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Sound Absorption of Brazilian wooden panels and their use as Building Components

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ABSTRACT

In this study, the normal incidence sound absorption coefficients were obtained from three types of wooden panels (with different thicknesses of them): Oriented Strand Boards (OSB); Medium Density Fiberboards (MDF) and Wood-wool cement boards (WWCB). The panels were manufactured according industrial processes, using Brazilian woods and reaching lower levels of CO_2 eq emissions in its Life-cycle Assessment when compared to the conventional building techniques for vertical sealings in Brazil. The panels are used in the furniture market, but the results show that the material can be used in order to improve the sound absorption of a room as an acoustic panel, a ceiling or other type of building element.

Keywords: Wooden panels, sound absorption.

1. INTRODUCTION

The built environment, which includes buildings and infrastructure, involves large quantities of material and energy consumption and is an essential component of the economic and social development (17). The construction industry is responsible for considerable natural resources diminution and generates a substantial amount of wastes (16).

The reduction of CO_2 emissions in the construction sector is a key element for the achievement of energy conservation and emission-reduction goals worldwide (27).

Life cycle assessment (LCA) is a technique regulated by ISO 14040 (19) and ISO 14044 (20) that compiles the inputs and outputs of a product or service quantifying its carbon footprint. The LCA takes a comprehensive and systemic approach to environmental evaluation, and because of that, the interest in incorporating LCA methods into building construction is increasing, supporting decisions for selection of environmentally preferable products, as well as for evaluation and optimization of construction processes (1,7). The life cycle impact assessment (LCIA) is the first step of the LCA calculation process and the output of it is the carbon footprint.

According to Caro (8) "carbon footprint is an easy-to-apply tool for monitoring and quantifying greenhouse gas emissions, as well as checking mitigation/reduction programs at different scale. It is able to capture the total amount of greenhouse gas emissions directly and indirectly caused by a country, an activity or accumulated over the life stages of a product". Its unity is the CO_2 eq (carbon dioxide equivalent).

Huang et al. (17) described that the three main pivotal opportunities to reduce the carbon emissions of a construction sector are the use of low embodied carbon material and services at life cycle

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perspective; the energy efficiency increasing of construction machines and the promotion of the renewable energy use.

In Brazilian typical buildings, Evangelista et al. (13) described the concrete, steel and ceramic tiles as the highest environmental impact materials, with repercussions for the structure, masonry and coating subsystems. Crippa et al. (9) predicted a carbon footprint about 335 kg CO_2eq/m³ (50.3 kg CO_2eq/0.15m of thickness) for a sealing built with clay brick and plaster undercoat and about 302 kg CO_2eq/m³ (45.3 kg CO_2eq/0.15m of thickness) for a sealing built with concrete block and plaster undercoat. These sealing systems are commonly built in Brazilian buildings.

Estokova et al. (12) related that vertical bearing walls and partition walls represented 28.3% of the carbon footprint estimated for twenty conventional masonry houses built in central Europe. It is only behind the foundations, which had 57.8% of representative in the carbon footprint.

This research aims to analyze the sound absorption properties of some wood panels, made from Brazilian woods, suggesting their use as building elements in Brazilian construction sector as acoustic panels, floors, ceilings or coating subsystems in order to improve the sound absorption of a room.

Three different types of wooden panels will be tested in order to achieve their sound absorption coefficients: Oriented Strand Boards (OSB), Medium Density Fiberboards (MDF) and Wood Wool Cement Boards (WWCB). By nature, wood is made of carbon that is captured from the atmosphere during tree growth. The effects of substitution and sequestration are why the carbon impact of wood products is favorable (5).

Their carbon footprint (cradle-to-gate) is shown in Table 01. The presented value per m³ for WWCB was calculated considering a thickness of 25mm (4.85 KgCO_2eq/0.025m).

Table 1 – LCIA of different panels

Type of panel	Quantity of material, m³	Kg CO_2 eq	Source
OSB	1.00	127.0	(15)
MDF	1.00	199.0	(24)
WWCB	1.00	194.0	(30)

Aiming in the acoustical properties, it is well known that the reverberation time (RT) in a room can be detrimental to speech intelligibility (21). The RT can be increased or decreased according to the building materials absorption properties. From the materials perspective, sound absorbing porous materials perform an important role in the room acoustics (11), and the reverberation time can be reached by adding or suppressing absorption areas, as the descriptions of the pioneering work of Sabine (26), who developed a model based on the statistical theory of sound field – it considers the same density of sound energy at any point of a room, with the same probability of incidence at any directions. This model could be used in a room with known volume and sound absorption coefficients.

Different models were developed through the years, improving the Sabine's model, as shown in the research of Nowoświat et al. (22). The sound absorbing properties of the material is expressed by the sound absorption coefficient α as a function of a sound frequency band. The "α" values ranges from 0 to 1.00 referring to a total reflection situation to total absorption situation (11).

2. MATERIALS AND METHODS

The OSB is a multi-layer panel made from strands, with strips of wood with a length greater than 50mm and a thickness less than 2mm, glued with a synthetic resin. The strands in the outer layers are parallel and aligned to the length of the panel. The strands in the center layer of layers can be randomly oriented (or aligned) generally perpendicular to the outer layers (14). At most, Brazilian OSB are manufactured with pine wood particles obtained from dedicated forests mainly from *Pinus elliottii* and *Pinus taeda* (loblolly pine) (15). These species are not native and reforestation programs provide them. Ferro et al. (15) discussed the environmental aspects of the OSB production through its Life-Cycle Assessment.

According to Piekarski et al. (24), the MDF "is an engineered wood product, made by breaking down softwood into wood fibers and combining them with wax and resin to form panels by applying high temperature and pressure". The same research gives its Life-Cycle Assessment according to the Brazilian way of production. The MDF is primarily used as furniture, in joinery industry and in interior architecture design.

The Brazilian WWCB is also produced from dedicated forests (as the OSB and the MDF). As the described by de la Grée GD et al. (10), the WWCB is produced by the following sequence: the stored wood logs are cut into in small blocks (about 25cm in length), so that shredded to wood-wool in super fine straw (width≤1mm), fine straw (1-3mm in width) or thick straw (width ≥ 3mm). Then, the wood-wool is dipped in a solution to accelerate the compatibility at wood-wool-cement paste interface and are afterwards pressed do decrease water content. The wet wood wool moisture content with cement powder are fed into a continuous mixer. After that, the mixture is transported to a distribution machine which spreads the mixture in layers into the molds which will be pressured by a hydraulic press. After the setting of cement, the boards are taken from the molds for further curing, and a process of storage starts. Finally, the plates can be painted, stacked and placked. An example of the LCA for a WWCB is described in Thinkstep et al. (30).

It was tested different thickness of the panels, as shown in Table 02. 100 samples were measure which means that 10 samples were set for each type of panels.

Table 2 – List of samples

Type of panel	Thickness, mm	Density approximately, g/cm^3	Number of samples	How is referenced	Indicated letter in Figure 1
MDF	9.00	0.55	10	MDF – 9mm	c
MDF	12.00	0.55	10	MDF – 12mm	b
MDF	15.00	0.55	10	MDF – 15mm	a
OSB	8.00	0,52	10	OSB – 8mm	f
OSB	12.00	0,52	10	OSB – 12mm	e
OSB	25.00	0,52	10	OSB – 25mm	d
WWCB with thick straws	17.00	0.40	10	WWCB – TKS 17mm	j
WWCB with thick straws	25.00	0.40	10	WWCB – TKS 25mm	i
WWCB with thick straws	50.00	0.40	10	WWCB – TKS 50mm	g
WWCB with super fine straws	25.00	0.46	10	WWCB – SFS 25mm	h

The Figure 1 shows the different types of panels tested in this research.

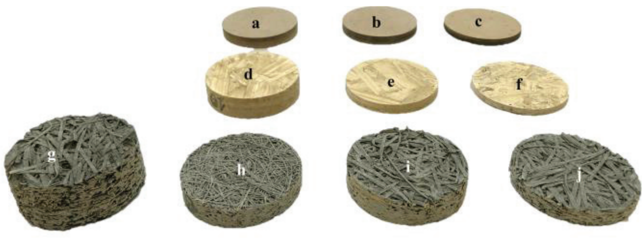

Figure 1 – Samples

An impedance tube (manufactured by SCS ControlSys, model 9020 B/K, with 98±2mm diameter) was used and the measurements were performed with the Transfer Function Method (28), providing the normal incidence sound absorption coefficient (α_N). A noise generator – Brüel & Kjær Type 3160-A-042 (6 channels) – and two array microphones with preamplifiers - Brüel & Kjær Type 4935 – controlled by a PULSE^{TM} completed the instrument set for measurements. The guidelines of ASTM C384-04 (4) and ISO 10534–2 (18) were applied.

After the measurements (10 samples per type of panel), a confidence interval (95% confidence level) was established with a t-distribution for each frequency between 100Hz and 2000Hz. A new average was calculated with the values into the confidence interval,

All the graphs and calculations were performed in the "R" software (25).

The Noise Reduction Coefficient was calculated according ASTM C423-17 (5), defined as "Round the average of the sound absorption coefficients for 250, 500, 1000, and 2000 Hz to the nearest multiple of 0.05".

3. RESULTS AND DISCUSSIONS

The Figures 2 to 6 present de normal incidence sound absorption coefficient for each type of panel. The plotted curves consider the new averages after the confidences intervals treatments.

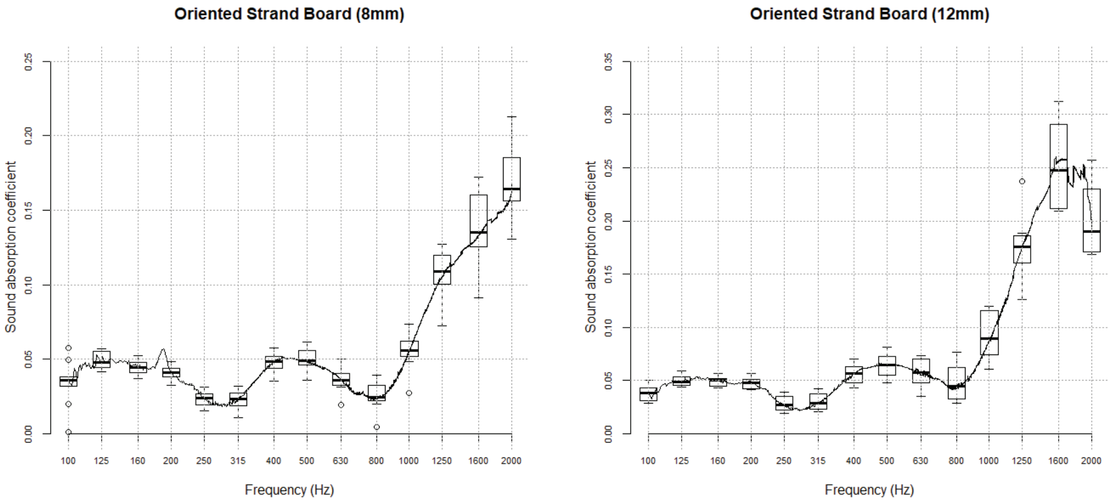

Figure 2 – α_N for OSB – 8mm and OSB – 12mm

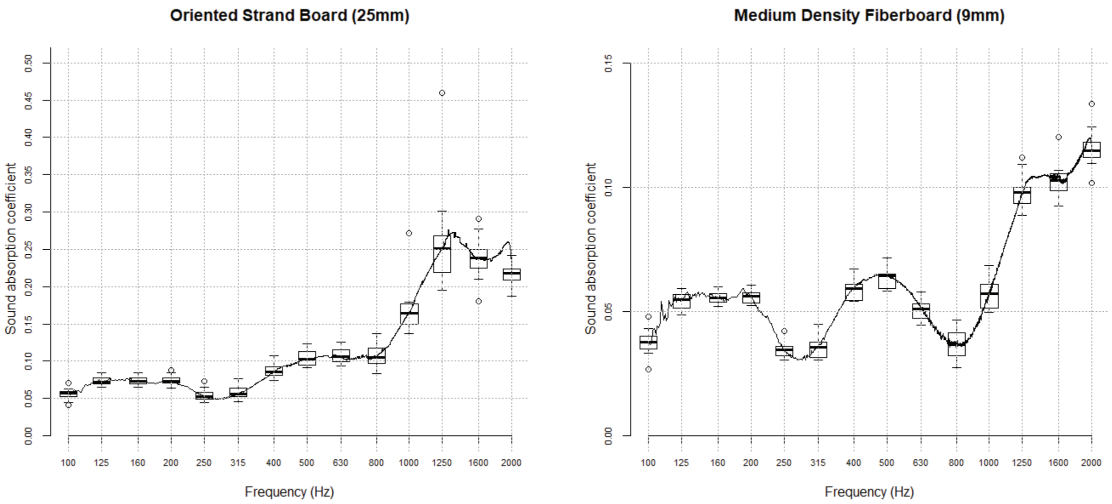

Figure 3 – α_N for OSB – 25mm and MDF – 9mm

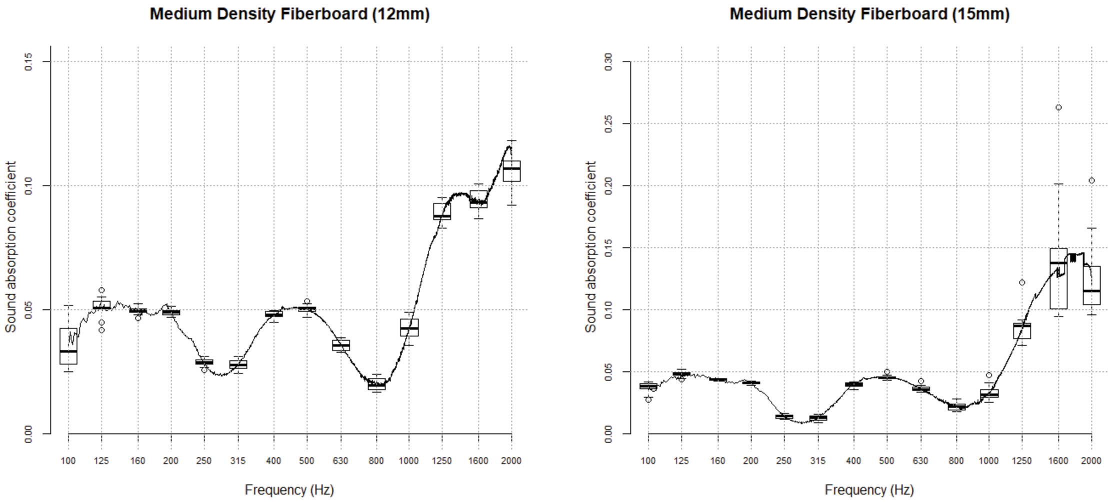

Figure 4 – α_N for MDF – 12mm and MDF – 15mm

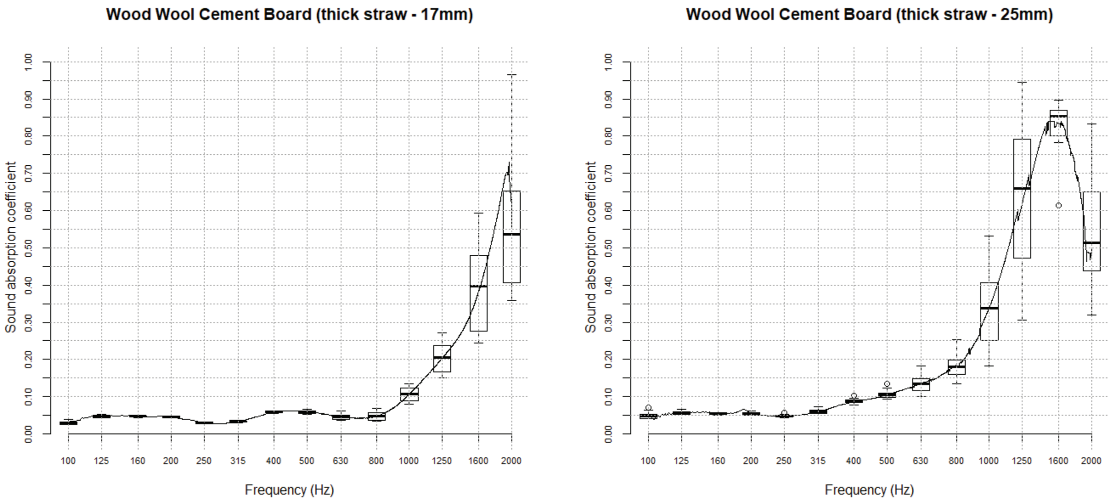

Figure 5 – α_N for WWCB – TKS 17mm and WWCB – TKS 25mm

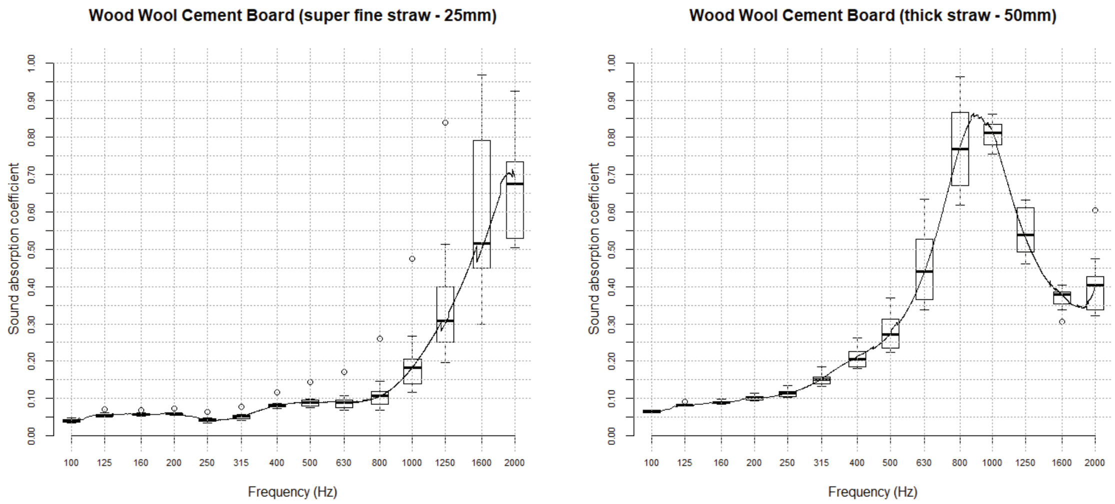

Figure 6 – α_N for WWCB – SFS 25mm and WWCB – TKS 50mm

Figures 7,8 and 9 show the sound absorption coefficients for different thicknesses of the OSB, MDF and WWCB, respectively.

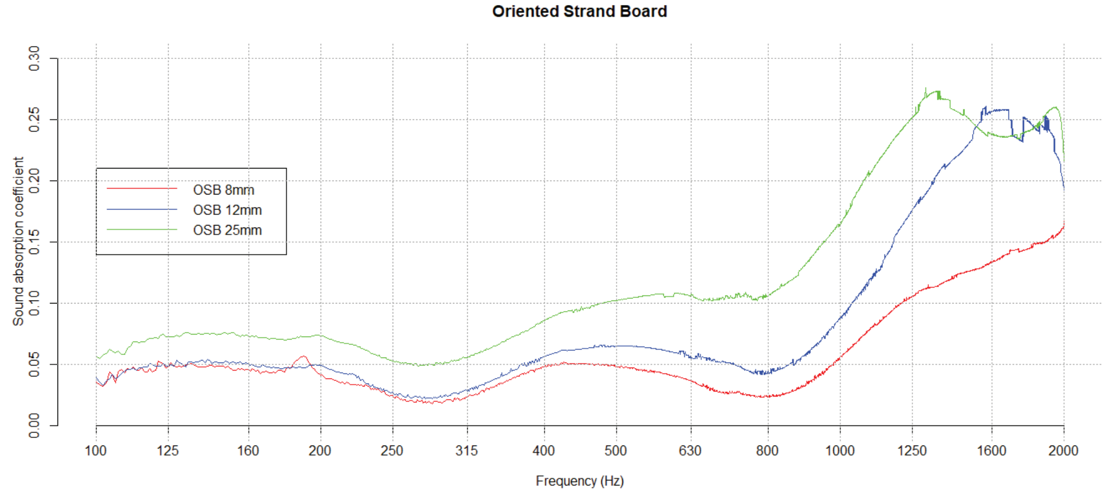

Figure 7– α_N for different thicknesses of OSB

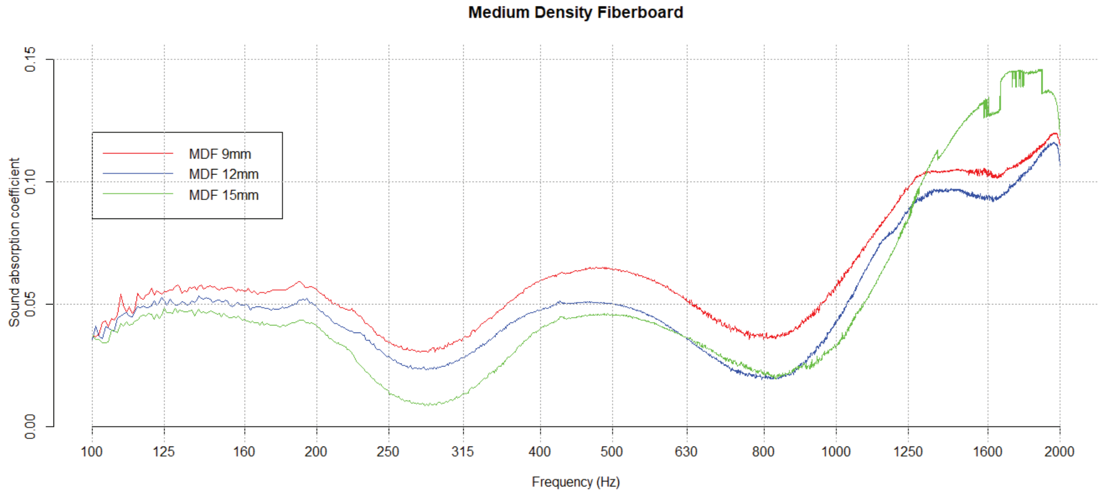

Figure 8– α_N for different thicknesses of MDF

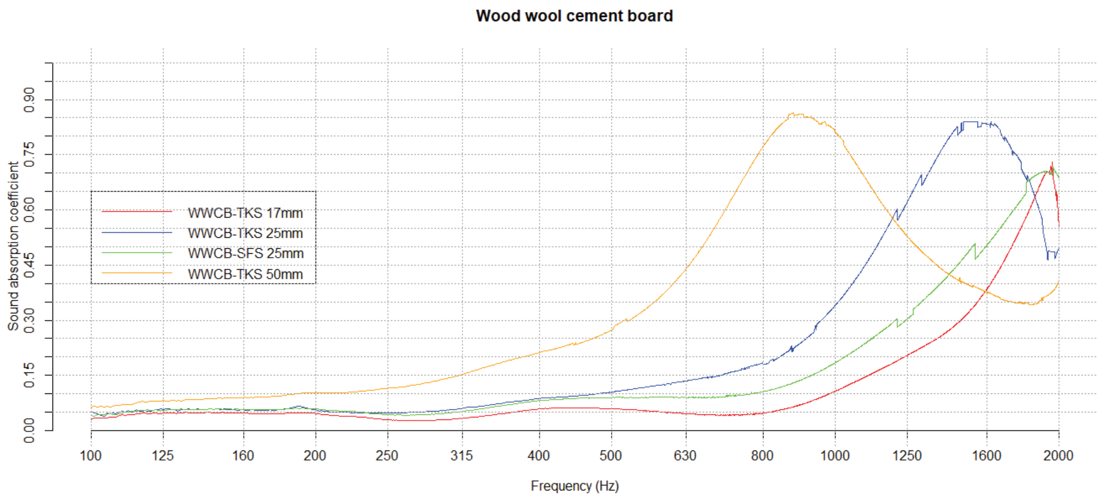

Figure 9– α_N for different thicknesses of WWCB

Table 03 shows the NRC of the panels.

Table 3 – NRC of the panels

Type	MDF 9mm	MDF 12mm	MDF 15mm	OSB 8mm	OSB 12mm	OSB 25mm	WWCB TKS 17mm	WWCB TKS 25mm	WWCB TKS 50mm	WWCB SFS 25mm
NRC	0.10	0.10	0.10	0.10	0.10	0.15	0.20	0.25	0.45	0.30

Palomar et al. (23) measured the normal incidence sound absorption coefficient for different compositions of lime-cement mortar obtaining the maximum value of 0.113 for a mortar with 1.59 g/cm³ of density, 96±2mm diameter and 40±2mm thick. If compared to the NRC values in Table 3 it could be concluded that the wood panels have better sound absorption coefficients than Brazilian commonly coating system.

The WWCB performed the best values for sound absorption and could be strongly recommended to acoustic treatments in order to decrease reverberation times. The WWCP – TKS 50mm has a α_N about 0.80 at 1kHz, which is a considerable value. The WWCB – TKS 25mm got higher coefficients than WWCB – SFS 25mm for frequencies above 450Hz, which means that the thick straws provide better absorption than the super fine straws. The highest α_N for MDF panels at low-frequency range is the MDF – 9mm (thinnest one). For the OSB, the highest values are those measured for the thickest one (OSB – 25mm).

Comparing the measured values of WWCB – SFS 25mm with other α_N values for a similar material (25 mm thick WWCB with 1.0 mm strand width and density of 0.448 g/cm^3) from the research of Botterman et al. (6) a similarity between the curves can be observed. The same occurs with the MDF – 9mm compared with the results of a 9mm thick MDF described by Wassilieff (31). For the OSB, comparing the measured results with those related by Smardzewski et al. (29) for an OSB with 17.5mm thick it could be noted that the plotted curve has the same design, but different values.

4. CONCLUSION

The study presented the normal incidence sound absorption coefficients obtained from three types of wooden panels (with different thicknesses of them): Oriented Strand Boards (OSB), Medium Density Fiberboards (MDF) and Wood-wool cement boards (WWCB). The panels described in this research can be used as ceilings, floors or part of internal vertical sealings instead of plaster or lime-cement mortar, which are widely used in Brazilian buildings. The OSB and the WWCP can also be used as a partition or façade wall in light steel framing or wood framing construction techniques. In both situations the levels of carbon footprint of buildings should be decreased because their lower level of carbon footprint (described in Table 1) when compared to Brazilian typical construction materials. Also, they have higher sound absorption coefficients than the lime-cement mortar, and they can be used in order to improve the acoustic conditions of a room.

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