Desde la Facultad
Da faculdade
From the Faculty

Structural thermal panel wall composed of guadua and cardboard

Experimental model applied to the climate of the Coffee Region

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Cassandro-Cajiao, R. (2018). Structural thermal panel wall composed of guadua and cardboard. Experimental model applied to the climate of the Coffee Region. *Revista de Arquitectura (Bogotá), 20*(2), 90-109 doi: http://dx.doi.org/10.14718/RevArq.2018.20.2.2116

http://dx.doi.org/10.14718/RevArq.2018.20.2.2116

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Resumen

Se propone un prototipo de panel compuesto, tipo SIP (Structural Insulated Panel), panel térmico estructural, como muro envolvente de vivienda, elaborado con materiales de origen natural renovables, específicamente guadua y cartón reciclados. El panel se compone de dos tableros externos OSB (Oriented Strand Board), tablero de virutas orientadas, y un aislante intermedio de cartón. En el estudio se elaboran dos modelos SIP experimentales con procesos de fabricación diferentes, los cuales son analizados y comparados con cuatro referentes comercializados a nivel mundial. Todos los paneles son simulados térmica y acústicamente en condiciones climáticas y meteorológicas de la ciudad de Pereira (Risaralda), con el fin de evaluar y comparar los resultados, lo que demuestra la viabilidad y competitividad del panel propuesto. Este estudio espera servir, además, como referencia de futuras investigaciones en la búsqueda de mejores materiales sustentables para la construcción.

Palabras clave: análisis de ciclo de vida, contaminación ambiental, materiales de construcción, panel OSB, panel SIP, recursos forestales, sostenibilidad ambiental.

Structural thermal panel wall composed of bamboo and cardboard. Experimental model applied to the climate of the Coffee Region

Abstract

This paper proposes a SIP (Structural Insulated Panel) type composite panel prototype, a structural thermal panel, as a building envelope wall made of renewable natural materials, specifically bamboo and recycled cardboard. The panel consists of two external OSB (Oriented Strand Board) boards, oriented chipboard, and an intermediate cardboard insulation. In the study, two experimental SIP models are developed, using different manufacturing processes, which are analyzed and compared with four commercial references worldwide. All the panels are simulated thermally and acoustically in the climatic and meteorological conditions of the city of Pereira (Risaralda), in order to evaluate and compare the results, demonstrating thus the viability and competitiveness of the proposed prototype. In addition, this study aims to serve as a reference point for future research in the search for better sustainable construction materials.

Keywords: Life-cycle analysis, environmental contamination, construction materials, OSB panel, SIP panel, forest resources, environmental sustainability.

Muro painel térmico estrutural composto de bambu e papelão. Modelo experimental aplicado ao clima da zona cafeeira

Resumo

Propõe-se um protótipo de painel composto, tipo SIP (Structural Insulated Panel), painel térmico estrutural, como muro envolvente de moradia elaborado com materiais de origem natural renováveis, em específico bambu e papelão reciclado. O painel está composto de duas placas externas OSB (Oriented Strand Board), placas de aparas orientadas e um isolante intermediário de papelão. Neste estudo, foram elaborados dois modelos SIP experimentais com processos de fabricação diferentes, os quais são analisados e comparados com quatro referentes comercializados no mundo inteiro. Todos os painéis são simulados térmica e acusticamente em condições climáticas e meteorológicas da cidade de Pereira (Colômbia), a fim de avaliar e comparar os resultados, o que demonstra a viabilidade e competitividade do proposto. Este estudo espera servir, além disso, como referência para futuras pesquisas na busca de melhores materiais sustentáveis para a construção.

Palavras-chave: análise de ciclo de vida, poluição ambiental, materiais de construção, painel OSB, painel SIP, recursos florestais, sustentabilidade ambiental.

Received: May 23 / 2018 Evaluated: July 30 / 2018 Accepted: August 13 / 2018

Introduction

Context

This article presents the results of the research entitled "Panel wall composed of guadua for housing units," which was completed as a degree work to obtain the title of Master in Sustainable Design at the Universidad Católica de Colombia, within the research line of Design and Technology. The project was carried out between 2015 and 2017, and its main objective was to develop a composite wall panel model using renewable natural materials, as a building envelope or exterior wall for housing units in a warm tropical zone.

The continuous growth of world population and its demand for housing makes the construction of dwellings an ongoing research topic that seeks to optimize materials regarding resistance, durability, functionality, economy, low environmental impact, and energy consumption in their life cycle.

Replacing the conventional materials of housing construction with renewable natural materials such as guadua, in places where there are guadua crops and production, is a tangible alternative for social and economic sustainability, since its industrialization will have benefits such as employment generation and low housing construction costs with interior comfort.

The importance of this tree or *gramineae* in construction and industry in Colombia is evident and has a promising future. According to the engineer Edgar Giraldo (2003, p. 19) and Mejía et al. (2009), "in Colombia, approximately 100,000 people derive their livelihood from the exploitation, management, and commercialization of guadua." Its benefits start with its planting since it is the best CO2 pollutant collector, including also oxygen generation, rapid growth, and multiplicity of applications (construction, textiles, ornamentation, and medicine).

The Regional Autonomous Corporations (CAR, for its initials in Spanish) are the entities responsible for ensuring the care and use of natural resources, through the Single Regulatory Decree of the Environment and Sustainable Development Sector (Decree 1076 of 2015), as well as the Forest Statute of the region, which regulates the exploitation of this and other species. In this case, the entity regulates the sustainable management of guadua from its planting to the execution of projects that allow its development with economic and social benefits for the region with the greatest number of crops, that is, the Coffee Region, which includes the departments of Caldas, Quindío and Risaralda, Tolima and Valle del Cauca (Mejía & Moreno, 2013).

During a field visit in mid-June 2017 to the factories or companies of "Induguadua" in La Tebaida, and "Armeideas en Guadua" in Calarcá, located in the Coffee Region, it was evident that the resulting waste percentage ranged from 30 to 40%, noting that in most cases these are used as fuel for the drying process of the guadua or for the production of coal, which produces a large amount of CO2 and further pollutes the environment. For this reason, it is a priority to propose alternatives for the use of this waste that do not pollute and take advantage of the excellent physical, mechanical, and aesthetic qualities of guadua for a variety of uses.

The global situation due to climate change, environmental pollution, and population increase requires a permanent search for alternatives and more efficient solutions for sustainability regarding production process, manufacturing, use and recycling, and energy consumption reduction, with a minimum production of CO2 emissions and other polluting gases.

The environmental impact and energy consumption of conventional construction materials, such as cement, concrete, clay, and PVC, are a major global concern, which makes it necessary to rethink building architecture by returning to its origins in the construction sector, using local materials with low energy costs and minimal environmental impact.

In the history of Colombia, in informal population settlements around the main cities, guadua has had—and continues to have—a constant and representative presence, which is one of the reasons why it is called with the derogatory term of "wood of the poor" (Colorado, n. d.).

> The generalized idea that guadua does not offer security for complex constructions and that its use should be limited only to popular-type dwellings was so influential that architects and engineers ignored, for years, historical testimonies that spoke of a tradition that had been developed since the end of the 19th century, in which bamboo was precisely the preferred material to build and to counteract earthquakes that shook the coffee region and other areas of similar conditions in the country (par. 32).

Today, it can be confirmed that these antecedents awoke in professionals, technicians, researchers, and farmers a futuristic vision towards the use of this natural, renewable, and sustainable resource, which is urgent to be materialized in specific projects.

The research focused on the use of guadua, which grows in specific climatic conditions of the tropical zone, with a warm temperate climate, that make

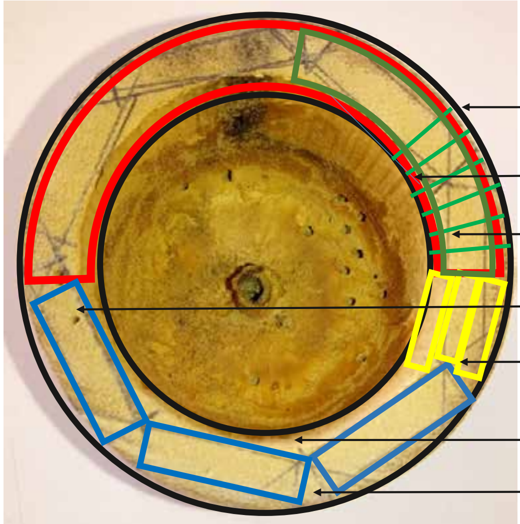


Figure 2. Lightweight composite panel "Eurolight," from the Egger manufacturer company
Source: Egger Inspiración Eurolight (2016, p. 3).

Figure 1. Elements extracted for construction
Source: Own elaboration, 2017, CC BY.

up an important part of the Colombian territory. It is used in construction due to its optimal physical and technical properties, so much so that, from pre-Hispanic times, it was the protagonist (with the native species *guadua angustifolia*) in the construction of dwellings in small towns and peripheral city areas (Varela & Chaviano, 2013). Guadua, during its transformation process to manufacture poles, canoes, slabs, panels or fibers, produces a large percentage of waste, which are generally used as fuel or transformed into charcoal, which generates greater environmental pollution.

The main function of a building envelope is to maintain constant thermal insulation properties and it includes all the elements that divide or separate the exterior from the interior. Its fundamental purpose is to keep the average internal thermal comfort between 18 and 20 °C.

The specific research objective was to take advantage of the resulting residual material, which means approximately 40% of the guadua culm (Figure 1), and to transform it into strands or flakes for the manufacturing of OSB (Oriented Strand Board) boards, in compliance with international regulations (Garay & Damiani, 2013), in order to form the main external surfaces of a SIP (Structural Insulated Panel) or structural thermal panel (Cardenas et al., 2015) (Figure 2), with an intermediate insulator made of recycled cardboard to be used as a building envelope for housing units in the Coffee Region, replacing thus conventional materials and offering a sustainable alternative.

Composite SIP panel

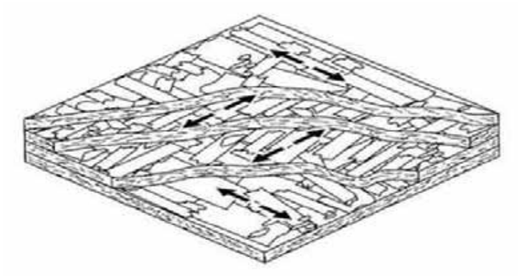
The industrialization of products based on residual or waste wood has solved many problems of raw-material deficit worldwide, and has opened up the opportunity to increase its applications, exalting qualities such as high resistance coefficient and thermal properties, which is reflected in its increased production from 12 million m3 in 1950, to 125 million m3 at present (Fernández, 1993). One of these products is OSB boards, also known as sterling board.

These boards are a relatively new product. The United Nations Organization for Food and Agriculture (FAO), in its statistical database, has global data on OSB, which show a 7% growth in production and commercialization in 2015 compared to the previous year, due to a growing trend towards eco-sustainable production (FAO, 2016). In spite of this, there is no production of OSB boards in Colombia, and the demand is very low, probably due to a lack of knowledge about OSB boards as a construction alternative, as well as to industrialization processes. Experience in other countries shows that these boards are a real, sustainable, and efficient alternative for light, fast, and resistant construction.

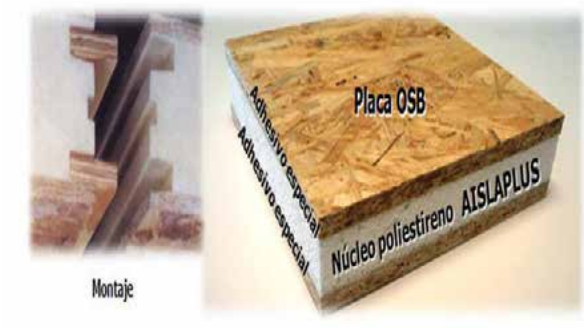
Currently, the materials of a SIP type composite panel (structural insulation panel or thermal structural panels) consist of two external boards made with flakes or strips of pine or fir wood (OSB), pressed and joined using chemical adhesives and oriented in the longitudinal sense, as well as two internal ones, placed in the perpendicular sense (Figure 3). Additionally, they have an internal core that functions as a thermal insulation, usually in polystyrene (Arquigráfico, 2016).

OSB boards are usually sold in a 244 x 122 cm (8 x 4 ft) format, with a thickness between 7 and 18 mm. Its main uses in construction are as bases for roofs, beams, joists, floors, stairs, as well as exterior and interior wall panels, among others.

OSB boards, according to their characteristics and specifications, are classified into four groups, recognized by manufacturers worldwide; regarding consumption, it is OSB-3 that has been standardized for the specific use of panel in a building envelope wall; and it is the one used for this research. The uses of the four groups are described below:



Ⓐ Figure 3. Cross orientation of strips in an OSB board
Source: Arquigráfico (2016).



Ⓐ Figure 4. SIP system, components
Source: Klasspanel (s. f.).

OSB-1. Interior use, basically furniture. It is the most basic range and its commercialization is currently very limited.

OSB-2. Load-bearing applications in dry environments.

OSB-3. Load-bearing applications in relatively humid environments; it is the most used type of board, with the best quality-price ratio.

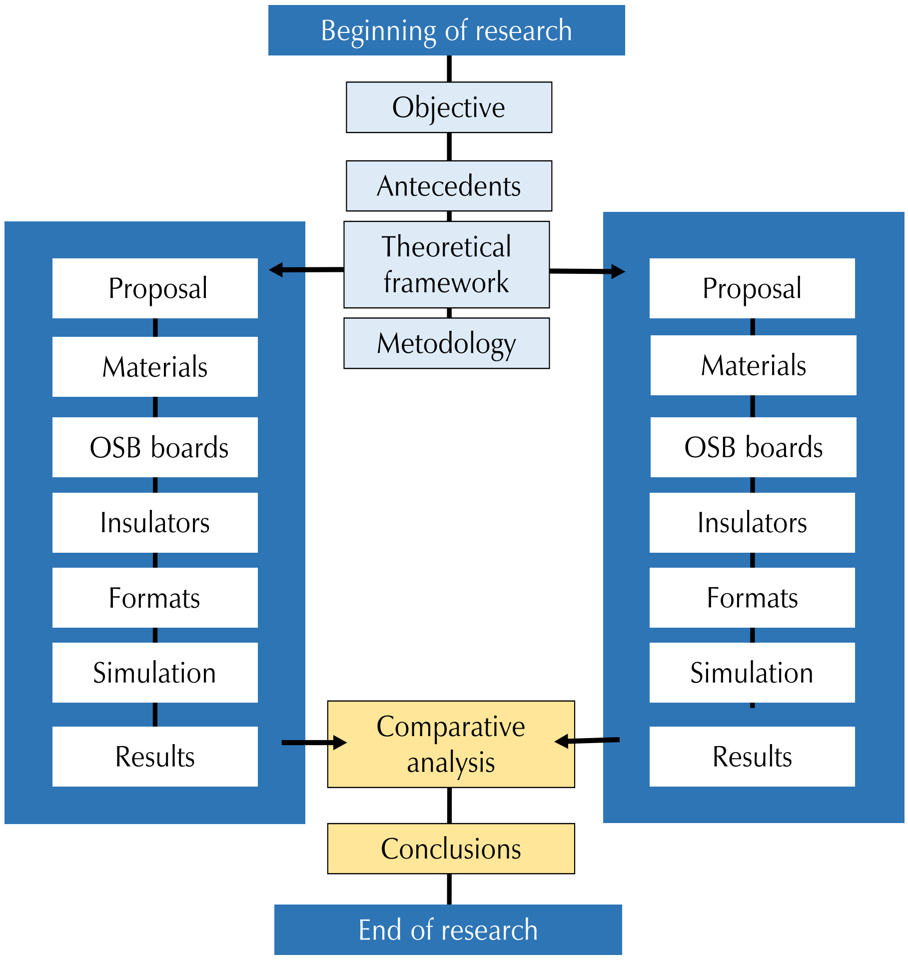
OSB-4. High load-bearing performance in relatively humid environments (Santana, 2015).

The most used internal insulation in SIP panels is EPS (expanded polystyrene) sheets, which consist of 98% air and 2% polystyrene. The thermal insulation capacity of a material is defined by its thermal conductivity; its unit is W/(m·K) and depends on the material's density (kg/m3). Therefore, thermal conductivity is higher in low-density sheets; it decreases as density increases and reaches a minimum above 30 kg/m3 (Grupo Isotex, 2015).

Expanded polystyrene has no low temperature limit, while the maximum allowable temperature depends on exposure time (Figure 4). In case of short exposure, it can withstand temperatures higher than 100 oC. However, during longer periods of exposure, it tends to deform and lose its rigidity.

Methodology

The research considered, in the first instance, antecedents and similar products that exist on the market today, using an experimental-descriptive method to examine the specific characteristics of panels employed in a specific place and climate, which are virtually simulated by means of thermal and acoustic softwares to describe their performance. Additionally, laboratory tests were carried out that complemented the proposed models, regarding resistance to horizontal and vertical load, and acoustic absorption.



Ⓐ Figure 5. Conceptual map of the development of this research
Source: Own elaboration, 2017. CC BY.

It is important to clarify that the scope of this research is limited to the realization of laboratory test models that allow evaluating thermal and acoustic behavior, weight, and horizontal and vertical resistance, to be compared with the values indicated by each manufacturer on the technical sheets, according to the regulations of their respective country of origin (Apa's Corporate, 2015). This, without taking into account all the characteristics of the final product, which would require more time and economic resources.

Figure 5, which corresponds to the conceptual map of the development of this research, shows the parallel processes that were carried out between referents and proposals to address the adjustments or drawbacks of each proposal.

Experimental procedure

1. Selection of four referents shown in Table 1. These were defined according to several aspects: their similarity in terms of dimensions regarding total thickness (approximately 100 mm), materials of the boards (agglomerated wood), as well as the specific use of panels as an exterior wall or building envelope (objective of the proposed model). In addition, they should be among those with the largest commercial representation internationally.
2. Realization of thermal and acoustic simulations for each referent (Table 2), by means of the THERM 7.5 and dBKAisla 3.01 softwares, taking as climatic data those of the city of Pereira (Risaralda), which was selected due to being one of the biggest growers and consumers of guadua for construction in the Colombian Coffee Region, with technological, social, and environmental advances in the region. As for the thermal characteristics of the product, data were collected from technical sheets, which in turn correspond to internationally authorized and standardized tables regarding the thermal properties of construction materials (Arquimaster, n. d.).
3. Development of two experimental models with the support of the companies Muiskay SAS in Bogotá and Primadera SAS in Gachancipá (Cundinamarca) for the production of OSB boards with guadua strips, following the general characteristics of the referents in terms of dimensions and thickness, and using the proposed basic materials of guadua strips and recycled cardboard.
4. Thermal and acoustic simulations for the experimental models using the THERM 7.5 and dBKAisla 3.01 softwares, with climatic data from the city of Pereira (Risaralda).
5. Laboratory tests of compression and acoustic resistance for the two proposed models.
6. Preparation of comparative tables, with the results obtained in the simulations of referents and experimental models.
7. Results and discussion. Comparative analysis of thermal and acoustic behavior.
8. Conclusions.

Results

Referents

The starting point for this study is a theoretical framework built on documentation and bibliographic sources on SIP panels (composed of OSB boards and intermediate insulation), as well as their historical antecedents, materials, technical characteristics, and classification according to international specifications.

The four most representative referents on the international market are selected (Table 1), taking into account only those characteristics (thickness, dimensions, materials, weight, resistance, and thermal transmission) and uses that are similar to the ones proposed in this research. Data for each SIP panel, necessary for the simulation, were obtained from the specifications and technical sheets of each manufacturer, which usually reports the U-value (thermal transmission) and R=1/U (thermal resistance), through global knowledge and application tables (Arquimaster, n. d.; Vagge & Czajkowski, 2012), indicating total thickness and composition as well.

The total thermal transfer of the SIP panel is the sum of the values of its components: exterior OSB board + insulation + interior OSB board.

This table collects main thermal data for each SIP panel, necessary for the simulation, which were obtained from the specifications and technical sheets of each manufacturer, showing as a generalized characteristics the use of a polystyrene insulator and two OSB boards, made of pine or fir strips.

For the analysis and simulations, the maximum and minimum temperatures with annual averages were taken into account, as well as precipitation and relative humidity, data extracted from Ideam and Meteonorm for the city of Pereira. It is worth noting that a unique physical-spatial wall condition is sought, with a relationship between the interior and the exterior (inside-outside), without considering any specific space or environment, since it would have variables of all kinds such as: type of terrain, roof, fenestration level, etc., and the objective here is to examine the specific individual contribution of the panel.

An average annual relative humidity of 76.5% and an average rainfall of 228 days/year are factors that directly affect the values of resistance to humidity for the panel (Weather Atlas, 2016). Due to this, reference panels are categorized as OSB-3 boards (according to the European Standard UNE-EN 300), designed to work in humid places, which basically refers to the adhesive with waterproofing action used in the manufacturing of facade panels or building envelopes. Data about the resistance, thickness, and weight per square meter of the referents were also taken into account, in order to compare them with the experimental models.

Thermal simulation of referents

The results obtained in four referents—without considering thermal bridges since the panel is intended to be adapted to existing or particular structures of different characteristics—present minimal variables due to their similar constitution. Their internal temperature difference in response to external conditions indicates comfort

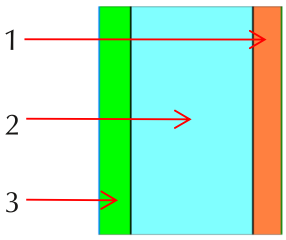
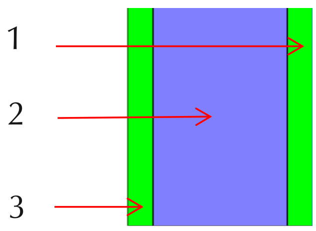
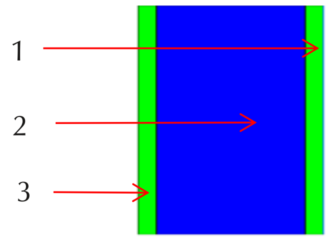
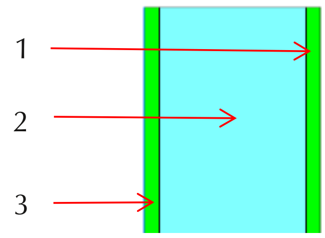
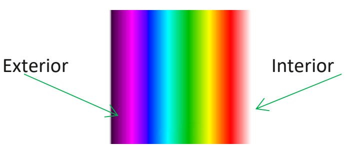
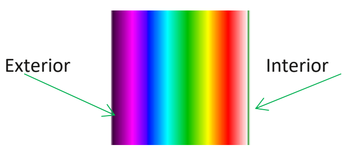
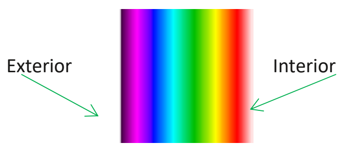
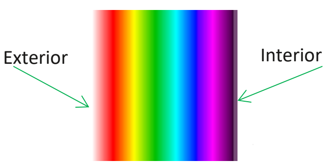
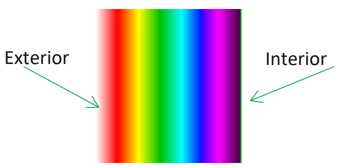
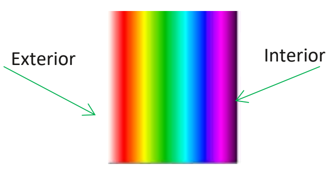
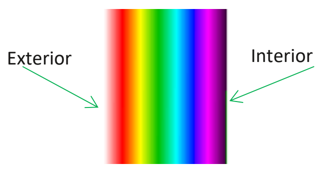
E-ISSN: 2357-626X
ISSN: 1657-0308

REFERENCE SIP PANELS		
1. DESCRIPTION	**PANEL 1**	**PANEL 2**
1.1 Manufacturer	THERMOCHIP. By Cupa Group.	HEMSEC SIPS. Structural Insulated Panel
1.2 Country	Spain	England
1.3 Product reference	OSB(TOH)	PANEL THICKNESS - RESIDENTIAL
1.4 Image		
1.5 Web page	www.thermochip.com/empresa/sobre-nosotros/	www.hemsecsips.com/products-SIP_Residential.html
2. COMPOSITION		
2.1 Format in milimeters	2440 x 600	2440 X 1200
2.2 Three-layer panel composition	Osb + Polystyrene + Hydrophobic agglomerate	Osb + Rigid foam + Osb
2.2.1 Internal board	Osb 15 mm	Osb 11 mm
2.2.2 Intermediate insulation	Extruded polystyrene 80 mm and density of 30 kg/m^3	Rigid polyurethane foam103 mm, density is not indicated
2.2.3 External insulation	Hydrophobic agglomerate 16 mm	Osb 11 mm
2.4 Total thickness in millimeters	111 mm	125 mm
3. SPECIFICATIONS		
3.1 Total weight panel x m^2	19.17 kg/m^2	18.57 kg/m^2
3.2 Maximum vertical load	1435 kg/m^2	Not indicated
3.3 Maximum horizontal load	345 kg/m^2	Not indicated
3.4 Thermal transfer. Total U	0.360 W/M^2k	0.260 W/m^2 K

REFERENCE SIP PANELS		
1. DESCRIPTION	**PANEL 3**	**PANEL 4**
1.1 Manufacturer	THE WALL. Structural Insulated Panel	LP. Building Product
1.2 Country	United States	Chile
1.3 Product reference	PANEL OSB-OSB	STRUCTURAL THERMAL SIP PANEL
1.4 Image		
1.5 Web page	http://www.thewall.cl/index.php?route=product	https://lpchile.cl/es-ES/producto/otros/lp-panelsip
2. COMPOSITION		
2.1 Format in milimeters	1220X2440	1220X2440
2.2 Three-layer panel composition	Osb + Polystyrene + Osb	Osb + Polystyrene + Osb
2.2.1 Internal board	Osb 11.1 mm	Osb 9.5 mm
2.2.2 Intermediate insulation	Expanded polystyrene 92 mm and density of 15 kg/m^3	Expanded polystyrene 76 mmand density of 15 kg/m^3
2.2.3 External insulation	Osb 11.1mm	Osb 9.5 mm
2.4 Total thickness in millimeters	114 mm	95 mm
3. ESPECIFICACIONES		
3.1 Total weight panel x m^2	16.12 kg/m^2	15.12 kg/m^2
3.2 Maximum vertical load	Not indicated	1356 kg/m
3.3 Maximum horizontal load	Not indicated	397 kg/m

Ⓐ Table1. Characteristics of the reference SIP panels

Source: Own elaboration, 2017.

PANEL 1	PANEL 2	PANEL 3	PANEL 4
THERMOCHIP. By Cupa Group.	HEMSEC SIPS. Structural Insulated Panel	THE WALL. Structural Insulated Panel	LP. Building Product.
OSB(TOH)	PANEL THICKNESS - RESIDENTIAL	PANEL OSB-OSB	PANEL SIP TERMICO ESTRUCTURAL
			
0.360 W/m²k	0.260 W/m² K	0.364 W/m²K	0.515 W/m²K
(1)Osb + (2) Polystyrene + (3) Hydrophobic agglomerate	(1)Osb + (2) Rigid foam + (3)Osb	(1)Osb + (2) Polystyrene +(3) Osb	(1)Osb + (2) Polystyrene + (3)Osb
			
Average annual minimum temperature 15.8 ºc	Average annual minimum temperature 15.8 ºC	Average annual minimum temperature 15.8 ºC	Average annual minimum temperature 15.8 ºC
			
Average annual maximum temperature 26.3ºC	Average annual maximum temperature 26.3ºC	Average annual maximum temperature 26.3ºC	Average annual maximum temperature 26.3ºC
			
Variable in low temperatures increases inside with an average 1.32ºC	Variable in low temperatures increases inside with an average 1.7ºC	Variable in low temperatures increases inside with an average 1.75ºC	Variable in low temperatures increases inside with an average 1.58ºC
Variable in high temperatures descreases with an average 2.59 ºC	Variable in high temperatures descreases with an average 2.55ºC	Variable in high temperatures descreases with an average 2.63 ºC	Variable in high temperatures descreases with an average 2.37 ºC

Ⓐ Table 2. Results of heat transfer through two-dimensional conduction according to panel components

Source: Own elaboration, 2017.

values with average differences that range from 2.1 to 2.8 °C at low or minimum temperatures, and an average decrease of 3.2 to 4.0 °C at high or maximum temperatures (Table 2).

Acoustic simulation – referents

Noises are generally composed of pressure variations of different frequencies. The human auditory system is capable of hearing sounds of frequencies in the range of 20-20,000 Hz. Insulation, in all cases, is an ascending constant that presents less noise absorption when frequency increases (Table 3). Its variations are minimal since the absorption level is directly related to the density of materials and their thicknesses, which in this case are very similar and are p resented as a reference range for the product.

Experiment development
Model 1

Materials

a) Guadua fiber flakes (Figure 6), made with the waste of the manufacturing process of panels, canoes, slivers and other cuts that are sold for crafts and construction. In this case, they were obtained through the company Induguadua S.A, located at Kilometer 15 via Armenia-La Tebaida.

E-ISSN: 2357-626X
ISSN: 1657-0308

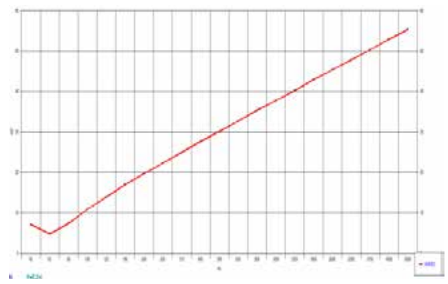
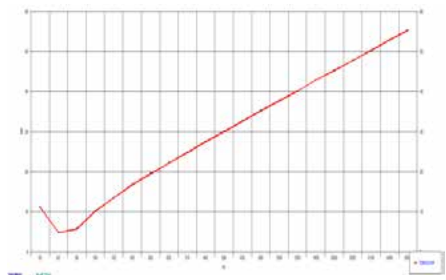
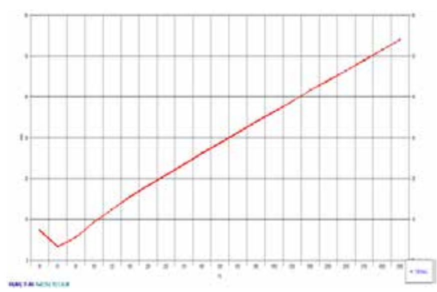
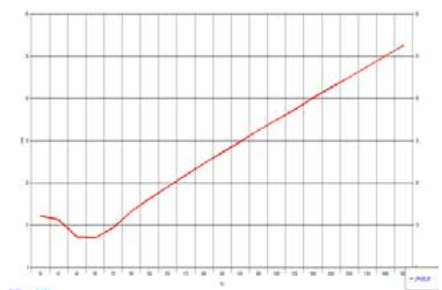
ACOUSTIC SIMULATION REFERENTS		
1. DESCRIPTION	**PANEL 1**	**PANEL 2**
1.1 Manufacturer	THERMOCHIP. By Cupa Group.	HEMSEC SIPS.Structural Insulated Panel
1.2 Product reference	OSB(TOH)	PANEL THICKNESS - RESIDENTIAL
1.3 Image		
2. COMPOSITION		
2.1 Format in meters	2.440 x 0.60	2.44 X 1.20
2.2 Three-layer panel composition	Osb + Polystyrene + Hydrophobic agglomerate	Osb + Rigid foam + Osb
2.2.1 Thickness in meters	0.015 m +0.08 m + 0.016 m = 0.111 m	0.011 m + 0.103 m + 0.011 m = 0.125 m
2.2.2 Total density	170 k/m³	149 K/m³
2.2.3 Young's modulus	11 GN/m²	11 GN/m²
2.2.4 Damping coefficient	0.11	0.11
Software. BDKAISLA 3.01 **Frequency vs. decibels graphs** **Obtained from the database of the *software* DBKAISLA 3.01** **RESOLUTION 0627 DE 2006** **Maximum permissible levels of noise emission expressed in decibels dB(A) for urban housing** **dwelling 65 DB(A) Day** **55 DB(A) Night**		
1. DESCRIPTION	**PANEL 3**	**PANEL 4**
1.1 Manufacturer	THE WALL. Structural Insulated Panel	LP. Building Product.
1.2 Product reference	PANEL OSB-OSB	STRUCTURAL THERMAL SIP PANEL
1.3 Image		
2. COMPOSITION		
2.1 Format in meters	2.44 X 1.20	2.44 X 1.20
2.2 Three-layer panel composition	Osb + Polystyrene + Osb	Osb + Polystyrene + Osb
2.2.1 Thickness in meters	0.0111 m + 0.092 m + 0.0111 m =	0.0095 m + 0. 067 m + 0.0095 m
2.2.2 Total density	140 K/m³	176 k/m³
2.2.3 Young's modulus	11 GN/m²	11 GN/m²
2.2.4 Damping coefficient	0.11	0.11
SOFTWARE. BDKAISLA 3.01 **Frequency vs. decibels graphs** **Obtained from the database of the software DBKAISLA 3.01** **RESOLUTION 0627 DE 2006** **Maximum permissible levels of noise emission expressed in decibels dB(A) for urban housing =** **dwelling 65 DB(A) Day** **55 DB(A) Night**		

Table 3. Acoustic simulation of referents. Software DBKAISLA
Source: Own elaboration, 2017.

b) Adhesive for the formation of boards. Pegatex, Carpincol 2500: high-concentration water-based PVA (polyvinyl acetate) synthetic adhesive.

c) Recycled cardboard toilet paper tubes. These were collected for approximately two months, in the homes of family and friends (Figure 6).

d) Adhesivo PVA – 60 adhesive glue to unite the three layers.

e) Exterior waterproofing varnish for permanent contact with humidity.

Figure 6. Recycled guadua fiber and recycled cardboard tubes
Source: Own elaboration, 2017, CC BY-ND.

MODEL 1 PROPOSED COMPOSITE PANEL MODEL		
1. DESCRIPTION		
1.1 Experimental model	**Specifications**	**Observations**
1.2 Place	Manufacturer TALLER GUADUA	http://muiskay.wixsite.com
1.3 Address	Av. Carrera 68 No. 28-27sur	muiskay@hotmail.com
1.3 City	Bogotá. D.C.	
		
1.4 Image model	Sustainable housing project	Empresa
1.5 Manufacturing consultant	Architect Fabián Martínez	
1.5.1 Position	Teaching and research - CTCM . SENA	
1.5.2 Contact	fabianmartin@misena.edu.co	
1.6 Software	THERM 7.0 y OPAQUE 3.0	
2. COMPOSITION		
2.1 Format in milimeters	2400 x 600	
2.2 Three-layer panel composition	OSB + cardboard tubes + OSB	
2.2.1 External board	14 mm	
2.2.2 Intermediate insulation	90 mm	
2.2.3 External insulation	14 mm	
2.4 Total thickness in milimeters	118 mm	
3. SPECIFICATIONS		
3.1 Total weight panel x m2	19.2 kg	
3.2 Maximum vertical load	418 kg	
3.3 Maximum horizontal load	1.040 kg	
3.4 Thermal transfer. Total U	0.41 W/m²K	
3.5 Acoustic insulation	12.78%	

Table 4. Model 1: Proposed composite panel
Source: Own elaboration, 2017.

Manufacturing

The procedure carried out for its manufacturing is not standardized (in the countries where it is produced) with respect to the adhesive used or the type of pressing. What is intended here is to look for an alternative of non-toxic adhesives and lower energy consumption during the pressing.

All the flakes were immersed in Pegatex Carpincol 2500 adhesive, and oriented according to the specifications given for OSB boards, then cold pressed under a pressure or load of 30 MPa (1 MPa = 10.2041 kg-f/cm2) for 3 hours and 40 minutes. They were extracted then in order to apply another layer of PVA adhesive and pressed again for 6 hours and 35 minutes.

- Drying: natural ventilation for 48 hours.
- Application of Deva-TARIMEX waterproofing varnish.
- Assembly of insulation with double cardboard tubes, recycled toilet paper, glued to the external panels with Carpincol 2500.
- Total assembly of the composite panel and final drying (Figure 7).
- Deva-TARIMEX waterproof varnish application.

Characteristics

Table 4 shows the main characteristics of the Model 1 composite panel.

Thermal simulation

An average internal temperature of 17.6 °C is observed with respect to external minimums of 15.8 °C, resulting in an increase of 1.91 °C. With respect to average maximum external temperatures of 26.3 °C, it decreases to 23.2 ºC with an interior/exterior difference of 2.86 ºC, which is basically due to the vacuum generated by the recycled cardboard tubes of toilet paper rolls, disposed in a double way to give greater resistance, located as insulation inside the panel (Table 5).

E-ISSN: 2357-626X
ISSN: 1657-0308

Figure 7. Manufacturing process of the OSB board, Muiskay company
Source: Own elaboration, 2017, CC BY-ND.

THERMAL SIMULATION

PANEL MODEL 1

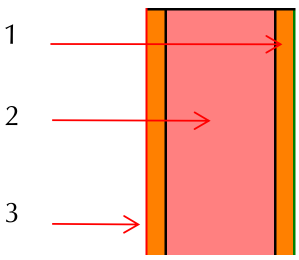
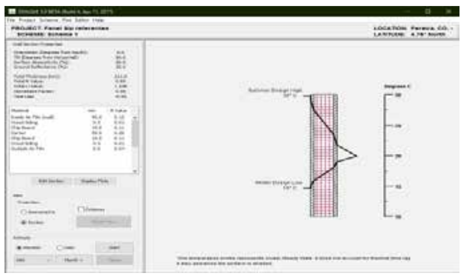
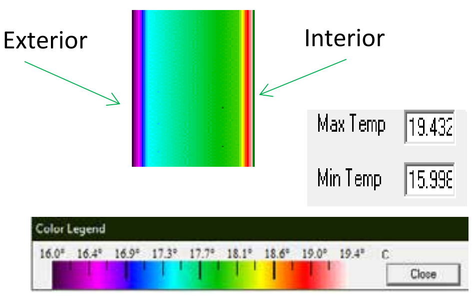
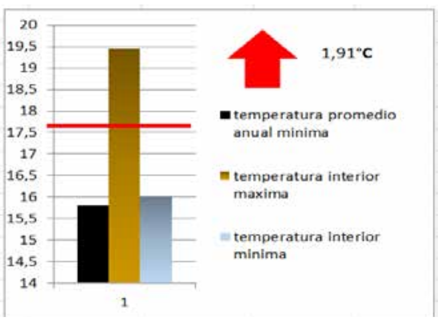
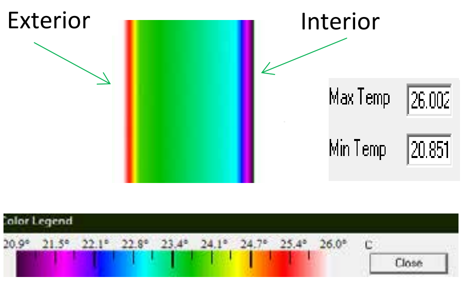
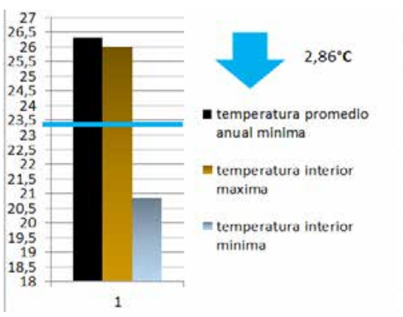
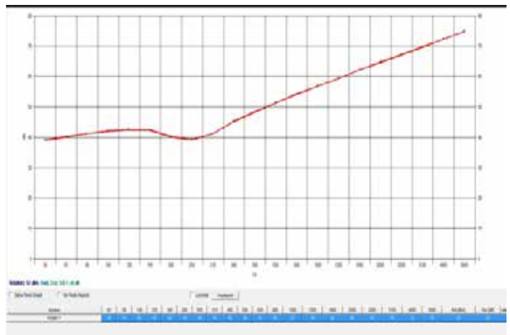
PANEL OSB-RCC-1	OBSERVATIONS
	
0.360 W/m²k	
(1)Osb +(2) cardboard tubes +(3) osb	
	
Average annual minimum temperature 15.8 ºC	
	
Average annual maximum temperature 26.3ºC	
	

Table 5.Thermal simulation Model 1
Source: Own elaboration, 2017.

ACOUSTIC SIMULATION MODEL 1	
1. DESCRIPTION	
1.1 Experimental model	
1.3 Image	
2. COMPOSITION	
2.1 Format in meters	2.40 X 0.60
2.2 Three-layer panel composition	OSB + **cardboard tubes** + OSB
2.2.1 Thickness in meters	0.014 + 0.090 m + 0.014
2.2.2 Total density	142.205 kg/m³
2.2.3 Young's modulus	11 GN/m²
2.2.4 Damping coefficient	0.11
SOFTWARE. BDKAISLA 3.01 **Frequency vs. decibels graphs** **Obtained from the database of the software DBKAISLA 3.01**	
RESOLUTION 0627 OF 2006	
Maximum permissible levels of noise emission expressed in decibels dB(A) for urban housing **dwelling 65 dB(A) Day** **55 DB(A) Night**	

63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	RA [dBA]	Rw [dB]
40	41	42	43	42	40	39	41	45	48	51	54	57	59	62	65	67	70	72	75	52	52

Table6. Acoustic simulation Model 1

Source: Own elaboration, 2017.

Index D, level difference or gross insulation: D = L1 – L2

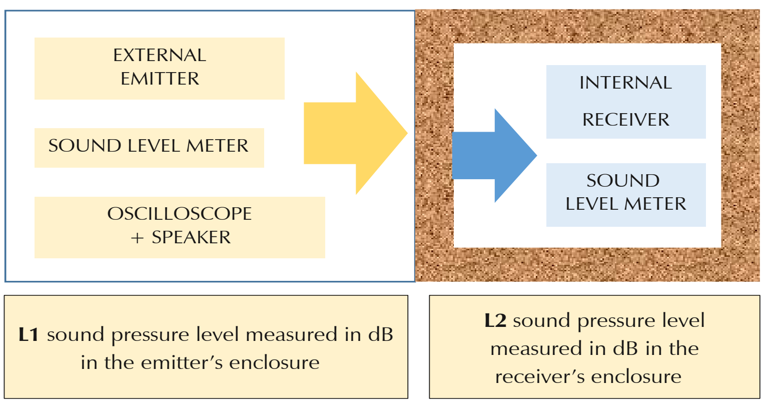


Figure 8. Procedure of acoustic simulation in laboratory

Source: Own elaboration, 2017, CC BY.

Figure 9. Equipment used for the Acoustics Laboratory of the proposed panels.

Source: Own elaboration, 2017, CC BY.

Acoustic simulation

The acoustic simulation shows constant ascending insulation levels in the panel, without variations at 40 acceptable decibels, according to noise, and frequencies between 50 and 250 Hz, the permitted levels being between 55 and 65 decibels. The insulation reaches frequencies up to 1,750 Hz within the acceptable limit, but it does not represent values different from those shown by the referents, only a greater absorption constant in decibels, an average auditory tolerance. The structure of external OSB boards that generates spaces between strips allows a number of sound waves to penetrate through them (Table 6).

Laboratory tests

Acoustics. Acoustic absorption was measured in the laboratory of the Universidad Católica de Colombia, simulating a closed interior space with a cardboard box of one cubic meter volume, placing on one of its sides the experimental model. For internal measurement, a sound level meter was used that recorded decibels according to the applied external noise, at lower frequencies through a noise generator amplifier that indicates frequency as database *(Figures 8 and 9)*.

MODEL 1			
External noise in Hz frequency	External noise in decibels dB	Internal noise in decibels dB	Difference in decibels dB
1730	96.4	78.4	18
1450	90.2	77.5	12.7
1003	84.4	70.2	14.2
921	77.7	69.8	7.9
735	69.4	63.1	6.3
669	67.2	56.3	10.9
367	59.6	48.6	11
226	55.4	41.4	14
Average value of acoustic insulation			**11.875**

Table 7. External noise level versus internal level and absorption percentage
Source: Own elaboration, 2017.

PHYSICAL RESISTANCE RESULTS OF MODEL 1		
Test sample dimensions	**Unit**	**Quantity**
Area	m²	0.0625
Thickness	ml	0.118
Weight	kg	1.2
Materials		
1. Guadua wooden OSB boards	Unit	2
Density	kg/ m³	738
2. Tubular double cardboard tubes	Diameter	5
Density	kg/ m³	22,32
Load application		
Stress surface of the press	m²	0.0177
Horizontal load	kg	1,040
Vertical load	kg	418

Table 8. Horizontal and vertical resistance test
Source: Own elaboration, 2017.

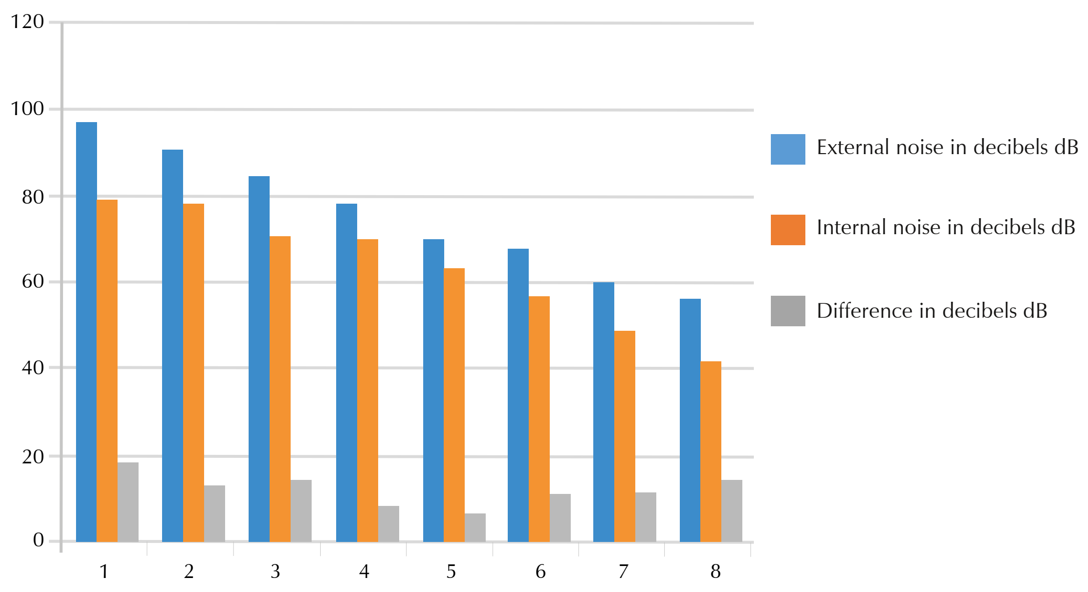


Figure 10. Internal insulation results with regard to exterior values
Source: Own elaboration, 2017.

Table 7 shows the results obtained, which reflect external frequency, external and internal noise, and difference, in order to find average acoustic insulation (Figure 10), which showed a difference of 11.88 dB as a result of an absorption percentage that ranges from 18 to 20%, which is representative considering that in a housing unit there are additional elements that make up spaces such as ceilings, roofs, windows, floors, etc.

Tests of resistance to compression. A universal single-column tension and compression testing machine (Figure 11) was used to subject the model panel to compression, which showed resistance to the limit of deformation without breaking.

The values obtained, both in vertical and horizontal load testing, are in the range indicated by the selected referents from the global construction market. The panel functions as a non-structural element and its resistance to stress is linked to its function as an envelope (Table 8).

Model 2

Materials

a) Guadua fiber strips or shatters as a residue from the manufacturing of panels, canoes, slivers and other cuts that are commercialized as building elements, obtained through the company Induguadua, Armenia-La Tebaida.

b) Adhesive for the formation of boards: urea-formaldehyde.

c) Insulation: triple honeycomb cardboard sheet or Honeycomb board (Table 9) T = 31 mm each; Manufacturer Perlad SAS.

d) Adhesive Carpincol 2500–Pegatex to unite the three layers.

e) Varnish (transparent solvent-based urethane) for wood exteriors..

Manufacturing

This model was developed following the main guidelines currently used by manufacturers (Apa's Corporate, 2015), with the only difference of changing pine and fir strips for guadua strips (Figure 12):

- Selection of guadua raw material in flakes or strips (T = 0.6/1.2 mm) with dimensions of 10 to 20 mm wide and 15 to 30 mm long, suitable for manufacturing OSB boards, with a humidity up to 5% through convection oven.

PROPOSED COMPOSITE PANEL MODEL		
1. DESCRIPTION	MODEL 2	OBSERVATIONS
1.1 Experimental model		
1.2 Place	Plant PRIMADERA	http://www.primadera.com/
1.3 Address	Carretera Central Norte km 49 - Vereda la Aurora	
1.3 City	Gachancipá - Cundinamarca	



1.4 Image model tests	Factory PRIMADERA SAS	"Urban wood"
1.5 Manufacturing consultant	Ingeniero José A. Gutiérrez	
1.5.1 Position	Director of processes and research	
1.5.2 Contact	jogutierrez@pimadera.com	
1.6 Software	THERM 7.0 y OPAQUE 3.0	
2. COMPOSITION		
2.1 Format in milimeters	2400x 1200	
2.2 Three-layer panel composition	OSB + Honeycomb Cardboard Sheet + OSB	
2.2.1 External board	11 mm	
2.2.2 Intermediate insulation	100 mm	
2.2.3 External insulation	11 mm	
2.4 Total thickness in milimeters	122 mm	
3. SPECIFICATIONS		
3.1 Total weight panel x m²	21.92 kg	
3.2 Maximum vertical load	1.970 kg	
3.3 Maximum horizontal load	518 kg	
3.4 Thermal transfer. Total U	0.34 W/m²K	
3.7 Acoustic insulation	13.13%	

Ⓐ Table 9. Model 2, panels. Technical sheet
Source: Own elaboration, 2017.

E-ISSN: 2357-626X
ISSN: 1657-0308

Figure 11. Equipment (hydraulic press) used to test horizontal and vertical load resistance

Source: Own elaboration, 2017, CC BY.

Figure 12. Manufacturing process of test samples and board

Source: Primadera SAS, 2017.

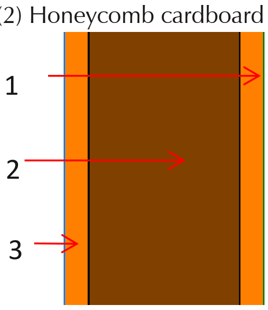
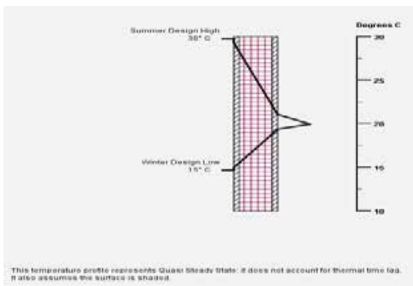
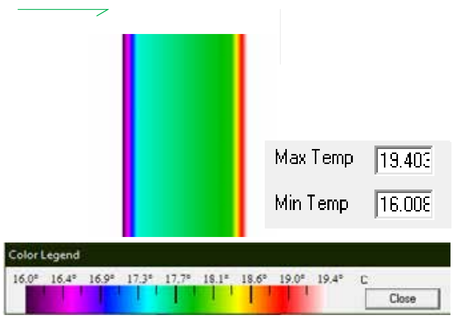
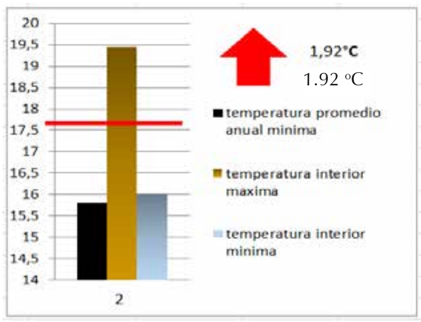
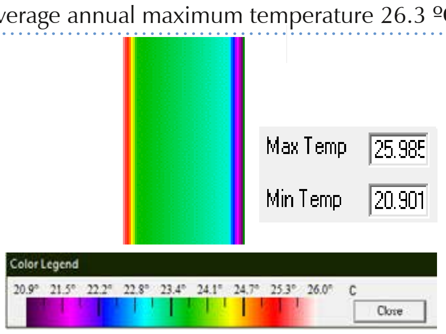
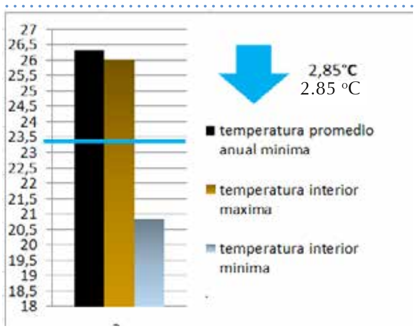
THERMAL SIMULATION	
MODEL PANEL 2	
PANEL OSB-RCC-2	OBSERVATIONS
	
0.260 W/m² K	
(1)Osb + (2) Honeycomb cardboard sheets + (3)Osb	
	
Average annual minimum temperature 15.8 ºC	
	
Average annual maximum temperature 26.3 ºC	
	

Table 10. Thermal simulation Panel 2

Source: Own elaboration, 2017.

- Gluing the particles with urea-formaldehyde resin with the following specifications: 1,270 kg/m³ density; 65% solids, forming the layers of the board, which is put into a mono-floor press at a temperature of 210 °C, with a specific pressure of 42 kg/cm² and a pressing time of 4 min. Finally, physical-mechanical tests are carried out in a universal machine, to measure the properties of internal bonding and the modulus of elasticity and rupture.

Due to the technology used in this case, the resulting board is closer to an agglomerated wood board than an OSB board. Therefore, the results presented high physical-mechanical properties, as experienced in agglomerated wood boards.

Characteristics (Table 9)

Thermal simulation

Average internal temperatures similar to Model 1 are observed; with regard to external minimums of 15.8 ºC, there is an increase of 1.92 ºC, while in maximum temperatures, an average decrease of 2.85 ºC is observed, which is basically due to good thermal insulation produced by the vacuum between the honeycomb cells in recycled cardboard. This represents important values of internal temperature control, as a fundamental part in the housing comfort of a building (Table 10).

Acoustic simulation

Acoustic simulation values (Table 11) show constant ascending insulation levels in the panel,

ACOUSTIC SIMULATION MODEL 2

1. DESCRIPTION

1.1 Experimental model

1.3 Image

2. COMPOSITION	
2.1 Format in meters	2,40 X 1,20
2.2 Three-layer panel composition	OSB + hexagonal cardboard + OSB
2.2.1 Thickness in meters	0.012 + 0.090 m + 0.012 = 114
2.2.2 Total density	155.6 kg/m³
2.2.3 Young's modulus	11 GN/m²
2.2.4 Damping coefficient	0,11

SOFTWARE. BDKAISLA 3.01

Frequency vs. decibels graphs

Obtained from the database of the

Software dBKAisla 3.01

RESOLUTION 0627 OF 2006

Maximum permissible levels of noise emission expressed in decibels dB(A) for urban housing dwelling 65 dB(A) Day

55 dB(A) Night

63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	RA [dBA]	Rw [dB]	de
40	41	42	43	42	40	39	41	45	48	51	54	57	59	62	65	67	70	72	75	52	52	

Table 11. Acoustic simulation Panel 2

Source: Own elaboration, 2017.

E-ISSN: 2357-626X
ISSN: 1657-0308

without variations at 40 acceptable decibels, according to noise, and frequencies between 50 and 250 Hz. Within the permitted levels between 55 and 65 dB, insulation reaches frequencies up to 1,750 Hz within the acceptable limit, but these values are not different from those shown by the referents, only a greater absorption constant in decibels of average auditory tolerance.

Laboratory tests

Acoustics. Table 12 shows an average absorption of 13.14 dB and an average acoustic insulation of 15 to 20%, a representative percentage that is basically due to the density and compaction of OSB boards, which increases their insulation quality.

Resistance to compression. When subjecting it to compression, the model panel presented resistance to the limit of deformation without breaking. The values obtained, both with a vertical load of 518 kg and a horizontal load of 1,970 kg, are within the acceptable values in the studied referents (Table 13). The boards presented greater strength and less deformation, but the internal insulation system in cardboard collapsed, which resulted in crushing with horizontal load and a greater resistance with vertical load.

Comparative evaluation of results

Results were evaluated comparing thermal and acoustic simulations, both for referents and the manufactured experimental models, indicating their efficiency in comfort level and allowing an objective and conclusive measurement.

MODEL 2			
External noise in Hz frequency	External noise in decibels dB	Internal noise decibels dB	Difference in decibels dB
1730	96.4	76.8	19.6
1450	90.2	75.5	14.7
1003	84.4	68.4	16
921	77.7	62.6	15.1
735	69.4	57.6	11.8
669	67.2	55.6	11.6
367	59.6	51.4	8.2
226	55.4	47.3	8.1
Average value of acoustic insulation			**13,1375**

Table 12. External noise level compared to the interior of the panel and its absorption percentage

Source: Own elaboration, 2017.

PHYSICAL RESISTANCE RESULTS OF MODEL 2			
Test sample dimensions	**Unit**	**Quantity**	**Observation**
Area	m²	0.0625	
Thisckness	ml	0.122	
Materials			
1. Guadua wooden OSB boards	Unit	2	
Density	kg/m³	697	
2. Honeycomb cardboard	Diameter	5	
Density	kg/m³	27.4	
Load application			
Stress surface of the press	m²	0.0177	
Horizontal load	kg	1,970	
Vertical load	kg	518	

Table 13. Horizontal and vertical resistance test for Model 2

Source: Own elaboration, 2017.

RESULTS OF THERMAL SIMULATIONS. SOFTWARE THERM 7.5							
THERMAL SIMULATION	Unit	Referent 1	Referent 2	Referent 3	Referent 4	Model 1	Model 2
		THERMO CHIP	HEMSEC SIPS	THE WALL	LP SIP	MUISKAY	PRIMADERA
Thickness three-layer panel	mm	150	110	110	95	118	122
U-value	W/m2K	0.36	0.26	0.364	0.515	0.41	0.34
R-value = 1/U	K-m2/W.	2.78	3.85	2.75	1.94	2.44	2.94
Average minimum external temperature 15.8	°C	15.8	15.8	15.8	15.8	15.8	15.8
Maximum internal temperature	°C	18.861	18.759	18.925	18.411	19.432	19.402
Minimum internal temperature	°C	16.196	16.233	16.175	16.355	15.996	16.006
Average internal difference	°C	2.665	2.526	2.75	2.056	3.436	3.396
Maximum internal difference	°C	3.061	2.959	3.125	2.611	3.632	3.602
Minimum internal difference	°C	0.396	0.433	0.375	0.555	0.196	0.206
Average int. temperature with respect to the exterior	°C	1.729	1.696	1.75	1.583	1.914	1.904
Average maximum external temperature 26.3	°C	26.3	26.3	26.3	26.3	26.3	26.3
Maximum internal temperature	°C	25.702	25.649	25.736	25.466	26.002	25.985
Minimum internal temperature	°C	21.702	21.86	21.611	22.382	20.851	20.901
Average internal difference	°C	4	3.789	4.125	3.084	5.151	5.084
Maximum internaldifference	°C	0.598	0.651	0.564	0.834	0.298	0.315
Minimum internal difference	°C	4.598	4.44	4.689	3.918	5.449	5.399
Average int. temperature with respect to the exterior	°C	2.598	2.546	2.627	2.376	2.874	2.857

CONCLUSIONS. RESULTS	Unit	Referent 1	Referent 2	Referent 3	Referent 4	Model 1	Model 2
		THERMO CHIP	HEMSEC SIPS	THE WALL	LP SIP	MUISKAY	PRIMADERA
Average minimum external temperature 15.8	°C	15.8	15.8	15.8	15.8	15.8	15.8
Average temperature increases with respect to the exterior	°C	1.73	1.7	1.75	1.58	1.91	1.91
Average maximum external temperature 26.3	°C	26.3	26.3	26.3	26.3	26.3	26.3
Average temperature decreases with respect to the exterior	°C	2.6	2.55	2.63	2.37	2.88	2.86

Table 14. Thermal simulation results
Source: Own elaboration, 2017.

RESULTS ACOUSTIC SIMULATIONS							
ACOUSTIC SIMULATION	**Unit**	**Referent 1**	**Referent 2**	**Referent 3**	**Referent 4**	**Model 1**	**Model 2**
		THERMO CHIP	HEMSEC SIPS	THE WALL	LP SIP	MUISKAY	PRIMADERA
Thisckness three-layer panel	mm	150	110	110	95	118	122
Insulation density	kg/m³	30	30	15K	15	22.32	27.4
Boards density	kg/m³	670.00	640.00	640.00	610Kg/m³	548.00	738.00
Insulation levels	55 db	55 db	55 db	55 db	55 db	55 db	55 db
	hz	3.150	4.500	4.450	4.700	980	3 s150

Table 15. Results of acoustic simulations
Source: Own elaboration, 2017.

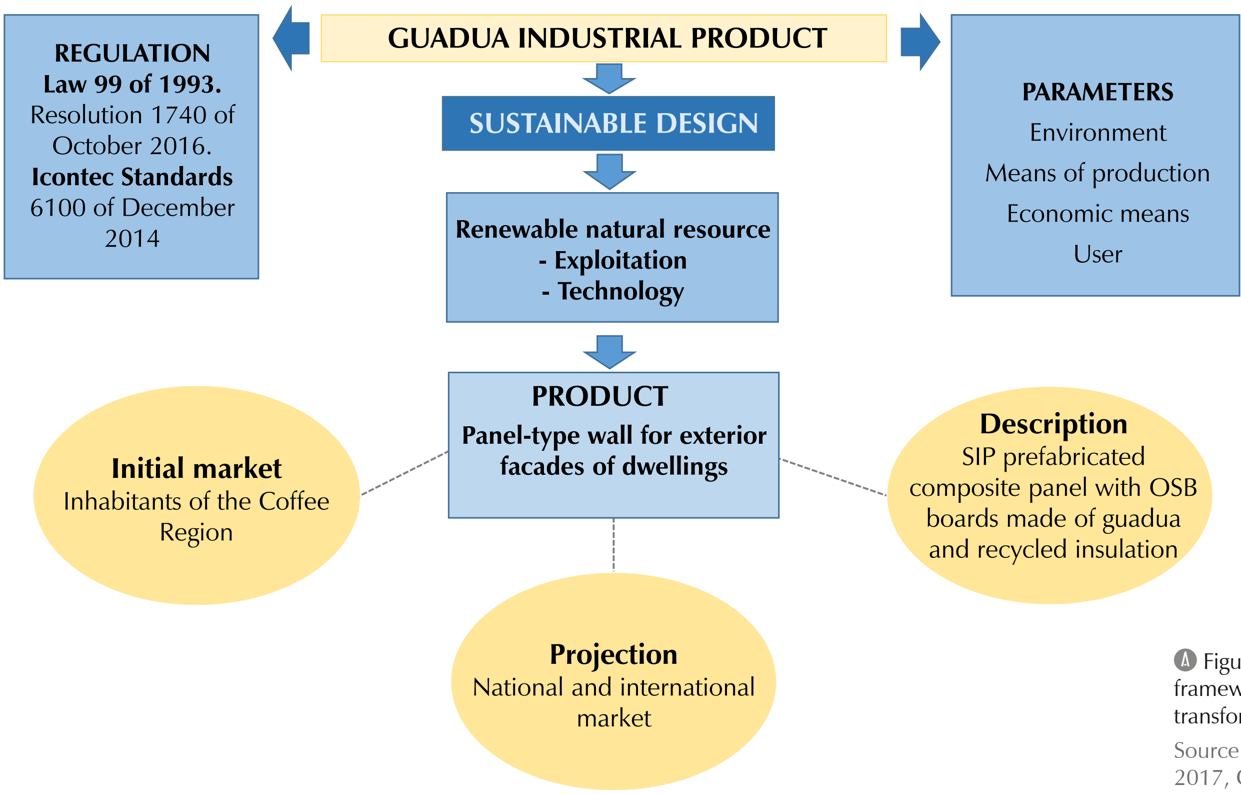


Figure 13. Conceptual framework applied to the transformation of guadua

Source: Own elaboration, 2017, CC BY.

Thermal insulation

With regard to thermal insulation, the values obtained (Table 14) indicate that both referents and experimental models maintain a relative homogeneity in internal comfort levels. Those with a minimum temperature between 17.71 and 21.9 °C stand out as the best (Model 2), and those with a temperature between 17.38 and 22.38 °C as the most unfavorable (LP SIP, Chile).

Acoustic insulation

Insulation levels, according to the norm of acceptable decibels, indicate that Model 2 maintains the same conditions as referent 1 according to what is presented in Table 14, although some of the referents have insulations with higher frequencies, product of denser insulators, but made with petroleum derivatives. Similarly, among the experimental models (Table 15), better levels are observed in Model 2, due to cardboard density and the hermetic nature of the hexagonal composition of the Honeycomb cardboard.

Current situation of the guadua industry in Colombia

The protagonist in the current environment for the industrialization of guadua is the following legal framework: Law 99 of 1993, "By which the Ministry of Environment is created, the Public Sector in charge of the management and conservation of the environment and renewable natural resources is reordered, the National Environmental System, SINA, is organized, and other dispositions are dictated;" Resolution 1740 of 2016, "By which general guidelines are established for the management, use, and establishment of guadua and bamboo farms, and other provisions are dictated;" Icontec Standards NTC 6100 (2014), "type I environmental labels. Colombian environmental stamp. Environmental criteria for products of first and second degree transformation of guadua angustifolia Kunth," and the forest self-certification given by the Forest Stewardship Council (FSC); entities and standards that guarantee the quality and future of the project.

On the other hand, the private organizations of guadua farmers have allowed certain integration in search of technification and better socioeconomic and environmental conditions (Figure 13). The manufacturing of the product is projected, in the first instance, for consumption by the inhabitants of the Coffee Region and for a future expansion of its market, with the alternative of using not only residual, but also recycled materials.

Discussion

The research supports the manufacturing process of SIP panels using unconventional materials such as guadua waste strips and recycled cardboard; the results of resistance to compression and thermal and acoustic insulation demonstrate that they are a viable and competitive product compared to those that are now on the market, as well as a sustainable alternative under passive energy principles.

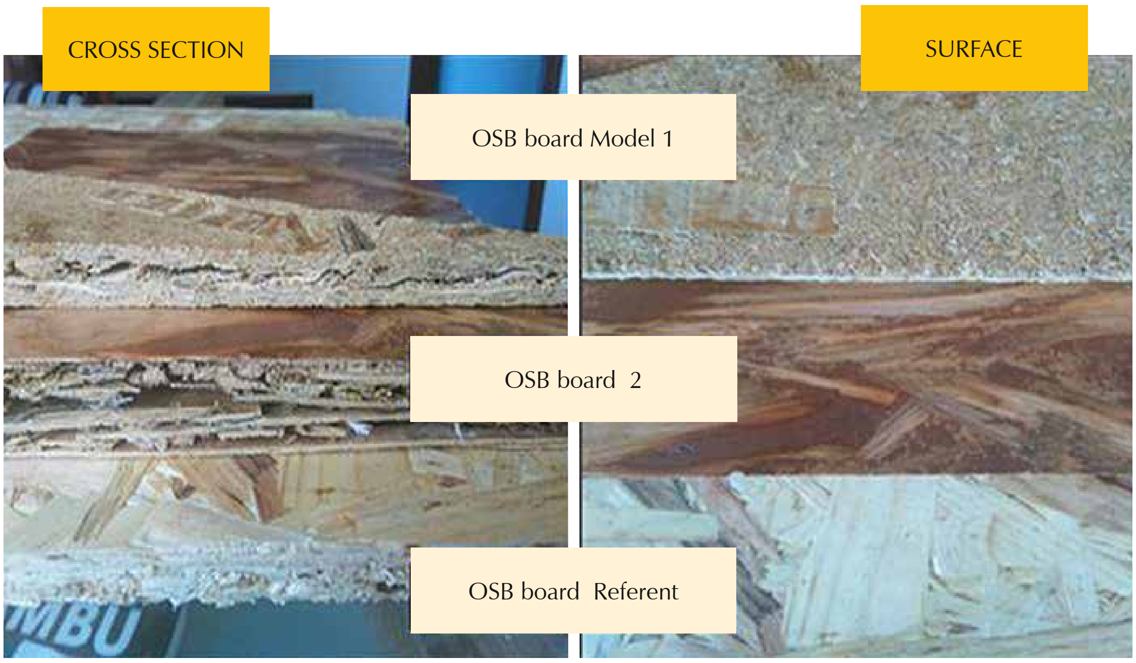


Figure 14. Composition of the reference OSB boards and proposals 1 and 2
Source: Own elaboration, 2017, CC BY.

Manufactured SIP panels have two major unfavorable and unsustainable aspects: the use of polystyrene (derived from petroleum) as an internal insulator and phenol-formaldehyde (synthetic resin) as an adhesive applied in high percentages.

Guadua strips as main raw material must reach a dryness between 4 and 5% humidity to guarantee adhesion between strands through pressing. In addition, for its transformation into flakes of specific dimensions and diameters, it requires the prior selection of residual or recycled materials.

In Model 1, the OSB board has a good aesthetic texture and clearly shows the cross-arrangement of strips or flakes (Figure 14), but lower hardness as well, with a horizontal resistance of 1,040 kg/m^2, and a vertical resistance of 418 kg/m^2, similar to the values indicated by the referents. The adhesive (polyvinyl acetate, PVA) requires greater fixation over the strips since they are very rigid and resistant fibers that leave spaces or cavities among them. However, in the assembly of the SIP panel, its thermal insulation results of +2.90 °C at high temperatures, and -1.9 °C at low temperatures, present very similar values, and also show that recycled cardboard tubes used in the study are a good alternative as thermal and acoustic insulation.

Model 2 had a greater compaction of guadua strips in the elaboration of the OSB board; for this, it was necessary to mix the strips with other very fine sawdust-like guadua particles to fill up the free spaces between crossed flakes, using phenol-formaldehyde in smaller percentages, in order to avoid its toxicity.

Results evidenced greater horizontal (1,970 kg/m^2) and vertical resistance (518 kg/m^2), but with irregular texture and lower percentage of flakes in its exterior finish (Figure 14), which is a typical characteristics of OSB boards. In the conformation of the SIP panel, the intermediate insulation of Honeycomb cardboard produced lower values in terms of acoustic absorption.

Similarly, with a weight of approximately 19 kg per square meter, the prototypes are within the average weight of the referents, allowing thus their easy handling for transportation and assembly.

Conclusions

For a sustainable construction, it is necessary to implement different strategies in the selection of materials, manufacturing, assembly, and operation that demonstrate a significant decrease in the CO_2 emission of the construction product, in this case, during its life cycle from the collection and classification of waste, its transformation, manufacturing, use, and further recycling.

It should be noted that in Colombia regulations are aimed at the manufacturing of agglomerated boards with wood particles, but not at manufacturing with OSB-type strips, which is absent in the country and, consequently, SIP panels of this type are not produced either. Consequently, the results of thermal, acoustic, and resistance factors are compared and validated with the values of experimental laboratory test samples, according to the information provided on the technical data sheets of the referents.

Based on these premises, this research aims to present an alternative that serves as a model in the use of local renewable natural resources that are transformed, manufactured, and used with low environmental impact. In this case, society in the specific place of the study is linked to agricultural economy represented by coffee production, where guadua appears as a protagonist of

E-ISSN: 2357-626X
ISSN: 1657-0308

socio-cultural heritage in the construction of housing units, recognized in turn as part of the identity of the social fabric and its collective memory.

The composite panel wall completes its entire life cycle in the same place for local people, from the recycling of waste material to its transformation, industrialization, commercialization, construction, use and further recycling, in such a way that, for obvious reasons, its energy consumption decreases given that it does not require large amounts of energy for its manufacture and transportation throughout its life cycle.

Finally, data obtained from the experimental models showed that, for the region in question (tropical, warm, wet), thermal envelope becomes a system of heat conservation (night) and cooling (day), maintaining temperature and acoustic insulation, while it is also a passive energy contribution of air conditioning for comfort.

In addition, it is possible to think about further adjustments in the manufacturing and adaptability of existing structures and models to be built, which will have to be considered as the next stage in the development of this research. In this sense, the initial objective was to propose assembly products with renewable natural materials for architectural integration, always within the philosophy of sustainable construction in favor of the quality of life.

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