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Abstract

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ABSTRACT

The production and study of alternative material produced with lignocellulosic waste to application in livestock production installation is not common in Brazil, however, is a great sustainable alternative as substitutes of conventional materials, therefore, the present study aimed to evaluate the structural performance of modular panel of homogeneous sugarcane bagasse particleboards and reforestation wood, by numerical and experimental analysis, with application prospect as lateral closure in cattle handling facilities. The evaluation of the modular panel performance was conducted by a numerical simulation by way of finite elements, in laboratory by soft body impact test, in situ, applied to a crowding pen of corral for cattle management. The results indicated good correlation among experimental and theoretical values and the modular panels met satisfactorily the proposed use as a lateral closure for cattle handling facilities.

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1. INTRODUCTION

The birth, growth, and development of plants and animals in agricultural production systems depend on specific buildings that provide adequate conditions to these situations, requiring specific architectural designs. In agriculture, buildings must produce optimal environmental conditions for plants and animals and ensure hygiene and health for the workers involved in the day-to-day care of these living organisms at different stages of their development (FUENTES et al., 2010; PICUNO et al., 2015; PICUNO, 2016).

Regarding the facilities for beef cattle, Carneiro (1979) states they are always more rustic and simpler when compared to those of dairy cattle, basically consisting of corrals, fences, and scales. In agreement with these statements, Fiorelli and Medeiros (2008) mention that rural facilities for beef cattle are most often performed with projects and old technologies, not focusing on animal welfare and worker safety.

Management activities in the pasture or confined cattle production system require adequate facilities for the management of the animals. Euclides Filho et al. (2002) claim that improper installation and endanger the animals and the staff responsible for its management, contribute reducing competitiveness and commitment quality of meat and leather. Thus, a well-designed bovine handling facility has as main benefits the bruises reduction in the animal carcasses and injuries in the people, having a significant impact on the ease of handling and movement of the animals, as well as on the well-being of these (GRANDIN, 1983; PETHERICK, 2005).

A corral for bovines comprises a group of structures necessary to manage the animals, as holding pens and gates, access/sorting alley, crowding pen and gate, working chute, headgate and holding chute/squeeze, scale and loading chute. It is used to safely and efficiently confine cattle for observation, routine sanitary management and handling procedures (BICUDO et al., 2002).

The internal walls of the crowding pen, working chute and loading chute access ramps should be smooth and free of protrusions, such as nail tips, screws, or hardware that could damage the animal. Paranhos da Costa et al. (2002) cites the efficiency between handling and the material which is made surrounded the corral and other areas of work with animals, especially regarding the sealing of the side walls of the premises. Which prevent the cattle get distracted or frightened by external events, causing stop, retreat and even animal jump, delaying the completion of the work.

Several papers relating the production of particleboards based on agroindustrial residues, as substitutes for conventional materials, have been found in the literature. As shown by Maduwar et al. (2013), with the aim of developing sustainable materials that promote the natural resources use reduction.

Among all the lignocellulosic residues, the sugarcane bagasse has been highlighted, being used and studied by several researchers. These have been testing the potential of their use as the main raw material or as part of the composition and production of particleboards (FIORELLI et al., 2013; JONOOBI et al., 2016; SANTOS et al., 2014; TABARSA et al., 2011; MENDES et al. 2010; MESQUITA et al. 2018; ZHANG et al., 2018). This is due to its lignocellulosic structure one name of hardwoods, which contains less lignin content and higher pentosan content (SOUSA et al., 1986).

Sugarcane bagasse is classified as a solid residue and can be considered a by-product, resulting from sugarcane crushing in the sugar-alcohol plants. The proportion of production depends on the amount of fiber present in the sugarcane cultivars, estimated in Brazil at 270-290 kg of bagasse for each ton of processed cane (BRAZIL, 2011).

Development and application of new technologies application in facilities intended for agricultural production are not common in Brazil. Thus, it creates a shortage and dependence as the parameters, recommendations and technologies developed abroad, these being appropriate the specific needs of their realities. Therefore, this paper proposes the material production for improving the production system, based on a lignocellulosic waste and evaluation of performance when applied in facilities for livestock production.

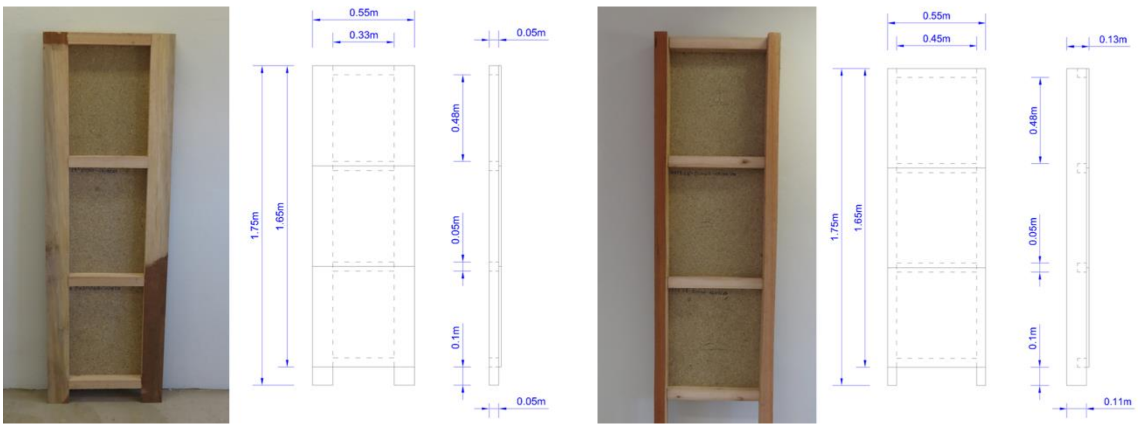
The present work had as objective to produce and evaluate the structural performance of modular panel of reforestation wood and homogeneous sugarcane bagasse particleboards. The structural analysis will be performed through numerical simulation and experimental measurement. The outstanding result enables the panels to be applied as a lateral installation closure for cattle.

2. MATERIAL AND METHODS

For manufacturing the modular panels, beams and rafters of sawn timber of the genus *Eucalyptus spp*. from planted forests. The homogeneous sugarcane bagasse particleboards were produced following the guidelines established by Sartori et al. (2012).

2.1. Assembly of modular panels

The assembly of the modular panels followed two models that differed by position of the wood beams making up the panel structure: Closing Panel (CP) and Structural Panel (SP) (Fig. 1). To prepare the modular panels were used beams (0.05 × 0.11 m) and rafters (0.05 × 0.05 m) of wood, and three homogeneous particleboards of sugarcane bagasse agglutinated with two-component polyurethane resin based on castor oil (PU-castor oil). The structure was made by fitting the wood and the screws fixed the particles.

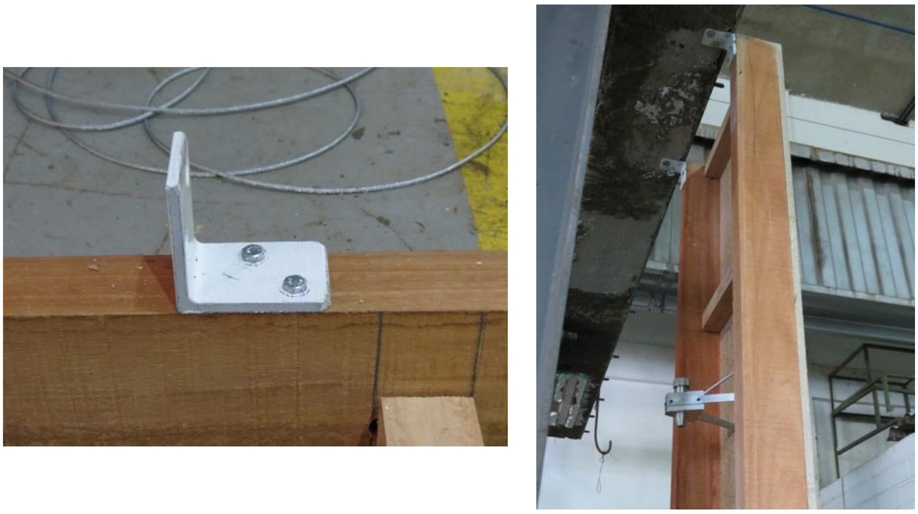


(a) (b)

Fig. 1. Type of modular panels and their dimensions: (a) Closing Panel. (b) Structural Panel.

2.2. Soft Body Impact Test

Soft body impact test was carried out following the precepts of the ABNT standard MB-3256: 1990 - Modular internal light partitions - Impact resistance verification. Through this test it was possible to verify the behavior of the modular panel when subjected to impacts applied to the structure, simulating an impact caused by an adult bovine. To perform the test, it was placed modular panels in a gantry with beams adjustable to their structure, composed of steel and concrete. The fixation of the modular panel was performed using metal parts, made for such use (Fig. 2).



(a) (b)

Fig. 2. Fixing the modular panel. (a) Metal part for fixing. (b) Fixing the modular panel to the gantry.

The span between the gantry beams was 1.75 m (Fig. 3a). As a soft body, a synthetic leather bag of 0.35 m in diameter and 0.90 m in height was used, filled with a mixture of wood shavings and sand in a ratio that would complete its volume and reach the mass of 40 kg (Fig. 3b). It fixed the device for registering the transverse displacements in the center of the modular panel, corresponding to the impact location of the soft body and it recorded the displacement on a sheet of graph paper (Fig. 3c).

(a) (b) (c)

Fig. 3. Soft body impact test: (a) Modular panel positioned and fixed to gantry. (b) Leather bag used as a soft body. (c) Device for recording displacement at impact.

For performing the soft body impact test was released from various heights corresponding to different energy intensities. Table 1 shows the heights and respective impact energies, considering the 40 kg mass of the leather bag. The highest energy used in the tests was 600 J, which corresponds to an impact of an adult cattle, all measurements were performed in duplicate.

Table 1. Impact energies corresponding to the soft body abandonment height.

h (m)	E (J)
0.15	60
0.30	180
0.45	240
0.90	360
1.20	480
1.50	600

After each test, it was measured the residual and instantaneous transverse displacements. A visual inspection throughout the modular panel was carried out to identify ruptures and cracks in the wood structure, particleboards and the connecting elements (fitting and screws).

2.3. Numerical simulation

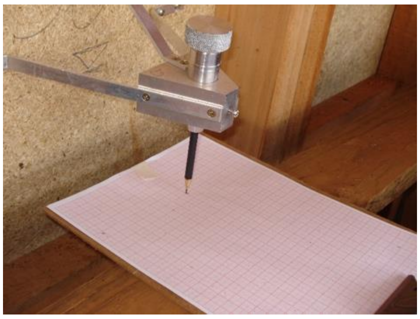
It was performed the dynamic nonlinear numerical simulation of modular panels structural behavior (geometric and contact) in Radioss V120 software, with explicit integration in time. The simulations were done under the same conditions set forth in the soft body impact test as described above. The values of the mechanical properties of the constituent materials of the modular panels (homogeneous sugarcane bagasse particleboards and *Eucalyptus* spp. Wood) were used. It was considered the elastic-linear behavior for materials. The simulations were done on a computer with a 4-core I3 processor, the time of each simulation was 3 h.

Modular CP and SP panels were evaluated at 6 soft-body drop height levels, similar to the experimental procedure of the soft-body impact test (Table 1). For the theoretical modeling, solid elements were considered hexahedral for the wood and for the sandbag, shell elements for the homogeneous sugarcane bagasse particleboards and bar elements for the steel cable. For the boundary conditions, the modular panels were fixed (all degrees of freedom) at the ends, as performed in the soft body impact test. The steel cable was fixed (displacement only) at its upper end. It was attributed a vertical acceleration of 9.81 m/s^2 corresponding to gravity. The contact restrictions were established between the sandbag and the modular panel.

2.4. Structural performance evaluation of modular panels applied to management corral

Modular panels were applied in a cattle management corral at the University of São Paulo (USP), Faculty of Animal Science and Food Engineering (FZEA), Campus of Pirassununga-SP. It was attached to the crowding pen sides (Fig. 4a). All CP were supported and fixed on the existing crowding pen side wall, since ones were only fixed at their ends on the floor and at the top, having their length free. It measured the horizontal displacements in four modular panels of SP types, with the same device used in the soft body impact test (Fig. 4b), it installed in the geometric center of each SP. The SP modular panel was evaluated under two different management system: i) experimental management (with the amount of controlled animals) and ii) conventional management (without controlling the amount of animals).

(a)



(b)

Fig. 4. Bovine management center: (a) Crowding pen internal view. (b) Device to measure horizontal displacement.

3. RESULTS AND DISCUSSION

3.1. Soft body impact test

Table 2 shows instantaneous transverse displacements and residual values to CP and SP samples got for each impact point, and the observation of occurrences after each impact applied to modular panels.

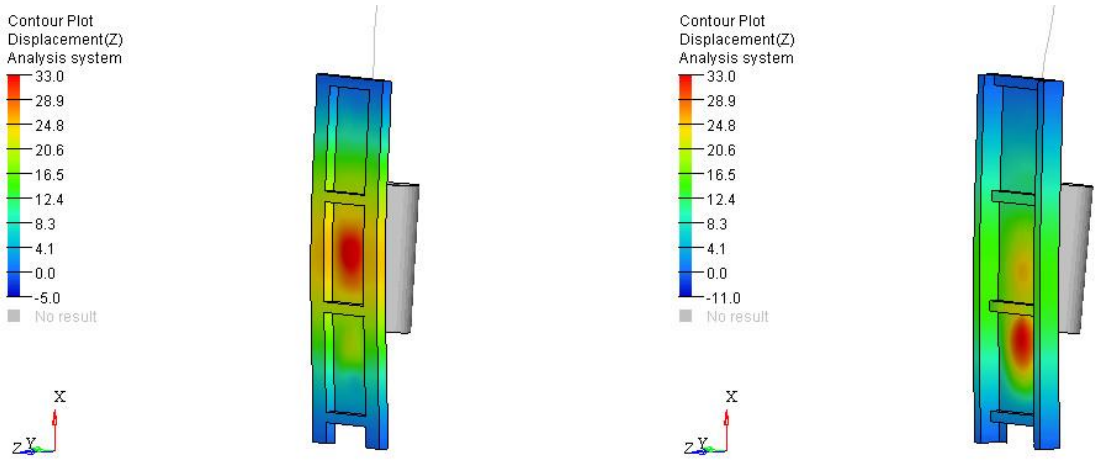
Table 2. Transversal displacement of the soft body impact test in SP and CP for different energy levels.

Heigh (m)	Impact numbers	Energy (J)	Transversal displacement (mm)				Occurrence
			Instantaneous		**Residual**		
			SP	**CP**	**SP**	**CP**	
0.15	**1**	**60**	3	8	0	0	No Occurrence
	2		3	8	0	0	No Occurrence
0.30	**1**	**120**	6	11	1	1	No Occurrence
	2		6	13	1	1	No Occurrence
0.45	**1**	**180**	9	18	1	2	No Occurrence
	2		7	20	1	2	No Occurrence
0.60	**1**	**240**	10	24	2	2	No Occurrence
	2		11	25	2	1	No Occurrence
0.90	**1**	**360**	15	30	2	5	No Occurrence
	2		20	23	5	1	No Occurrence
1.20	**1**	**480**	23	28	5	5	No Occurrence
	2		19	31	2	3	No Occurrence
1.50	**1**	**600**	27	37	5	6	No Occurrence
	2		28	36	4	6	No Occurrence

The SP and CP modular panels present average value for instantaneous transverse displacements of 22 mm and 13 mm, respectively. The results show that the SP presented a better efficiency in resisting the applied impact. This is due to the structural configuration of its construction with the wooden beams in the largest moment of inertia position. It was also observed that after the soft body impact test there was no occurrence of cracking, fissures and other types of damages in the components and structure of CP and SP.

3.2. Numerical simulation

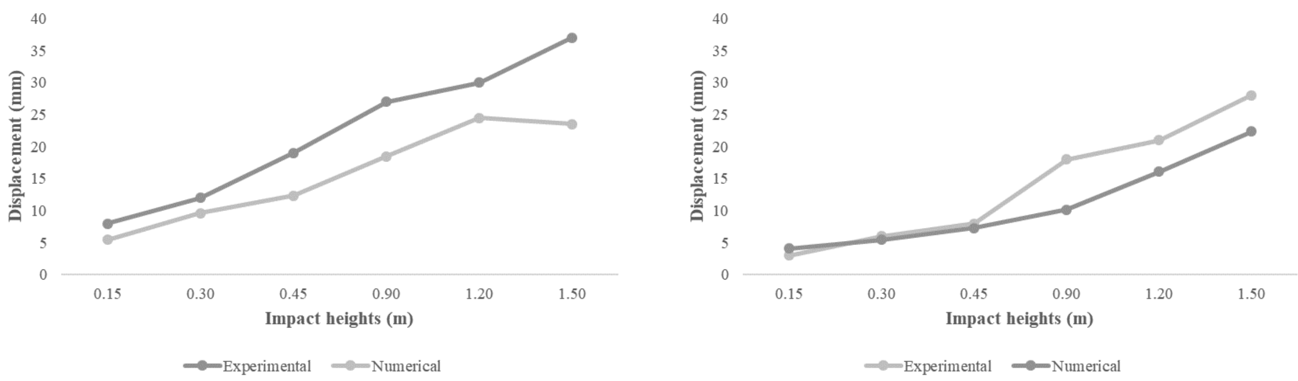
Fig. 5 shows the maximum transverse displacements of the SP and CP samples got through numerical simulations. Fig. 5a presents the results for the CP modular panels, and Fig. 5b for the SP, the impact height was 1.5 m.



(a) (b)

Fig. 5. The figure shows the horizontal displacement distribution, by numerical simulation, for the height of 1.5 m for the samples of (a) CP and (b) SP.

Theoretical maximum transverse displacements values obtained by performing the numerical simulation, and the experimental results of the soft-body impact test, for the six different levels of impact height tested, are presented in Fig 6.



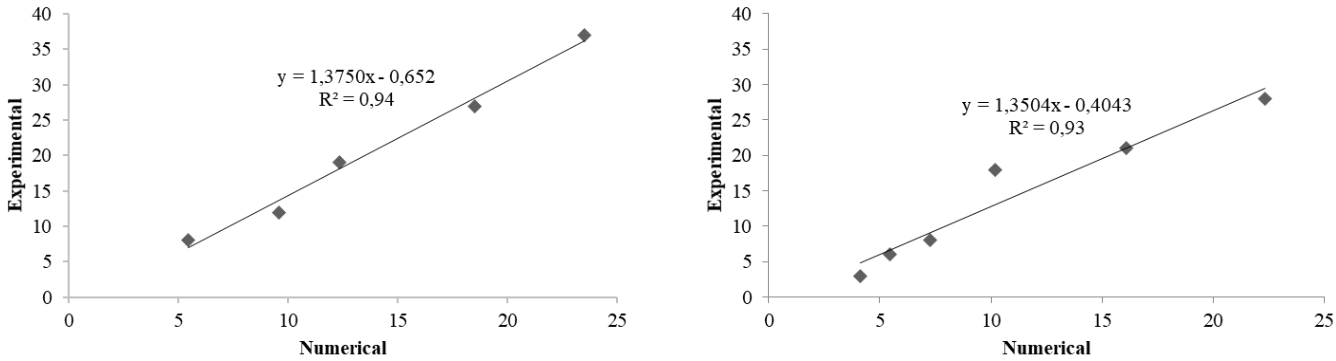
(a) (b)

Fig. 6. Data obtained experimentally and by numerical simulation of transverse displacements for samples (a) CP and (b) SP.

The numerical simulation showed lower transverse displacement values than those obtained in the soft body impact test. This is due to the numerical form of structural system linkage (end fitting), which made the system more rigid than the real one. Only for the SP sample at a clearance height of 0.15 m the numerical value was higher than the value in the assay.

For the impact heights corresponding to the energies of 60, 120 and 180 J (see table 2), a correlation between the numerical and experimental values was observed. For heights over 0.90 M and J = 360, the values began to diverge. This effect can be explained by the occurrence of an inlay in the connections between the homogeneous sugarcane bagasse particleboards to the modular panel wood structure, a condition that was not considered in the numerical model. The SP samples presented lower values for transverse displacements for all the impact heights when compared to the CP samples, i.e., a panel with a more rigid structure.

In order to verify a correlation between the variables studied, a linear regression analysis was performed between the results of experimental and numerical simulation transversal displacement. These are shown in Figs. 7a and 7b, for the CP and SP samples, respectively. The analysis showed a linear relationship between the parameters studied, with a reliability of over 93% for both samples.



(a) (b)

Fig. 7. Scatter diagram of experimental and numerical samples transverse displacements (a) CP and (b) SP, respectively.

3.3. Modular panel applied in crowding pen of corral for cattle management

Table 3 shows the average values of the maximum horizontal displacements of SP modular panels measured during the experimental managements (with the amount of controlled animals) and conventional (without controlling the amount of animals).

Table 3. Average values of maximum instantaneous transversal displacements of SP modular panels.

Kind of management	Day	Maximum instantaneous transversal displacements (mm)	General Average (mm)
	1	0.25	
Experimental	2	3.75	1.50 ± 1.95
	3	0.50	
	1	4.25	
Conventional	2	5.00	4.25 ± 0.75
	3	3.50	

When analyzing the maximum instantaneous transverse displacement, for the three days of management tested for each treatment in both conditions, a maximum value of 3.75 mm was observed for the experimental management and of 5.00 mm for the conventional one. The trend of greater displacements in the SP modular panels in the conventional management days was clearer when observing the general average of the treatments, getting a value of 4.25 mm for the conventional and 1.50 mm for the experimental one.

The value difference of SP modular panel displacement between the conventional and experimental management was 2.75 mm, i.e., SP modular panel presented the 65% transverse displacement higher when conventional management was applied. This variation can be explained by three main factors, being the first one related to the animal category, since for the Conventional treatment, young animals of the Nellore breed, with an approximate age of 14 months, presented a more agitated and reactive temperament to the handling, thus leading to a greater movement in the moment of agglomeration in the crowding pen and greater and more intense contact with the lateral walls of the installation. The other two factors that may have contributed to explain the greater displacement observed in the SP are related to: a) way of conducting the management, being a more dynamic management and representing the employee routinely in rural properties; b) failure to respect the crowding pen stocking rate, with the allocation of a larger number of animals at the filling stage of the crowding pen stocking rate.

The results of the maximum horizontal displacements of SP modular panels for the experimental and conventional managements compared with those obtained on the soft impact test and numerical simulation have demonstrated the efficiency of SP on the application proposed. The average value of the maximum instantaneous transverse displacement was 5 mm, much lower than the 28 and 22 mm obtained in the soft body impact test and numerical simulation, respectively.

4. CONCLUSIONS

Based on the results of this study, the following concluding remarks can be mentioned:

Theoretical and experimental transversal displacement values of the modular panels of homogeneous sugarcane bagasse particleboards and reforestation wood (CP and SP) showed a relationship between the data, validating the proposed numerical model.

SP presented better structural performance when compared to the CP closure panels, when subjected to the tests of soft body impact and numerical simulation.

SP, when applied as a lateral closure in a crowding pen of corral for cattle management, presented a transverse displacement lower than the values obtained in the soft body impact test and in the numerical simulation, confirming the technical feasibility of this constructive component.

The production of modular panels of homogeneous sugarcane bagasse particleboards and reforestation wood for use as a lateral closure in a crowding pen of corral for cattle management may be recommended.

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