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Alternative Materials As an Opportunity to Reduce Environmental Impacts in the Construction Sector

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Abstract: Construction has become a serious environmental problem due to its high demand on natural resources and the massive production of large volumes of waste that require special handling. Because of this, it is necessary to rethink the materials used in the sector, together with the methods of extraction and production, as well as the application of instruments that facilitate the reduction of the impacts associated with construction works, from the design stage or obtaining raw materials. In this way, a bibliographic search of various electronic documents was used, mainly from the databases of the National University, among other academic search engines. The methodological process was based on a qualitative research, where theory and bibliographic review were the frame of reference. The purpose is to identify alternative materials such as adobe, wood, hemp, straw, bamboo, and eco-bricks made from household waste, which can replace the use of traditional materials. In this sense, the present bibliographic research allowed demonstrating that alternative materials are capable of providing the same structural support to a construction work, compared to other conventional materials. It also highlights the added value that these options provide to the construction sector, reducing the associated ecological footprints and improving the environmental balance, since the high environmental costs of resource extraction are reduced and other negative environmental impacts are minimized.

Key words: bioconstruction; alternative materials; conventional materials; environmental impact

1. Introduction

The increase in population density worldwide has led to the development of a phenomenon characterized by an increase in urbanization, construction works of various kinds, as well as the consumption of raw materials and inputs associated with the implementation of such works. Thus, construction has become a serious environmental problem due to its high demand on natural resources and the massive production of large volumes of waste that require special handling. Indeed, it is estimated that 50% of all materials extracted from the earth are transformed into construction materials and other products and that, in turn, when these materials are discarded as waste, they represent up to 50% of all waste generated [1].

In addition, in conventional construction, most of the materials used have high environmental costs because they require high energy costs for extraction, transport and transformation. At the same time, the incorporation of chemical substances to these materials to improve their technical characteristics, without due consideration of the environmental repercussions, harms both the health of ecosystems and people [2]. In this sense, it is important to emphasize that alternative construction materials are those that can be used in the construction of certain structures, without being designed for that purpose, i.e., they are not specifically designed for construction. These materials exclude all those that are designed and planned for construction and that are generally used for all types of work, so they are considered to be of conventional use and involve high impacts associated with their manufacture, such as: stone, glass, ceramics, conglomerates, metals, plastics, paints and bituminous materials [3].

At the country level, the construction sector contributes significantly to the national economy, which is why it is in constant growth. Thus, according to a report by the Central Bank of Costa Rica in 2017, the sector has shown an increase at an interannual rate of 0.7%, which is related to the production of a large amount of construction waste, especially with a production rate of 24.1 kg/m². As an example, it can be said that 250,360 tons of construction waste were generated in 2016 [4].

That said, it should be noted that, in order to avoid negative repercussions at the environmental level, it is necessary to rethink the materials used in the sector, along with the extraction and production methods, as well as the application of instruments that facilitate the reduction of impacts associated with construction works, from the stage of design or obtaining raw materials. In view of this, bioconstruction emerges as an alternative to conventional construction, which can be conceptualized as the creation of healthy and comfortable habitats from natural resources with low environmental impact, such as wood, soil and straw, with environmental impact being understood as a change in the environment as a result of the activities, products or services of an organization [5].

This architectural current [6, 7] is based on the following criteria:

- The prioritization of locally sourced materials and low energy costs.
- The use of materials that improve people's health, i.e., free of toxicity and that reduce the accumulation of dust particles, the proliferation of microorganisms and the emission of harmful gases.
- The use of durable materials that biodegrade easily at the end of their useful life and/or can be reused.
- The use of materials that allow the regulation of indoor air humidity.
- The use of materials that facilitate the thermal comfort of the interior environments of a building without the use of electrical or mechanical equipment or any other active system.

Under these considerations, this article aims to identify alternative construction materials through qualitative research for comparison, in terms of environmental impact, with conventional materials.

2. Materials and Methods

The research is characterized as qualitative, since theory and bibliographic review are the frame of reference of this article [8]. The methodology was based on the systematic search of bibliographic information from scientific articles, theses and electronic books in the databases of the National University, as well as in renowned academic search engines such as Dialnet, Scielo, Science and Google Scholar. It is worth mentioning that as search criteria, the year of publication was sought to be between 2008 and 2018, with the exception of references considered as classic, i.e., that have not lost relevance and pertinence over time.

3. Results and Discussion

Humans spend about 90% of our time indoors, where, according to the Scientific Committee on Health and Environmental Risks of the European Union, more than 900 substances and particles, both chemical and biological, with possible negative effects on health, can be contained [9].

Thus, conventional construction materials are associated with the release of toxic and carcinogenic substances such as formaldehyde and benzene, which are used as adhesives and solvents, respectively. Likewise, PVC, one of the main construction materials, due to its chemical composition, is related to the generation of organochlorine products, which cause diverse toxic effects in living beings, including immunological, reproductive, endocrine and nervous system damage [9].

In addition to these aspects, construction materials have a high environmental impact due to the large amount of energy used in their manufacture, as well as the associated greenhouse gas emissions throughout their life cycle, i.e., in the extraction of raw materials, the transformation processes, as well as their transportation to their final destination of use. Below is a list of the amount of energy used throughout the life cycle of different construction materials, per cubic meter of material, where it can be seen that alternative materials (straw, sand, adobe and earth) require the least amount of this resource [6].

Table 1. Amount of energy used in the life cycles of various materials

Material	MJ/m^3
Straw	30.5
Sand	232
Adobe	490
Pressed earth block	810
Local stone	2,030
Expanded polystyrene	2,340
Concrete	3,890
Ceramic brick	5,170
Ceramic tile	5,250
Plywood	5,720
Asphalt	7,140
Cement	15,210
Polyurethane	44,400
Polypropylene	57,600
PVC	93,620
Steel	274,570

In view of this, bioconstruction is committed to the use of construction materials with lower environmental impacts in the search for sustainable development of the construction sector. Among these materials we can mention:

Adobe: Adobe is a mass of earth molded in the shape of a brick and dried in the sun, which is used in the construction of walls. In ancient times, the first buildings were built with raw earth, a harmless material found in abundance on the planet. It does not contain toxic substances and can be reintegrated into nature at the end of its useful life. In addition, it can be easily obtained locally, which reduces its environmental impact associated with greenhouse gas emissions during transportation. In addition, construction with this material does not require high temperatures, so its energy consumption is considered low. Likewise, its production has a low impact because it lacks problems such as deforestation or extractive mining involved in other construction materials [9, 10]. In terms of its properties, it has a great capacity to store heat and subsequently transfer it (a quality known as thermal inertia), which is characterized by the attenuation of external temperature changes and the creation of thermal comfort, facilitating the energy efficiency of buildings by reducing energy demands for cooling or heating. It also has acoustic insulation and moisture regulation properties. In addition, it is a non-flammable and economically affordable material [9, 10].

Wood: As long as it is free of toxic treatments and comes from sustainable forest management, it is considered one of the building materials with the lowest environmental impact. It acts as a natural regulator of the indoor environment since its porosity facilitates ventilation; it stabilizes humidity, filters and purifies the air. At the same time, it has insulating properties, both thermal and acoustic, as well as permeability to terrestrial radiation. In addition, it is a resistant, elastic and lightweight material, which means that it can be used in various types of construction. In addition, products derived from wood also have the same characteristics, such as cork and natural rubber [3, 9].

Hemp: At present, blocks are made from the woody part of hemp, a versatile and fast-growing plant. This plant is a soil improver and does not require the use of pesticides, so its cultivation is characterized by its low environmental impact [11]. This block is called Cannabric and has insulating properties that create environments of high thermal and acoustic comfort. At the same time, its porosity facilitates ventilation, humidity regulation and air cleaning by acting as a filter and retainer of atmospheric pollutants. In addition, it is not susceptible to attack by parasites due to the absence of nutrients in its composition. On the other hand, it is a resistant and durable material, although it can be recycled at the end of its life cycle. In addition, it is characterized by retaining carbon dioxide and by not contributing to the emission of greenhouse gases during its manufacture, since it consumes very low amounts of energy. In addition, it is a material with high mechanical and fire resistance, so it can be used in a wide range of buildings [11].

Straw: Straw is a natural material with high availability worldwide, which is characterized by being compostable at the end of its useful life, so that, unlike conventional materials, its disposal at the end of a construction project is not a relevant problem. The use of straw bales as a structural element or as a filler or insulating material is an alternative in the construction of green buildings with low energy consumption, since the material contributes to maintaining the optimum temperature inside a building due to its thermal insulation characteristics [12]. In addition, up to 77 times less energy is needed for its production and transportation compared to conventional construction materials [12]. It is concluded that straw [12], as a construction material, is quite durable and useful, since there are still many structures built in the 19th century that are still standing today, with buildings with life spans of close to 100 years. In addition, since it comes from cereal plants, straw, like wood, hemp and alternative construction materials from plant species, contributes to the environment by capturing carbon dioxide through the photosynthesis process during its growth phase [13].

Bamboo: Bamboo as an alternative for construction is optimal because it can be found in all regions of the world. At the same time, its species are fast-growing, providing both economic and environmental benefits by facilitating its local acquisition in construction, reducing the negative impacts associated with transporting the material. In addition, bamboo provides ecological benefits by sequestering carbon dioxide at high rates due to its rapid growth and biomass production. With respect to its structural properties, bamboo is a composite material, with a distribution of its fibers that increases from the inside to the outside, behaving as a reinforcement similar to that of steel bars in concrete [14]. On the other hand, in comparison with conventional materials, bamboo fibers have greater advantages than others of synthetic origin, since they are renewable, biodegradable, less abrasive and have a lower energy demand for their production. It is also considered a versatile material, due to its high strength-to-weight ratio, ease of work and availability; thus, sometimes it could even replace concrete, wood or steel [14]. In turn, the use of bamboo contributes to the capture of carbon dioxide, which improves air quality conditions.

Eco-bricks made from household waste: Reference is made to a new trend in construction materials based on bricks made from recycled plastic bottles. At present, they do not have great structural resistance, so their use is based on the construction of walls or small houses. They are made from the introduction of sand or other non-organic waste, such as paper, cardboard or plastic bags, where the main objective is to fill plastic bottles with materials that provide resistance to them [15]. Among the advantages of this technique are that it is a simple recycling technology that can be carried out by people who do not have extensive technical knowledge of recycling or construction, easy to store and transport. At the same time, it reduces the impact on the construction process, reduces impacts associated with waste collection, such as transportation and final disposal. In addition, it also has structural advantages because it is a fully insulating and anti-seismic material [16].

4. Conclusions

Construction materials have a high environmental impact throughout their life cycle, from extraction to final disposal. However, it was determined that there are alternative materials that can be used in various construction works, with the same structural capacity as conventional materials. At the same time, alternative materials have advantages, such as the absence of toxic substances, which allows them to be reintegrated into nature at the end of their useful life.

It is also evident that, in the construction sector, more and more efforts are being made to use alternative materials, which are more environmentally friendly. In this sense, the application of these materials provides an added value to the construction works, since it generates a culture of efficiency in the use of resources, promoting rationality in their consumption in search of sustainable development.

The implementation of alternative materials generates a balance before the environmental impacts of the conventional construction sector, so that the environmental footprints are reduced, contemplating the reduction of polluting emissions, generation rates of hazardous and/or special handling waste, among others.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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