Street furniture in recycled and resignified materials

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Abstract. Seeking to strengthen sustainable construction through recycling and reuse of cardboard tubes as an efficient use of raw materials in the Municipality of Ocaña, this research was carried out as a proposal for the resignification of the cardboard tube as a material, generating technical, low-cost, and sustainable solutions, allowing the production of street furniture, to generate changes to those social dynamics impregnated by a reality of consumption, which needs new construction techniques and social innovation, that allow giving life to and making visible, sustainable urban spaces, friendly with the environment as well, thus contributing to the transfer of knowledge in the application of the technique. For this reason, it is important to analyze the use, utility and impact of the reuse of solid materials such as cardboard tubes, as it allows identifying different routes that articulate new contributions to social construction modifying customs and traditions, and building social manufacturing aiming at technological innovation for sustainable construction.

1. Introduction

Following the Stockholm Treaty in 1972, a debate for conservation and improvement of the human environment was initiated, for the benefit of present and future generations [1-2]. In addition to the above, the Rio declaration by the UN, in the environmental field, defined four sections within Agenda 21 that established the navigation route in terms of environmental care and it is thereafter, that construction sustainability takes relevance, having as main axes the social, economic and environmental dimensions. Therefore, sustainable construction must ensure saving resources, efficient production generation, risk reduction and strengthening of research as axes to transcend in the exchange of applied knowledge.

A broader perception of sustainable construction is described by the president of Spain Green Building who states that “Sustainable Construction can be defined as having a special respect and commitment to the environment, implying efficient use of energy and water, resources and materials that are not harmful to the environment, resulting in healthier outputs and aiming at reducing environmental impacts” [3].

Based on the aforementioned, the Colombian Council of Sustainable Construction in 2011 defines as the advantages of this type of construction "the implementation of sustainable systems generating strong benefits when lowering on average, 35% of carbon, between 30 and 50% of water and between 50% and 90% of waste-related costs, not including improvement in health and productivity of those who live there" [4].

The foregoing denotes the relevance and the need to strengthen the academic training of the new generation of civil engineers in a new form of construction in common agreement with their social and environmental settings.
Another view of sustainable construction is defined by Domingo Acosta who mentions that "Sustainable construction contributes to the reduction of its impact on the environment and contributes to equity, to the fight against poverty and to reduce vulnerability of our human settlements." [4]. That is why sustainable construction seeks equity within the internal and external development of the human habitat.

According to ASOVIDA Foundation, around 27700 tons of waste are produced per day, that is, an amount of half a kilogram per citizen, and from this waste, only about 10% is used by the so-called informal recyclers; the remaining percentage of waste is discarded in open landfills or buried. In the country, about 55% of the waste corresponds to material with organic characteristics, 10% to plastics, 13% to paper and cardboard, 7% to glass, 35% to metals and 12% to others, like textiles, leather and ceramics [6]. The disposal of these solid waste is done in plants specializing in its treatment; according to the Superintendence of public services of Colombia, the best plant is in the city of Arauca, followed by other important ones in the Department of Huila, in the municipalities of Garzon, Pitalito and La Plata, and in Medellín [7].

Waste generation is very associated with cities and their population and industrial growth compared to consumption habits [8], which have increased considerably over the last 50 years, so at various world summits this issue has been addressed consequently. According to the Rio Summit in 1992, on sustainable development, the problem of waste is addressed not only in terms of its collection and disposal, but in accordance with an integral concept of the life cycle of materials, which includes sustainable models of production and consumption [9].

As a result of the aforementioned, some countries of the world have developed methods to quantify the level of solid waste production per person. They have also applied innovative and effective policies, which have brought great benefits. Netherlands is a living example of these countries committed to caring for the environment, where 64% of the waste collected is recycled, 3% is confined and the remaining 33% is converted into electricity. As it can be seen, Netherlands is globally the main country in terms of use of emitted solid waste [10]. Another case is Sweden, which recycles 41.4% of solid waste, 45% is transformed into electricity and 13.6% goes to landfills. In Mexico City, out of the 12500 tons of garbage being daily generated, 87% is buried, only 13% serves as reusable material and compost, but the city no longer has space to continue burying wastes [11].

Therefore, the problem of solid waste is highlighted, as a common problem, which requires a high commitment by society; otherwise, the current process will continue, involving a minimum effort on the part of citizens, administrations and entities responsible for these tasks. Hence, we must intensify environmental protection and conservation policies and creation of new spaces with alternative materials guaranteeing a greater commitment to our environment, thus achieving sustainable housing and environments, using recycled materials such as cardboard tubes.

In recent times, cardboard, plastic and neoprene have been present in multiple products of daily use; besides, they have been shown as weak materials, so that at present they have only been used for recycling and classified as solid material, without any valuable use for the development of our society. Thus, we are wasting a renewable raw material of great production and easy recovery, which presents the advantages of a biodegradable material, which would allow it to position itself within eco-friendly building materials.

There are many arguments giving importance to sustainable construction and that make recycling and reusing relevant and, with it, the resignification of materials. The municipality of Ocaña, within its industrial and economic dynamics generates waste such as cardboard, bottles and different raw materials as part of the general consumption of the Municipality, so the relevance of this research is based on giving new life to these materials, generating technological, economic, environmental and sustainable solutions in the creation of sustainable street furniture, that allows propagating changes to the social dynamics of consumerism, which permeates the reality of Ocaña, generating new technologies in the manufacturing of street furniture, thus contributing to social and technologic innovation with the transfer of scientific-technical knowledge.
2. Methodology
The project has been developed as a classroom project that allows the students interacting with the recycled materials of their environment and signify them in useful elements, through the application of the technique and scientific knowledge about forces, loads and properties of the materials, which contributes to a project of social and technological innovation that will be useful for the community in general.

The project was divided into four stages. The first stage consisted of a sector analysis to establish the percentage of waste coming mainly from the industrial sector, mostly cardboard tubes. In the second stage, a material characterization was carried out to establish conditions of absorption, resistance and deformability.

The furniture design was the third stage, proposing different models based on guidelines such as resistance, ergonomics, comfort and efficiency. And, in the fourth and last stage, laboratory tests were carried out on the different models, mainly evaluating resistance and wear to define the final furniture models.

3. Results
Over the years, cardboard has been considered as a weak material with multiple common uses, but in a few occasions, it has been part of the solution in the creation of housing. And, it is from the 90s that another perspective is acquired, thanks to the advances achieved and accepted in other cultures such as the Japanese, where the architect Shigeru Ban found an answer in this material in the creation of new spaces such as libraries, theaters, churches, shelters and houses [12-13] allowing the world discovering the great advantages of this noble material. Initially, it was found so these places were identified, in addition to the recycling points that are shown in Figures 1, 2 and 3, which are responsible for organizing and preparing typical materials such as plastic and cardboard. This first stage also allowed the students getting closer to the social environment, especially with recycling centers and recyclers, and to know firsthand the external characteristics of the material and its origin.

![Figure 1. Recycling plastics.](image1)

![Figure 2. Recycling cardboard.](image2)
![Figure 3. Recycling neoprene.](image3)

The results obtained in the second stage, for the bending tests are shown in Figure 4, with a separation of 0.35m and a test speed of 0.02mm/min. The results shown in Figure 5 indicate a maximum load of 4.35kN with a deformation of 27.81mm and a true stress of 13.96MPa. The compression tests, as shown in Figure 6, were made for specimens of 87mm diameter and 220mm height with a speed of 0.25MPa/s;
the results shown in Figure 7 indicate a maximum load of 9.45kN with a deformation of 11.85mm and a real resistance of 7.34MPa. From the obtained results, it is observed that the cardboard tubes fail by crushing.

As a part of the third stage, the design was determined based on the characteristics of the material, the technical analysis of the loads, and the possible supports and possible articulations that it may have with other materials. Based on the above, a design meeting requirement as quality, comfort and ergonomics is sought.

Figure 4. Bending tests with cardboard tubes.

Figure 5. Stress vs strain.

Figure 6. Compression test in cardboard tubes.

Figure 7. Stress vs strain.
3.1. Furniture design

Furniture design is a fundamental part of the project. In this stage, the position of the materials is determined, and it can be combined with other materials like wood and plastic polymers that will give the furniture a greater rigidity and support in its structure, considering the comfort of the academic community of the Universidad Francisco De Paula Santander, where this furniture was planned to be installed. Figures 8 and 9 show the drawings and designs that were considered; likewise, Figure 10 shows the working sessions held as a part of the classroom project.

![Figure 8. Sustainable sofa made of cardboard tubes.](image)

![Figure 9. Sustainable chair made of cardboard tubes and recycled wood.](image)

![Figure 10. Working sessions](image)

3.2. Construction of the street furniture-real scale prototypes

Finally, the planned furniture was designed, and its loads were calculated as well, it was put at the service of the academic community so that it can see the results of a classroom project which allows interaction of the technique and the bio-construction within social innovation and technique in the re-signification of materials that are commonly discarded.

The street furniture building technique by using recycled cardboard tubes brings advantages to the sector in various aspects such as sustainable design, as well as comfort and economy. The technique
seeks to provide the population with access to aesthetic furniture with high structural quality, while fostering care for the environment and promoting sustainable construction.

Conveniences offered by the technique start with the origin of the used materials. Cardboard tubes are waste elements of the textile and paper industries, which have great strength in Colombia, so acquiring them is simple and cheap, either from the textile company itself or through the recycling material warehouses. Connecting tube elements is cheap and the assembly is simple. The process causes no pollution and produces a resistant and aesthetic product.

Reducing the mass of waste in the streets and landfills all over is a priority, at a time when waste is a rampant phenomenon in cities increasingly populated and in which the recycling culture is taking the most decisive role in the success of ensuring benefits for the most vulnerable populations of our city of Ocaña. Figures 11 to 12 show the different models built as the final result of this project.

![Figure 11. Sofa-bed made in cardboard tubes.](image1)

![Figure 12. Chairs made in cardboard tubes and recycled wood.](image2)

4. Conclusion

From recycling and reusing solid materials such as cardboard, plastic, neoprene, and other solid materials, it is demonstrated how they can be transformed into sustainable street furniture, which contributes to the exploration of new forms and uses of materials.

With the environmental and sustainable commitment of the Francisco de Paula Santander Ocaña University, it can be seen that from the School of Engineering there is a development of new proposals for street furniture contributing to reduce solid waste transforming them into new architectural and engineering elements, that have an adequate structural behavior, and a good behavior under different weather conditions that can wear out or corrode materials. As a classroom project, it was observed that the development of this furniture stimulates creation and development, and that real scale prototypes were very well received by the academic staff of the University.

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