REUSE OF ORGANIC WASTE TYPE IN THE DEVELOPMENT OF ECO-EFFICIENT AND SUSTAINABLE COMPOSITES

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ABSTRACT

The global tradition of building is severely affected by the shortage of materials from nature, which stimulates the development of technologies and construction systems related to the reuse of waste organic. For example, in Ecuador an area of 106,930 ha in 2012 was devoted to sugar cane plantations, having a production of 7.38 Mt (7.5% in the province of Loja) [1], which produce the organic residue sugarcane bagasse, mainly in mills owned by artisan manufacturers. Approximately 50% is used as fuel, fertilizer and livestock feed, the rest as waste accumulates in particular landfills with health problems. Recovery and use of this residue as a component of craft supplies of building materials is proposed in this communication. The design of composite materials containing organic vegetable wastes is proposed, and the measures of their physical and mechanical properties are described, pointing to elements that combine technical, specification standards and artisan production that will generate a production for low cost housing in the area of the province of Loja.This work is part of an ongoing investigation, conducted in collaboration by professors and researchers from the Universidad Técnica Particular de Loja (Ecuador) and the Technical University of Madrid (Spain), divided into two phases: the first an analysis is made in laboratory of some organic vegetable waste from the province of Loja; in the second part and simultaneously, are proposed and built prototypes of architectural elements, that incorporates the materials investigated. In the first stage results have been obtained of the mechanical and physical properties of composites with bagasse, in matrices made of plaster and cement, with additions of ashes of those vegetable waste materials, as well as impact on measures absorption and capillarity of these composite samples, confirming the effective delivery of materials with potential applications in building construction. In the second stage it was accomplished the manufacturing and constructive use of plates and sandwich panels at scale 1:1, determining dimensions, combining different elements, modulation, anchoring systems and their mechanical resistance, obtaining materials with acceptable values on toughness. There were explored various treatments to materials (organic fibers and matrices) for improving protection against external environmental agents. It was concluded that the composites made from vegetable organic additions of bagasse, with and without ashes from the same waste materials, in plaster and cement matrices allow reusing waste materials that are sustainable and provide eco-efficient execution of architectural projects solutions.

Keywords: composites, organic vegetable waste, bagasse, sustainable materials.

1.- Introduction

The industrial sector generates a series of waste recycling and reuse easier, for example, the steel metals, which can be re-melted to make new steel products with similar properties as the original one [2].

However, other waste are difficult to reuse or recovery, eg coffee husks, rice husk and sugar cane bagasse (an estimated one ton of sugarcane produces 280 kg of bagasse [3]) accumulation in landfill becomes sometimes a source of health and safety problems: plagues and insane odors, which also affects the vinasse, waste generated in the production of ethanol, which is a brown liquid with a high content of suspended solids.

Combustion is a common option in sugar industries, and as a general rule the last option because it generates greenhouse gases, although bagasse ash calcined at high temperatures have high pozzolanic [3] properties, as also have rice husk ashes [5].

The main objective of this research was twofold: to achieve total disappearance of these vegetable waste landfills and exploit the properties of the fibers from sugar cane, rice and coffee, and the pozzolanic nature of their ashes in the manufacture of new construction materials with applications mainly in low cost buildings, in local areas close to the places where these vegetable-organic were generated, by means of sustainable techniques.

Materials based on cement and gypsum as binders are fragile and brittle, but the long and short vegetable fibers incorporated improve their toughness in such a way that construction performance were increased [6-7].

An experimental trial and error methodology in simple laboratory and prototype simple building was established, obtaining the optimum ratios for hand lay-up process, components, the mixing techniques and construction abilities for these new composites. After determining the optimum compositions the main physical and mechanical properties were measured. Durability testing are currently implemented, also in laboratory and in prototype, on panels and boards manufactured with the optimum ratios of their predetermined components

To achieve these goals, two main phases were established: first to organize a team with researchers from the Technical University of Madrid (UPM) - Spain and researchers from the Universidad Técnica Particular de Loja (UTPL) - Ecuador and students of the Degree of Architecture UTPL, who performed the mechanics of new composite materials and components on standardized specimens tested in the laboratory, physical and chemical characterization, and afterwards the technical trials on different compositions were made for further development of the prototype construction elements.

The second phase was on the design and prototyping of binder composite panels - panels with vegetable fibers and vegetable fibers boards, currently under development, creating models for using prefabricated building components with these new materials, using parametric design and digital fabrication, thereby determining its best constructive application in urban and architecture.

2.- Production and sugar cane waste (bagasse)

In Ecuador there were a total area of 106,930 ha of sugarcane plantations in 2012 [1], with an estimated 7.38 million tons, of which 7.5% is in the province of Loja, where the UTPL belongs. Accounting for operating the mills that constitute the large sugar industrial chains, they are the same as for the production of ethanol, panela (a sugar based nice dessert) and artisanal alcohol production. In recent years there become a lot and very successful activities around this industry, generating a lot of direct employment.

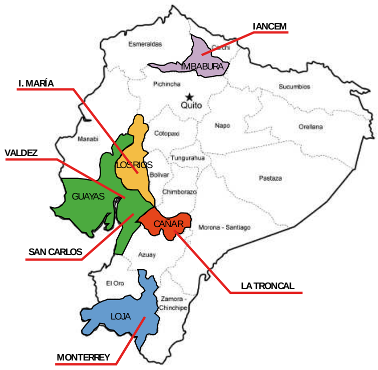

Fig. 1 “Location of sugar mills in Ecuador”. [8] (Modified by the authors)

In the province of Loja, Ecuador, production of sugar cane crops is mainly concentrated in areas of Malacatos, Vilcabamba and San Pedro de Vilcabamba, where there are small factories producing brown sugar, honey and rum for use by residents sector; however the most important in southern Ecuador industry is the sugar mill "MONTERREY" located in Catamayo, 36 km from the city of Loja, considered one of the most important in the country for its production and use of modern machinery that prevent environmental pollution. This factory makes planting, harvesting, sugar production and marketing at the national and even international level with small businesses.

However this important sugar industry, has resulted in the country not only benefits the economic sector, but also lots of (mainly bagasse) agro-industrial waste in small mills, which accumulate in large quantities generating the growth of bacteria and insects, threatening the health of people working in these industries of sugar and its derivatives [9].

2.1.- Bagasse from sugar cane

Bagasse from sugar cane is the fibrous residue remaining after sugarcane be squeezed and go through an extraction process. The most distinctive organoleptic characteristics of its main components and major utilities can be seen in scientific literature above referred [3-4; 10-11].

2.2.- Physical and Chemical properties of bagasse

Mean proportions of bagasse components, classified as solids water-insoluble, solid water-soluble, retained water and fiber can be also obtained in the literature [10-11]. In terms of chemical composition, bagasse contains cellulose, hemicellulose and lignin as main natural polymers. Also has small amounts of other compounds classified as minority, components soluble in organic solvents. Reference [11] contains their percentage average proportions, together with the fraction of ash resulting from complete combustion.

2.3.- Lifecycle of bagasse

The durability of pressed bagasse from sugar extraction of sugarcane until the onset of biological agents (mold) is primarily dependent on the drying and storage methods. If the material is not subjected to any method of disposal in appropriate environmental conditions and left outside under the rain and the sun, it starts a process of decay from 7 to 10 days from the extractive pressing of sugar, mainly due the retaining residual sucrose [12].

In craft factories bagasse accumulate uncontrollably, used as combustible material for operation of the machine (mill) for the production of sugar cane, or as fertilizer for sugarcane plantations. The excess of these two applications is abandoned to reach the point of breakdown, generating insects and unhealthy not only for workers in the mills but also for the inhabitants of the area, often causing closures of these traditional grinding mills factories, by the authorities.

3. Prefabricated panels and boards

Different building types of panels, mortar slabs and plaster reinforced with bagasse fibers have been selected for this research. They are inspired in wood boards, particle board or chipboard, made from ground wood particles (flakes, chips, and shavings), fiber-board, medium density panels (MDF) and oriented strand board (OSB).

Sandwich panels have also been manufactured and explored as building elements with rigid foams lightened core, with shell composite skins of gypsum or cement reinforced with short fibers from bagasse [13-15]. These panels and boards have constructive versatility, making them suitable for applications in facade elements, interior partitions, ceilings and even covered in small residential buildings of rural character, they are readily accepted by its ease of crafting and availability local component materials. However, they are also building elements that cater to simple processes of industrialization, without much investment in equipment.

4. - Manufacture of panels and table boards

4.1.- Materials

For manufacturing specimens, panels and table boards the following materials were used: Cement Type I for general use (NTE INEN 152: 2012) supplied by Holcim, nominal compressive strength 30 MPa at 28 days. Its analysis of oxides by X-Ray fluorescence (Bruker S1 Team TurboSD, UTPL) gave the following composition (Bogue`s formula): C3S = 59.48% = 12.64% C2S C3A = 9.65 % C4AF = 14.39%. Besides Portland Cement, Fine Plaster for Construction (NTE INEM 1685). Hydrated Lime (NTE INEN 247: 2010) was used too in this research, having a content of 62% CaO by XR fluorescence as measured in the same Bruker S1 Turbo, from UTPL.

Smoked on place bagasse fiber was obtained from landfills of San Pedro de Vilcabamba; washed in water for 24 hours to dissolve the residual traces of saccharose, dried and separated from the pulp. The bagasse fiber was chopped in short fibers and classified by sizes: 0.5 cm to 6.0 cm in length for small laboratory samples, and long fibers of 30 cm to 60 cm for boards and panels. It has also been used ash from combustion of bagasse (X-R analysis, 52% SiO2), and fired rice husk ash (X-R analysis, 62% SiO2), particle size gradation of fine particle: less than 0,075 mm. For improve compatibility bagasse - inorganic binding, due to the altered and remove putrid organic matter, the fiber was treated by hydrated lime slurry for times from 1 hour to 24 hours, before manufacturing specimens, panels and boards.

4.2.- Methodology

By the large amount of bagasse from sugarcane existing as waste in landfills, it was scheduled a wide experimentation with different types of composite panels and boards, also making samples in laboratory with a wide dimensional range: 4x4x16 cm^3 and other thinner (2 cm) dimensions, hereinafter described for mechanical bending tests, 10x10x15 cm^3 and compressive failure testing, among others.

The panels have also been manufactured having different dimensions for reasons of modulation in the building prototype under construction (from 15x15x2cm^3 to 60x90x3,5 cm^3; being 60x90x5 cm^3, those of sandwich panels type).

Treatment of the raw material was first performed, and laboratory measurements of their physical properties (density, moisture content, water absorption coefficient). Determination of different dosages, behavior and reaction (set, internal composite

cohesion) between bagasse and conglomerate materials (gypsum bagasse ash, bagasse ash cement, plaster, plastic additives and vegetable gums for improving the behavior under moisture and water), thus obtaining alternatives to those found on the market which can be used at the architectural level.
The boards manufacturing was based on the concept of easy preparation, they do not need furnace, they are prepared by hand and do not need high technology for processing, whereas people in the same sector, can build and apply on place, thus reducing environmental contamination and raw materials transportation.

4.2.1.- Specimens manufacturing

By the extent of the ongoing investigation here only are presented preliminary results of some laboratory tests. The rest shall be provided in subsequent letters and articles.
To establish possible constructive applications of these composites, it was taken as reference INEN Ecuadorian Technical Standards for the respective comparison with the requirements set forth therein. We analyze the samples drawn type conforming to the specifications of this legislation, so that they can be used in construction mainly as non-structural purposes in floors, roofs, partitions and enclosures.
Different types of specimens containing cement backer-bagasse ash-bagasse, gypsum bagasse, bagasse fiber-vegetable glue were designed and manufactured, even some boards of pulp from bagasse glued with polyurethane resin. After setting and drying, the specimens and table boards were subjected to bending tests, compression, water absorption, capillary test, fire resistance and drilling. The water/cement ratio in all samples was 0.5 wt. In materials made with a matrix of gypsum the fiber ratio water / gypsum varied between 0.65 and 0.75 by wt. Addition of ash to the specimens with cement and plaster incorporated at least 10% ash by weight of the binder.
Enclosed at the end of this manuscript a table describing the main components of specimens and boards tested. Samples were manufactured by hand. At the very beginning, dry bagasse fiber without pulp was selected; separating dry pulp from bagasse fiber. Fine particle of bottom ashes from the combustion of bagasse fibers were preferably used as pozzolanic additions in cement samples.

Fig. 2 “Specimens manufacturing”.

Sorting of bagasse fibers in short fibers of different size ranges was made by hand: 0-2 cm, 0-4 cm, and so on. Longer fibers for reinforcement and reinforced respectively of matrix composites conglomerate cement or plaster, were selected too by hand and measured before the mixing with conglomerates.
Practicable metal molds were produced, with which samples could be make as gypsum composites, reinforced cement with high fiber volume fractions, and plates, both with short fibers of pulp and bagasse, and in the case of only bagasse with longer fibers, but obviously limited to the dimensions of the molds. Besides mixtures of binders and gypsum cement mixtures were also fine-grained ash to evaluate its action with the ordinary pozzolanic cement. Gypsum and cement specimens with

short fiber reached by these method fiber additions comprise between 10% and 100%, by dry weight of conglomerate.
The specimens were demolded after 24 hours of execution. During that time, samples with hydraulic binders or pozzolanic additions were covered with a wet damp cloth for preventing initial shrinkage drying in the early stages of the hydration reactions, and for improving the curing. For demolding the damp cloth is removed, to evaluate the development of resistance inside the laboratory environment under room temperature conditions of temperature and relative humidity (20-22 ° C, 65% RH).
The samples containing only gypsum as bonding agent were dried in oven at 40 °C after setting, until constant weight, after 48 hours of its realization.

4.2.2.- Mechanical testing
Bending and compression tests were accomplished according to standard 900 INEN NTE - ASTM 1185, on samples with different components just described. Testing machine used was Versa Tester (bending), and ELE International Soiltest for compression, in the Materials Laboratory of Department of Geology and Mining and Civil Engineering, UTPL. Tests are described just below.

- Compression test: Specimens of 10x10x15 cm3, were hand manufactured with different dosages and materials, fresh mixtures were poured into molds and vibrated in order to reduce porosity and obtain better characteristics, once molds filled surface was leveled, and allowed to cure in the mold for 24 hours, removed away the mold to finish the curing time and drying.

- Three points bending test were accomplished, obtaining the flexural strength by means of the load-deflection graphs and then the flexural stress-strain. Specimens of 4x4x16 cm3 were produced besides samples cut from the panels and boards, of varying dimensions: lengths between 11 cm and 14 cm, from 5 cm wide and 12 cm, 1.5 cm, 2 cm and 3 cm thickness.

- Tensile test of bagasse fibers: several different types of fibers were selected and tied packed in bundles with different thickness for direct tensile testing of packed fibers (Fig. 5). The thickness of the specimens was measured after the tensile tests, for assessing the tensile stress with respect to the effective fiber section of each bundle.

- Anchorage strength: Selected samples were drilled with tapping screws drilled at 2 cm from the edge of each specimen.

4.2.3 Physical properties testing.-
Bagasse bulk density was measured by hydric methods with additional overweight to achieve full immersion in water, obtaining 0.19 g / cm3 on average. Moisture content, water absorption, water capillary suction and porosity. These physical properties are described elsewhere to not extend this communication.
Swelling of composite materials: This test was done to determine dimensional variations in specimens' thickness after water immersion for 2 hours and 24 hours, respectively, according to NTE INEN 899 standard.

$$\mathrm{H}_t(\%) := \frac{t2-t1}{t1} \times 100\ (\%) \qquad (1)$$

Being:
H_t (%) = Swelling (%)
t1 = thickness of specimen before immersion (mm)
t2 = thickness of specimen after immersion (mm)

Fire resistance was determined according to standard NTE INEN 804. Direct fire was applied on selected plates. The above referred standard establishes two fire resistant classes, 1) F30 = fire 30 minutes for residential buildings, and 2) F60 = Fire 60 minutes for non-residential buildings. The instrument used for this test was fueled by liquefied gas torch.

5.- Results and Analysis

Table 1 contains the results of compression behavior of tested samples that met the specifications of Standard Ecuador. In accordance with the information in this table 1, it was seen that analyzed composites showed a good behavior, better than proposed in the Standard Ecuador.

Specimen	Weight (g)	Height (cm)	Length (cm)	Width (cm)	Max. Load (kg)	Compressive Strength (kg/cm2)
Y2	1153.6	10	15	10	4212.4	28.08
Y4	1138.1	10	15	10	3177.7	21.18
Y5	1103.9	10	15	10	3660.6	24.4
B2	1107.9	10	15	10	2815.5	26.76
CN1	1400.6	10	15	10	2960.1	20

Table 1 “Compressive Strength”

Fig. 3 “Compression test”

The tensile strength of the fibers of bagasse average measured was 135.0 MPa and Young’s modulus of 11.5 GPa, consistent with literature data [16], although there is a wide dispersion in the literature on similar data because other authors indicate values of the tensile strength of 30.9 MPa for bagasse [17]. More work need to be done.
Regarding bending strength, Table 2 summarizes the characteristics of the samples that satisfied the above reported Standard, which determines a minimum value of 15 kg/cm2 of flexural strength for the constructive implementation of the corresponding material. The flexural strength is higher in gypsum-based elements, because this element has fast setting and presents quasi-ductile behavior, resisting a small deformation when the load is applied at the center of the board.

Fig. 4 "Bending test"

SPECIMEN	LENGTH (cm)	WIDTH (cm)	THICKNESS (cm)	Weigth (kg)	Load (N)	Bending Strength (N/mm2)	Bending Strength (kg/cm2)	Deformation (%)
y1	13.0	6.5	2.0	8.57	41.0	2.38	23.80	7.27
y2	13.0	6.0	2.0	8.56	39.5	2.38	23.82	5.13
y3	13.0	9.5	2.0	8.59	73.0	2.39	23.90	5.56
YA1	13.5	8.0	1.5	9.83	31.5	2.73	27.34	5.67
YA2	13.5	12.0	1.5	9.82	21.4	2.73	27.31	5.27
YFI	14.0	5.0	2.0	8.55	15.5	2.38	23.76	1.54
YF2	14.0	8.0	2.0	8.55	25.5	2.38	23.79	3.85
YB1	13.5	5.0	3.0	8.62	108.0	2.40	23.98	4.86
YB2	13.5	6.0	3.0	8.63	115.0	2.40	24.00	2.03
YB3	13.5	12.0	3.0	9.80	200.0	0.33	3.34	6.89
$YB^2 1$	13.0	8.0	2.0	8.53	70.0	0.22	2.23	2.31
$YB^2 2$	11.0	6.5	2.0	8.59	70.0	2.39	23.89	6.05
$YB^2 3$	11.0	6.0	2.0	8.60	84.0	2.39	23.92	3.85
$YB^2 4$	13.0	5.0	2.0	8.53	45.0	2.38	23.83	1.62
CNA1	13.5	12	2.0	9.84	49.0	2.74	27.38	2.03

Table 2 "Bending strength"

Table 3 lists the names and composition of the specimens described in the laboratory tests described in this communication.

Y1 to Y5: Plaster bagasse (mixture of fiber and pulp). Adding fibers on gypsum weight: from 24% to 100%. Fiber sizes (0-2 cm). Plate thickness: from 1.5 to 3 cm. Y2 contains 8% vegetable glue. Water (%) / gypsum (%): 20/40, 12 (+ 8glue) / 52.13 / 70.16 / 43.
CN1- CN2: Bagasse ash. 2 cm thick. CN1 mixture of fiber and ash (32%, 32%, 16%, 20%: ash, bagasse, vegetable glue, water). Bagasse: 0-2 cm. Without pulp. CN2 mixture of fiber (pulp) and ash (48%, 24%, 8%, 20%:%: ash, bagasse, vegetable glue, water). 0-2 cm bagasse pulp.
C1 to C3: Cement bagasse. Adding fiber and pulp. Thickness of 1.5 to 3 cm. C1 (50%, 10%, 25%, 15% cement, Bondex, fiber, water) fiber 20mm to 50mm, C2 (50%, 30%, 20% cement, fiber pulp + water) fiber pulp 0 20 mm. C3 (24%, 56%, 20%: fiber pulp and 0-1.5 mm and 20 mm.
B1 and B2: Cement, bagasse, Bondex. 1.5 to 2 cm thick. B1 (20%, 40%, 20%, 20% cement, Bondex, fiber, water) 0.5 to 20 mm fiber. B2 (40%, 10%, 40%, 20% cement,

Bondex, fiber, water) 20 mm to 40 mm fiber.
P1 to P3: Fiber with polyurethane resin. Thickness 1.5 cm to 2 cm. Composition: (80%, 20%: fiber, PU) types of additions: P1 pulp fiber and 0.1mm to 30mm; P2, pulp, 0.1mm to 50mm; P3, and pulp fiber, 10 mm to 50 mm.
F1 to F2. Long Fiber PU resin. Thickness 1.5 cm to 2 cm. Composition: (80%, 20%: fiber, PU) types of additions: 25 long fiber F1 x 15 cm; P2, pulp, 0.1mm to 50mm; F2 - F3 softwood 25 x 15 cm.
YA1 to YA2. Two specimens taken from the same plate. Pulp fiber and 0.5 mm to 20 mm. 50% by volume of plaster and 50% by volume of untreated fiber. Water (30% weight on dry mixture). Vegetable glue 5% by weight on the dry mixture.
YF1 - YF2. Plaster with short fiber (0.2 mm to 25 mm), untreated just washed. Water 40% on dry mixture. Vegetable glue 5%. dry mixture.
YB1 to YB3. Gypsum fiber and pulp, 0.5 mm; 70% gypsum 30% fiber. More resistant. Water 50% on dry mixture. No glue.
YB21 to YB24. Gypsum fiber and pulp, 0.5 mm; 70% gypsum 30% fiber. More resistant. Water 50% on dry mixture. Vegetable glue contains 10% dry mixture.
CNA1. Ash, cement, fiber 20% fiber, 40% bagasse ash, 10% tail. Water 40% on dry mixture.

Table 3 “Names and composition of specimens”

Fig 5 “Bagasse bundles direct tensile test”

Specimen	Initial thickness (cm)	thickness 2 hours in water immersion (cm)	thickness 24 hours in water immersion (cm)	Swelling at 2 hours (%)	Swelling at 2 hours (%)
Y2	2.12	2.13	2.19	0.47	3.30
Y4	3.15	3.16	3.21	0.32	1.90
Y5	2.10	2.11	2.17	0.48	3.33
CN1	2.12	2.13	2.18	0.47	2.83
C1	1.52	1.53	1.59	0.66	4.61
B2	1.52	1.54	1.71	1.32	12.50
P2	1.51	1.54	1.60	1.99	5.96
F1	2.14	2.18	2.20	1.87	2.80

Table 4 “Swelling (%)”

Measurements of swelling (%) are shown in Table 4. The Ecuatorian standard in this test establishes a maximum swelling of 20% for boards, so bagasse reinforced panels are within the range required by the standard INEN NTE 899, the maximum value of 12.50% was obtained for sample B2, resulting suitable for application to construction.

Fig. 6 “Swelling test”

During fire resistance test after 35 minutes and 63 minutes, respectively, it was observed a small perforation on the front face and in the rear face, respectively, of the boards fabricated with hydraulic binders and gypsum, respectively, different of behavior exhibit by quick-drying materials (fibers with synthetic glues and resins) which, when applying flames fire progressed rapidly, with a duration of 10 minutes for the fire damage occurs. However, after removing the application of fire burner, the ash produced is turned off automatically, showing only minimal damage in the place where the fire was placed. The boards with inorganic binders reached a minimum strength of about 30min, in according to fire standard.
The results of fire tests are shown in Table 5. The fire resistant class and the classification is determined by the duration of the action of fire, in minutes.

DETERMINACION DE RESISTENCIA AL FUEGO		
MUESTRA	Clasificación según la resistencia	
	Residencial F30	**E. verticales F60**
Y2	-	F60
Y4	-	F63
Y5	F31	-
CN1	F48	-
C1	-	F60
B2	-	F60

Table 5 “Fire behavior”

Fig. 7 “Fire test”

Anchorage test screw drilling and resistance were evaluated qualitatively, not quantitatively. The specimens, panels and boards after tested in bending, water (after drying) and fire in less affected areas were used. It was found that boards do no suffered damage or cracking when penetrating drill and tapping screw where necessary, so they are elements of easy anchoring, regardless of the structure to be applied [18].

Fig. 8 “Drilling and anchorage of screws in the table boards”

After the first phase of manufacturing samples and conducting mechanical and water tests with samples from large format plates, new specimens of cement and plaster made with high volume fractions of short fibers of bagasse pulp and particles bagasse ash larger where manufactured. Ashes of smaller particle sizes, and therefore thinner by pozzolanic addition were used as samples for cement made.
The mixture proportions of these samples were performed using new criteria for ease of manual mixing, as it is simulated in the laboratory and characterize quantitatively accessible procedures mixture artisan skilled operators but only manual means.
All results of bending modulus, compression behavior, the swelling rate, are within the range of values specified in each of the standards. However, it is being analyzed in greater depth the alternatives to modify the components of panels and boards for

improving their performance tests against termites, moisture, fire, thermal and acoustic insulation, evaluating various preventive treatments of plant fibers that can easily be performed in areas where research is addressed: improving traditional buildings by means of low cost construction. According to results obtained it can be defined which are among the important variables those that determine the mechanical and physical characteristics of nonstructural elements that can be produced by the proposed panels, they are the following:
- The thickness of the panels and boards
- Dimensions and cross section elements.
- The characteristics and properties of materials used in the production of the panels and boards.
- Preventive treatment of plant fibers.

6. Conclusions

Mechanical and physical tests performed on specimens based on the corresponding standards, effectively indicate that composite boards and panels manufactured from sugarcane residues with different compositions and the materials tested meet the specifications required for each of the denominations. Accordingly, it is possible to use them for civil construction systems that may be of no structural.

The addition of ash from bagasse and coffee husks improves the performance of the panels and boards.

Better resistance to fire cement board and gypsum bagasse fibers are obtained with pulp fibers and resins.

The swelling of the boards is less than the amount specified in the regulations, when the matrices are of plaster and cement.

Panels admit high fiber fractions (greater than 100% of the binder) by traditional manual manufacturing processes.

It is recommended that further testing of improved preventive treatment of the fibers, to ensure durability and make testing acoustic and thermal insulation.

ACKNOWLEDGEMENTS

The authors express their gratitude to Angel Tapia, Civil Eng., students Gabriel Ochoa and Magaly Jiménez, and to the group research managers Universidad Técnica Particular de Loja, who have contributed their expertise and work in the development of this work**.**

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