed, like the crowding pen, which contribute to the welfare of the animals during handling. A crowding pen is used to funnel the animals into the working chute. A properly designed crowding pen has a large impact on the welfare of the animals (BICUDO et al., 2002).

For Huhnke and Harp (2009) the working chute and crowding pen represent the core of the cattle handling facilities. The curved shape, with closed and sloping sides, is a desirable characteristic for successful management.

Apart from the architecture, it is necessary to use closed sides in the crowding pen and working chute. The building materials have to absorb the impact caused by the animal and at the same time have structural integrity. Wood has been used for decades in the handling facilities as an effective material but has limitations of constrained shapes, dimensions and supply. Thus, the association of wood with other construction materials represents an efficient solution for livestock production.

Among materials with potential for use in conjunction with wood stand out the particleboards. Particleboards originated in Germany in the early 40s, as a way of enabling the use of wood waste, due to the difficulty of obtaining woods with good quality caused by isolation of the country during the Second World War (MENDES et al., 2010). These panels are typically manufactured from wood particles bonded by adhesive or other synthetic binder. The wood and adhesive system is then hot pressed so the resin can be cured (IWAKIRI et al., 2004).

According to some studies, the panels can also be made from lignocellulosic waste material, which has a high mechanical strength, since the chemical composition of lignocellulosic materials is similar to wood. Residual lignocellulosic materials contain less lignin and hemicellulose compared to hardwoods, while having a higher content of pentosan type. Researches have indicated that the agroindustrial waste is more promising due to its low cost, abundance and structural similarities to wood, more precisely, compared with hardwoods, they have a lower lignin content and an increased content of pentosan (SOUSA et al., 1986).

According to data from CONAB (2012), the harvest of sugarcane in Brazil in 2011/12 were approximately 602 million tons, which generated about 168 million tons of sugarcane bagasse. Therefore in agreement with Silva et al. (2007), each

ton of processed sugarcane generates a total of 280 kg of waste.

Generally, the bagasse is burned to produce energy for industrial use, but due to its physicochemical characteristics, it is currently being used for several purposes, from the production of animal feed, biodegradable plastics, sodium bicarbonate and ammonium chloride, to the manufacturing of particle panels (SILVA et al., 2007).

Projections on the production of sugarcane bagasse show a steady increase over the years, with an estimated production of 285 million tons for the 2020/2021 crop (CONAB, 2011).

Several studies were developed to assess the viability of using sugarcane bagasse in the production of particleboards: Okino et al. (1997), Contreras et al. (2006), Battistelli et al. (2009), Xu et al. (2009), Mendes et al. (2009), Fiorelli et al. (2011), Barros Filho (2011). However, these studies evaluated the viability of using sugarcane bagasse to produce particleboards.

In this context, this work aimed to examine the construction and structural characteristics of a modular panel made from reforested wood and sugarcane bagasse particleboards made with a bi-component polyurethane resin based on castor oil (resin), for the application of closing the sides of crowding pens and working chutes of cattle handling facilities.

Material and methods

Reforested wood (*Eucalyptus* sp.), sugarcane bagasse and bi-component polyurethane resin based of castor oil were used for the production of modular panels.

Production of particleboards

Sugarcane bagasse particleboards were prepared using a heated automatic press with a load capacity of 1000 kg, as described by Maloney (1996). The sugarcane bagasse (Figure 1A) was collected from a processing plant and dried to a moisture content of 12%. The bagasse was used in fiber length of 0.008 m. The particleboards were prepared with 15% resin manufactured by Plural Brazil.

8 mm-long particles were mixed with the resin in a planetary mixer (Figure 1B). After mixing, the material was placed in a mold (Figure 1C), which was then inserted into the hydraulic press (Figure 1D) and pressed for ten minutes at 50 kgf cm⁻², and temperature of 100°C to a density of 1000 kg m⁻³ (high density – structural application). The particleboards were prepared with nominal dimensions of 0.40 m x 0.40 m x 0.01 m. From these

particleboards, 10 specimens were taken for each physicomechanical test, as recommended by the Brazilian NBR 14810 (ABNT, 2006) standard for Plywood Sheets. This standard was chosen due to the similarity between the sugarcane bagasse particleboards produced in this study and wood panels, to which the test was designed for.

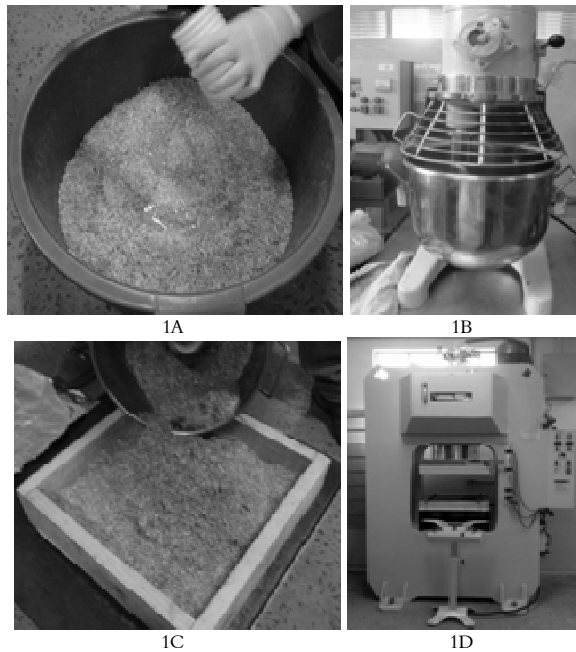


Figure 1. Steps of particleboard production. Sugarcane bagasse mixed with bicomponent polyurethane resin based of castor oil (A); 8 mm-long particles were mixed with the resin in a planetary mixer (B); the material was placed in a mold (C); the material was into the hydraulic press (D).

Physicomechanical characterization

The performance of the particleboards was evaluated by physical and mechanical tests according to the Brazilian NBR 14810 (ABNT, 2006) standard for Plywood Sheets. The properties evaluated were thickness swelling (TS), water absorption (WA), modulus of rupture (MOR), modulus of elasticity (MOE) and internal bonding (IB).

Thickness swelling (TS)

Thickness swelling tests were conducted according to the Brazilian NBR 14810 (ABNT, 2006) standard. Thickness swelling is calculated from the difference in thickness before and after soaking in water for 24h. This swelling was measured using a digital caliper accurate to 0.01 mm. The percentage of thickness swelling was calculated using the equation 1:

$$TS(\%) = \left[\frac{T_f - T_i}{T_i} \right] * 100 \quad (1)$$

where:

T_f is the final thickness after soaking for 24h and

T_i is the initial thickness.

Water absorption (WA)

Water absorption tests were performed according to the NBR 14810 (ABNT, 2006) standard. The samples before and after accelerated aging were soaked in water for 2 and 24h. Water absorption was calculated using equation 2.

$$WA(\%) = \left[\frac{W_f - W_i}{W_i} \right] * 100 \quad (2)$$

where:

W_f is the final weight after soaking for 2 and 24h and

W_i is the initial weight.

Mechanical testing

Flexural bending and internal bonding (IB) (Figure 2) tests were conducted using a universal testing machine at room temperature, according to the NBR 14810 (ABNT, 2006) standard. The loading rate applied to measure the bond strength was set to 4 mm min.⁻¹. The MOR and MOE were determined by a three-point bending test in the universal testing machine operating with a load cell capacity of 5 kN. A total of ten specimens were prepared and tested.

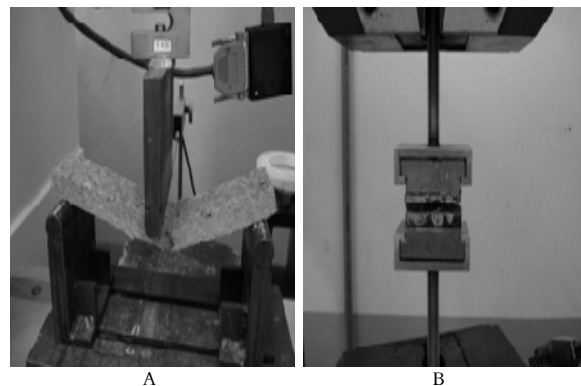


Figure 2. Bending test (A) and internal bond test (B).

Production of modular panels

To construct the modular panel (2.20 x 0.52 x 0.13 m), two timbers (2.20 x 0.11 x 0.05 m) and four sleeper timbers (0.06 x 0.42 x 0.11 m) of *Eucalyptus* sp. were used with four sugarcane bagasse particleboards (nominal density of 1000 kg m⁻³) of dimensions 0.52 x 0.52 x 0.02 m (Figure 3).

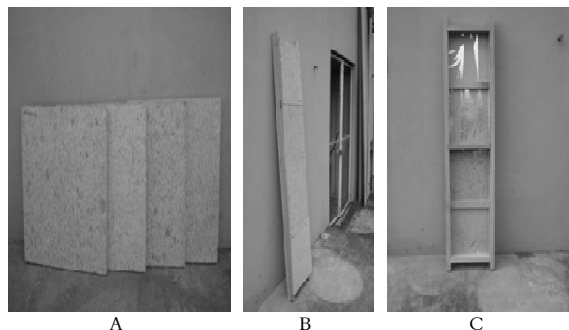


Figure 3. Sugarcane particleboards of 0.02 m width (A); front view of the modular panel (B); rear view of the modular panel with detail in structure of reforested wood (C).

The final dimension of the modular panel was established on the basis of the real dimensions of the working chute and crowding pen of cattle handling facilities (Figure 4). The width of 0.52 m was adopted in order to facilitate assembly (lower weight of panel) and also to allow the execution of curves.

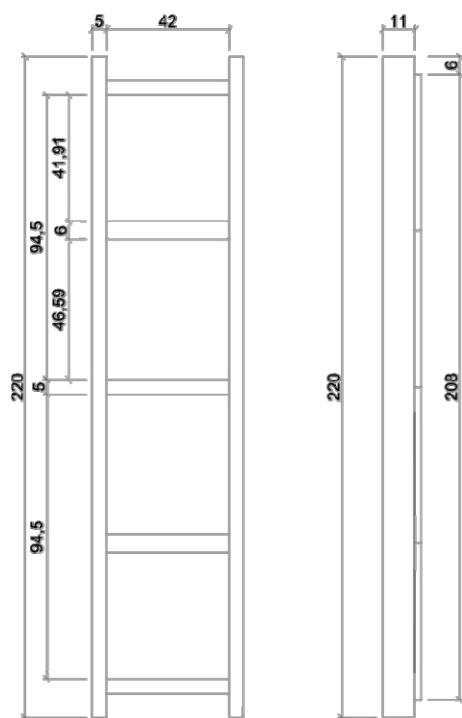


Figure 4. Rear and lateral view of the modular panel (dimensions in cm).

Mechanical characterization of the modular panel (soft body test)

The mechanical characterization of the modular panel was performed by the soft body impact test, with the goal of simulating the impact caused by the cattle. This test was carried out following the procedures of the normative MB-3256 (ABNT, 1990) – Divisórias leves internas moduladas –

Verificação da resistência a impactos. This standard was used given the similarity between the panel and the panels under study.

For this test, we employed a steel frame, leather bag, and a device for recording the transverse displacements. The steel frame had two beams (with vertical displacement) of steel filled with concrete, which were adjusted so that the gap between them was 2.20 m (Figure 5A). The attachment of the modular panel in the steel frame was performed by screws (Figure 5B). The leather bag with dimensions of 0.35 m diameter and 0.90 m height, which was used as the soft body, was filled with a mixture of sand and sawdust (40 kg) (Figure 5C). The record of the transverse displacements carried out by the device was set in the center of mass of the posterior surface of the modular panel (Figure 5D).

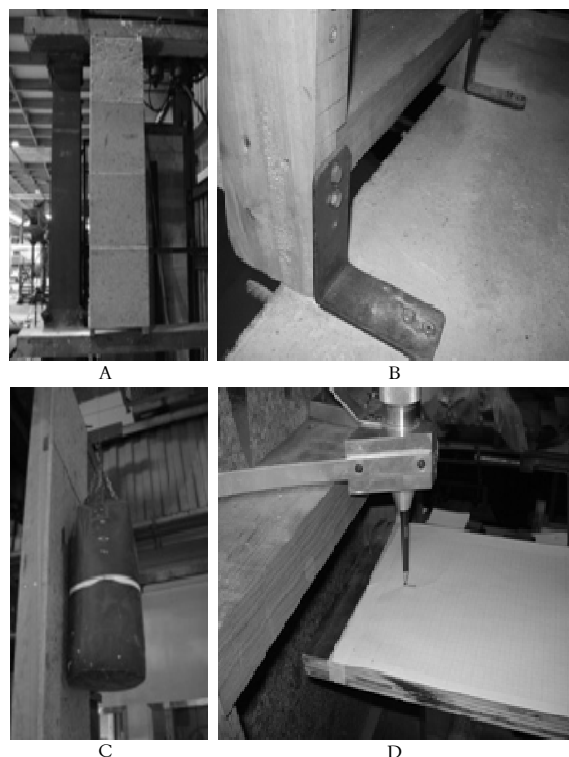


Figure 5. Panel set in the steel frame (A); attachment of the panel on the steel frame (B); leather bag used as soft body (C); device for recording the transverse displacements (D).

Different loads were applied to the modular panel at different intensities, corresponding to the impact caused by the animal, and we measured the horizontal displacement and structural changes. Table 1 lists the initial height of the soft body (40 kg), the energy caused by this body, bovine mass variation and the corresponding energy. An adult animal at a distance of approximately 0.15 m from

the side walls would produce an energy of 675 J, equivalent to the energy caused by the impact of the soft body when dropped from a height of 1.80 m.

Table 1. Height and energy corresponding to each impact of leather bag.

Soft Body			Bovine		
Soft body mass (kg)	Height (m)	Energy (J)	Animal mass (kg)*	Height (m)	Energy (J)
40	0.15	60	100	0.15	150
40	0.30	120	200	0.15	300
40	0.45	180	250	0.15	375
40	0.60	240	300	0.15	450
40	0.90	360	350	0.15	525
40	1.20	480	400	0.15	600
40	1.80	720	450	0.15	675

*Rosa et al. (2001).

Results and discussion

This section presents the results of the physical and mechanical characterization of the sugarcane bagasse particleboards and the mechanical characterization of the modular panel.

Physical and mechanical properties - sugarcane bagasse particleboards

Table 2 presents the results of the physical and mechanical properties of the sugarcane bagasse particleboards and the minimum values recommended by normative documents for particleboards of wood A208.1 (ANSI, 1999) - mat-formed wood particleboard and NBR 14810 (ABNT, 2006). The use of these normative documents is justified by the similarity of the product developed in this study with particleboards of wood.

Table 2. Mean values of physical and mechanical properties.

Physical and mechanical properties	Experimental (C.V.)	NBR 14810 (ABNT, 2006)	A208.1 (ANSI, 1999)
Density (kg m ⁻³)	947 (5.51)	551 - 750	800
TS (%)	2h 5.8 (20.9) 24h 20.0 (13.8)	8	-
WA (%)	2h 5.6 (8.8) 24h 20.1 (15.2)	-	-
MOE (MPa)	2848 (7.29)	-	2400 - 2750
MOR (MPa)	22.60 (6.32)	18	16.5 - 23.5
IB (MPa)	1.18 (31.64)	0.40	0.9 - 1.0

C.V. - Coefficient of variation.

Results were obtained from panels with a density of 947 kg m⁻³, classifying the particleboards as high density, according to the A208.1 (ANSI, 1999). This classification is important because minimum values of MOE, MOR, IB, TS and WA are closely related to the density. Similar values were obtained by Fiorelli et al. (2011), who evaluated the physical and mechanical properties of sugarcane particleboards made with bi-component resin based on castor oil resin with a density of 930 kg m⁻³. The particleboards showed swelling values in 2 hours just below the 8%

recommended by the NBR 14810 (ABNT, 2006), but above that recommended by the standard A208.1 (ANSI, 1999) in 24h.

The MOR property showed an average value of 22.67 MPa, within the recommended range for high-density particleboards by the standard A208.1 (ANSI, 1999) and exceeding the recommended values by the NBR 14810 (ABNT, 2006). Thus, it is possible to conclude that the particleboard under study can be used for industrial and commercial use. The MOR value of particleboards under study were superior to those obtained by Contreras et al. (2006), Battistelli et al. (2009), Okino et al. (1997) and Widyorini et al. (2005), indicating that the production process used was consistent and that the bi component resin based on castor oil presents an adhesive potential for manufacturing particleboards from sugarcane bagasse.

Values of the MOE of the particleboards in study were higher than the recommended by the standard A208.1 (ANSI, 1999), which is 2750 MPa. The results obtained for MOE are superior to those found by Okino et al. (1997), which identified a MOE below 2300 MPa for sugarcane bagasse particleboards bonded with urea resin.

Regarding IB, the particleboards in this study had higher values than those recommended by normative documents NBR 14810 (ABNT, 2006), and A208.1 (ANSI, 1999) and also above 0.4 MPa, the value found by Battistelli et al. (2009) and 0.6 MPa, observed by Okino et al. (1997). These results demonstrate that the level of resin used was appropriate, it is possible to evaluate the possibility of reducing the amount of adhesive so resin could be saved in the manufacturing process, also reducing the costs of the manufacturing process.

Mechanical properties of modular panel (soft body test).

The soft body test evaluated the resistance of the modular panel when requested by an impact load corresponds that caused by animals under conditions of use. Table 3 presents the values of horizontal displacement (instantaneous and residual) and identification of occurrences of flaws in modular panel.

Table 3. Result of soft body impact.

Height (m)	Weight (kg)	Energy (J)	Horizontal displacement (mm)		Occurrences
			Instantaneous	Residual	
0.15	40	60	7	2	No failure
0.30	40	120	12	4	No failure
0.45	40	180	18	7	No failure
0.60	40	240	23	8	No failure
0.90	40	360	25	11	No failure
1.20	40	480	34	13	No failure
1.80	40	720	38	15	No failure

The modular panel exhibited horizontal displacement of up to 38 mm (energy of 720 J) and returned to its starting position without any visual damage (fissure, rupture, crack or any other change), in the particleboards or in the structure of modular panel. Figure 6 illustrates the modular panel and a detail of the wood structure after the test of soft body, showing no change after successive impacts.

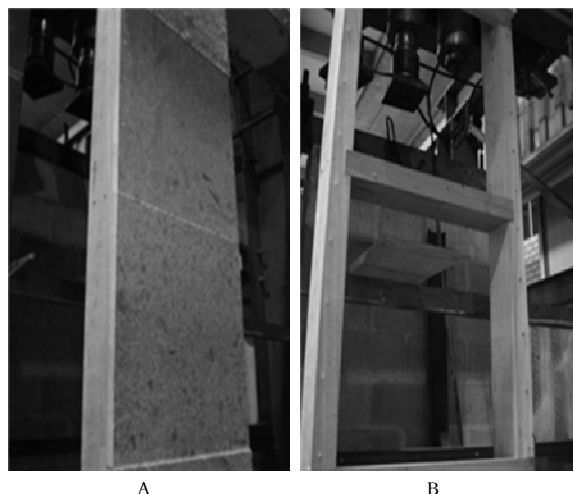


Figure 6. Detail of the modular panel after test (A); detail of the structure of the wood without the particleboards after test (B).

Results obtained by this test allowed to conclude that the modular panel meets the requirements, and can be used as side walls in the working chute and the crowding pen in cattle handling facilities.

Conclusion

Production parameters of particleboards are suitable, as confirmed by physical-mechanical results that meet the standards and are equivalent to the particleboards manufactured on an industrial scale, based on wood particles.

The structural behavior of the modular panel with reforested wood and particleboards of sugarcane bagasse, evaluated by the soft body test, indicated the overall efficiency in resisting impact loads equivalent to the impact of animals in real conditions of use, being viable its application as side closure of cattle handling facilities.

Acknowledgements

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