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Comparative analysis of the properties of Guadua Angustifolia Kunt as an innovative and cost-effective material in structural construction

Análisis comparativo de las propiedades de la Guadua Angustifolia Kunt como material innovador y rentable en construcciones estructurales

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Abstract

In construction the conventional materials have been evolving with the purpose of minimizing the problem with the environment, due to this new materials are born that are being studied, a clear example of this is the bamboo, that is a material 100% natural and with great diversity in Colombia. This work analyzes and compares the properties of bamboo angustifolia Kunth as a construction material, determining some of its most favorable characteristics according to the studies carried out in Colombia, giving it an approach for its use as a structural element in addition to cataloguing it as a renewable, sustainable and nature-friendly material. The content is organized with a classification of the studies and laboratories made to the guadua angustifolia Kunth, the characteristics found from those studies and the description of the different locations of guadua in Colombia.

Keywords: Bamboo, Structural, Construction, properties.

Resumen

En construcción los materiales convencionales han venido evolucionando con el fin de minorizar la problemática con el medio ambiente, debido a esto nacen nuevos materiales que están siendo objeto de estudio, un ejemplo claro de esto es el bambú, que es un material 100% natural y con gran diversidad en Colombia. Este trabajo analiza y compara las propiedades de la guadua angustifolia Kunth como material de construcción, determinando algunas de sus características más favorables según los estudios realizados en Colombia dándole un enfoquen para su uso como elemento estructural además de catalogarlo como un material renovable, sustentable y amigable con la naturaleza. El contenido se organiza con una clasificación de los estudios y laboratorios realizados a la guadua angustifolia Kunth, las características encontradas a partir de dichos estudios y la descripción de las diferentes ubicaciones de guadua en Colombia.

Palabras clave: Bambú, Estructural, Construcción, propiedades.

Introduction

The human being has been developing his capacities to create different types of constructions with different materials, taking into account the various environmental and economic problems that humanity is currently facing, has generated the need to seek a new approach in the selection and use of renewable and natural materials in construction, as an alternative to those of conventional use, in order to reduce such problems [1], such is the case of bamboo as a material that has been used in America since pre-Columbian times until today, as an innovative proposal for a sustainable future [2], being one of the best alternatives for the construction of housing with lower environmental and economic costs.

There is a great diversity of bamboo in Latin America where approximately 25 species are found in Colombia, among them the guadua Angustifolia Kunth [3], reaching heights of approximately 30m and diameters of 25cm, is one of the species with greater economic importance in the country due to its application in the construction of houses, bridges, gutters and aqueducts [4], is a renewable resource that fulfills an ecological function in its ecosystem, have the capacity to enrich the soil where it grows, regulate the air and purify the water [2], these virtues awaken the interest to investigate new properties and applications.

The guadua Angustifolia Kunth acquires in a short time its greater resistance, it is one of the most used species of bamboo in the construction thanks to its size, mechanical resistance and durability [5], due to its dimensions and low weight make this an ideal material for areas of high seismic risk, its physical-mechanical properties are very particular, mainly when it is submitted to flexion efforts, tension and compression on its axis, these properties are better than some conventional woods [2], besides having structural and physical characteristics, as well as its easy and economical obtaining has led to the development of several projects and scientific construction laboratories in the country, in order to know the potential of this type of bamboo.

However, even though they have mechanical properties, these can be affected by the change in moisture content, so it is considered necessary to take into account tests before, to observe the variation of resistance of the bamboo based on different humidities [1], this amount of water in the stem decreases with height and age, Another factor lies in the diameters of the guadua due to the fact that they contract when there is a loss of humidity, these contractions are less when the trunk is mature demonstrating its resistance to tension and flexion, in addition they possess a fibrous membrane in its cross section that when being submitted to efforts has great capacity of resistance to the compression [6].

At present, some goodness's are known that characterize this material, however, Guadua Angustifolia Kunth has not been studied in its totality [2]. Based on these scientific and engineering works already known, a comparative analysis of them is made, which allows to identify the properties of Guadua Angustifolia Kunth to catalogue it as an innovative, safe, profitable, resistant and environmentally friendly building material [7] demonstrating that it is a material that satisfactorily meets the design standards and criteria for use as a structural element in future buildings thanks to its favorable characteristics [8].

The present investigation will focus on studying the use of guadua angustifolia as an economic and innovative construction material for future housing in Colombia, because conventional materials are producing a certain type of contamination. Thus, the present work would

allow to show the significant changes in the field of construction, from the properties that the guadua has developed with the passage of time and to deepen the knowledge on the constructive process with this material.

Theoretical Frame

The guadua is one of the genus of bamboo from tropical America qualified as the third largest bamboo in the world, reaching heights of 30 meters and diameters of approximately 22cm [9], its obtaining depends on external factors in its natural environment such as climate, soil, slope of the land, etc. this type of plant is considered one of the species with the fastest growth of the planet, it can take approximately 4 to 6 months to develop its optimal height.

The guadua Angustifolia Kunth is the native species of Colombia, is distributed mainly in the Andean region, in its morphological composition can be distinguished the culmo as the important part, since traditionally it is the most used in the construction of houses, industrialization and manufacture of furniture [10] is a plant with high speed of growth and reproduces by itself, is used as raw material in friendly constructive systems with the environment mainly by its abundance, accessibility and easy obtaining [5].

Colombia is one of the pioneering countries in the structural use of bamboo, developing technologies for construction and a series of quality standards that guide the proper handling and use of bamboo as a raw material in construction [11]. This bamboo has important characteristics and is also valuable for its excellent structural qualities, because it has longitudinal fibers, which favor the bamboo stalks to resist the strong efforts that are subjected to the effect of wind and its own weight [12].

Authors such as [13] point out that bamboo has a lower heat of combustion because it is recommended for use as a construction material, since the risks of burning are lower. For all its characteristics it is a material considered in the construction of houses, since it is a high quality material to support the force to flexion and absorbs seismic energy [14]. The function of the conductive tissues, xylem and phloem that are in the bamboo butt are throughout the life of the butt as it happens in hard and soft wood of the dicots [15], in addition it is an anisotropic material, that is to say that its properties vary according to the thermal expansion and change of volume by humidity, which makes the bamboo behave like a wood.

A factor that makes guadua important is its economy, thanks to its speed of maturation allows its rapid use, also for its high expansion per hectare and the diversity of use that is distinguished [16], consequently guadua is an ecological alternative so it is recommended its cultivation as a measure to mitigate environmental damage to the ecosystem, since it is a natural resource that prevents soil erosion, while enriching it [17].

Materials and methods

At the present time the population growth has generated the increase of houses in the world, which has waked up the interest in knowing the properties that some materials possess to be used in the construction, in the suitable development of this analysis articles of tests and studies realized to the guadua Angustifolia Kunth as constructive material will be taken, studying the postulations of several authors on the topic, which will allow to know the behavior of this material on having been submitted to different tests and this way to compare it with other types of materials used in the construction as (steel, cement and clay masonry). In such a way that the guadua

Angustifolia Kunth is an important structural element in the construction of houses, bridges, viewpoints and other small-scale civil works. [1]. Therefore, during the last few years, the behavior of bamboo structures has been studied as a response to the growth in demand for this material in construction.

Results

In table 1 are shown the postulations of several authors about studies and trials made to the bamboo Angustifolia Kunth as a construction element.

Table 1. Tests and studies carried out on bamboo in Colombia.

TITLE OF RESEARCH	STUDIES OR TRIALS CONDUCTED	RESULTS
Effect of moisture content on the parallel tensile strength of Guadua Angustifolia Kunth bamboo fiber.	Tensile strength test parallel to the fibre Determination of moisture content.	The strength of the tested specimens was found not to vary considerably due to different moisture contents.
Internal structure of bamboo and its impact on mechanical properties.	Tensile strength with radial and tangential loads	It is found that the structure of a guadua Angustifolia Kunth, loses strength as it goes from its outer layer to its inner layer, because the fiber cells are reduced and in the knots because of its discontinuity.
Genetic diversity and population structure of Guadua Angustifolia Kunth in the Colombian coffee belt	Bamboo Guadua Angustifolia Kunth.	Despite the indiscriminate logging in the Eje Cafetero, a great genetic diversity of bamboo is detected thanks to the nine micro-satellite markers.
Bamboo durability case study, El Ranchón restaurant building.	Durability study.	It can be determined that the durability of a bamboo building can vary depending on factors such as the quality of the raw material, adequate humidity control and preventive maintenance.
State of the Art of the Guadua Chain in Colombia 2003 - 2012.	Choice of topics that have an investigative focus.	It is possible to determine the investigative growth that bamboo has had in order to be applied in different fields.
Feasibility study for the construction in guadua of a house in Melgar- Tolima.	Sustainability in natural resources for housing construction	Guadua is considered a feasible raw material for construction systems. It is a material that has advantages over seismic forces due to its low weight.
Study of the mechanical properties of Guadua Angustifolia fibre bundles	Stress test under the standardNTC-959 using a Lloyd's digital dynamometer.	The resistance of the culms in their different ages was compared, resulting in greater resistance in the intermediate fibre bundles.
Study of the physical characteristics of bundles of guadua Angustifolia fibre.	Determination of moisture content. Determination of the % of moisture absorption. Determination of bulk density.	The fiber bundles of guadua Angustifolia, showed low values in density, percentage of moisture content and water absorption, which positively indicates that it can be used as a reinforcement material in a construction.
Study of the composition and mechanical properties of the joining elements made of bamboo for polyhedral bridge structures and other applications.	Tensile stresses Compression stress	We compared the behavior of some synthetic and mineral materials that, in conjunction with bamboo, meet the tensile and compressive strength required for the design of structural joints.
Description of the production and potential of bamboo in the Valle del Cauca	Analysis of the production and economic potential of the bamboo production chain in the Valle del Cauca	The department lacks updated unified and reliable statistics regarding chain production in terms of sowing production and yield in addition to shortcomings in research of this material as an alternative in the field of construction.
Bending strength and elasticity of the bamboo Angustifolia Kunth of Pitalito, Huila	Determine the physical and mechanical properties of Guadua angustifolia Kunth, taking into account title G, of the Colombian Regulation of Earthquake Resistant Construction NSR. - 10.	The results of the modulus of elasticity of guadua Angustifolia were compared with those determined in the NSR 10 and significant differences were found under favourable conditions with its modulus of elasticity at bending.

Fuente: [18-27]

Table 1. Continuation tests and studies carried out on bamboo in Colombia.

Compressive strength parallel to the fibre of the Angustifolia guava and determination of the modulus of elasticity	Tests of compression resistance parallel to the fibre, admissible stress for the design of compression elements under different combinations of load and modulus of elasticity of the Angustifolia bamboo.	It was obtained that the compressive strength is higher when the culms are higher, mechanical deformometers were used and it was identified that the average compressive strength in the fiber was 56MP a modulus of elasticity of the guadua angustifolia tested was 17859MPa. A recommended allowable value of 11MPa with gravitational loads and 13MPa including wind in the analysis is that this material can be used as structural material.
Bamboo as a structural material: Generalities, applications and modeling of a typical structure.	Estudio del bambú como elemento estructural a partir de la construccion de un puente en madera y guadua comparando su comportamiento.	Se definió que el bambú es un material con grandes propiedades para ser aplicado en estructuras, ayuda a mitigar la deforestación de grandes masas selváticas, al tener en cuenta su densidad el bambú es más ligero, es flexible y resiste las vibraciones del suelo evitando así el colapso de la estructura.
The bamboo chain in Colombia	Study of import and export of bamboo in relation to other countries.	Colombia has 0.1% of production in the world, however 50 thousand to 60 thousand hectares are 95% natural and 5% cultivated, of which only 40% are used, although there are no significant figures of the use of this material in housing construction some of the tests conducted consider it ideal for construction in areas of high seismicity because of its ability to absorb energy and have flexibility, in other cases it is used as an auxiliary material such as between floors and manufacture of goods.
Mechanical behavior of pressed laminated bamboo bamboo glued using different adhesives and environmental conditions	Mechanical properties of the bamboo Angustifolia using 3 types of adhesives, EMUF, CMUF, PVA	The results showed that the laminate using melamine urea formaldehyde showed less resistance reduction when tested at parallel and perpendicular tension to the glue.
Response to the impact of Guadua bamboo Angustifolia Kunth	Split-Hopkinson (SHPB) and Charpy pressure bar tests	Impact tests showed that the energy is similar to ductile steel and 410 stainless steel. A maximum resistance of approximately 8 MPa was obtained.

Fuente: [18-27]

The guadua Angustifolia Kunth presents excellent, these have turned it into fundamental focus in the implementation of structural elements or complements of the same one, it is a light material perfect for resistant structures to tension and compression, for what it would be ideal to carry out constructive designs with the same one, at present some constructions exist with this type of material but knowing his properties and his abundance in Colombia will it be that this is sufficient? The studies made to the guadua Angustifolia Kunth must be focused and investigated in depth with the purpose of knowing its behavior when mixed with other materials and to give answer to the deficiencies that they present, with the purpose of offering to the future constructions security, resistance and economic.

Conclusions

• It is observed in the studies found in Colombia that the specimens of Guadua Angustifolia Kunth tested with different moisture contents did not present considerable variations in strength, but being a wood material it should be waterproofed to avoid rotting.

• The interest of the authors in investigating the Angustifolia Kunth bamboo in the field of construction is analyzed, emphasizing the replacement of the materials of conventional use in structural elements with renewable, sustainable and friendly components with the nature.

• It is analyzed that deforestation and indiscriminate cutting of vegetation can be an enemy for Guadua Angustifolia Kunth forests, but favorably in Colombia there is still a great diversity of these forests.

• When comparing the different postulations of several authors who handled this material, it can be seen that it is a material resistant to tensile and compressive stresses

• The results of the different postulations of the authors were varied due to the places where they were developed, presenting diverse characteristics with respect to the cultivation of guadua Angustifolia Kunth as for example

• In Medellin, the cultivation of guadua Angustifolia Kunth loses its resistance from external layer to internal layer.

• In Girardot, the cultivation of Angustifolia Kunth bamboo has advantages in the face of seismic forces due to its low weight.

• At Girardot, the cultivation of Angustifolia Kunth bamboo has advantages over seismic forces due to its low weight.

• In Barranquilla the resistance of culms at different ages gives greater resistance in the intermediate fibre bundles.

• In Cali there is a lack of statistical studies that demonstrate the production chain of the guadua Angustifolia Kunth

This means that in order to make reliable structural elements that offer security, sustainability and economy, each location of the Guadua Angustifolia Kunth must have its respective study or take into account the regulations exposed for each case, since its characteristics can vary according to its location.

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