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Journal of Architecture and Design

Definition of the Journal

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Support the International Scientific Community in its written production of Science, Technology in Innovation in the Humanities and Behavioral Sciences Area, in the Sub-disciplines of international architecture, technological innovation in architecture, industrial design, business design techniques, multimedia design, advertising design, web system design, residential architecture.

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The works must be unpublished and refer to issues of international architecture, technological innovation in architecture, industrial design, business design techniques, multimedia design, advertising design, web system design, residential architecture and other topics related to Engineering Sciences and Technology.

Presentation of the Content

In Issue 16, is presented an article *Nopal mucilage waterproofing applied to construction materials to reduce humidity in homes in Valle de Bravo, State of Mexico, Mexico,* by CASTELÁN-URQUIZA, Demetrio, with adscription at Instituto Tecnológico de Estudios Superiores de Valle de Bravo, in the next article *Seismic evaluation of asymmetric reinforced concrete buildings using methods based on the performance design philosophy*, by PALACIOS-HERNÁNDEZ, Otoniel, MORENO-MARTÍNEZ, Jatziri Yunuén, GALVÁN-CHÁVEZ, Arturo and MORENO-MARTÍNEZ, Viridiana, with adscription at Universidad de Guanajuato, in the next section *Comparative study of 6 types of lime for use in construction and architectural heritage restoration*, by SALAZAR-PERALTA, Araceli, PICHARDO-SALAZAR, José Alfredo, MONTES-CÁRDENAS, Jessica and PRETTEL-MARTÍNEZ, Ana María, with adscription at Tecnológico de Estudios Superiores de Jocotitlán, Centro de Bachillerato Tecnológico Industrial y de Servicios No. 161 and Centro de Bachillerato Industrial y de Servicios No. 203, in the next section *Vernacular architecture as heritage and its materials*, by CASTILLO-REYES, Alberto Rosendo, VÁZQUEZ-TORRES, María del Rayo, MARTÍNEZ-LÓPEZ, Víctor Manuel and OLMOS-CRUZ, Liliana, with adscription at Benemérita Universidad Autónoma de Puebla.

Content

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Nopal mucilage waterproofing applied to construction materials to reduce humidity in homes in Valle de Bravo, State of Mexico, Mexico

Impermeabilizante de mucílago de nopal aplicado a los materiales de construcción para reducir la humedad en las viviendas de Valle de Bravo, Estado de México, México

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Abstract

Nopal leaves (*Opuntia ficus*-indica) excrete a “viscous” substance called mucilage. Create and evaluate a waterproofing prototype made from nopal mucilage used in housing construction materials to reduce humidity and saltpeter. It was possible to verify an effective performance of the waterproofing of the mixture of test 1, based on nopal mucilage, water, alum stone, lime and soap, with an average absorption of 4.33%, test 3, includes mucilage, water , lime, and salt, which presented an average absorption of 6.83%, test 2 is the one that absorbed the most water since it only contains water, mucilage and alum stone, with a total of 7.50% absorption.

Mucilage, Natural waterproofing agent, Ecological prototype

Resumen

Las pencas de nopal (*Opuntia ficus*-indica) excretan una sustancia “viscosa” llamada mucílago. Crear y evaluar un prototipo de impermeabilizante hecho de mucílago de nopal utilizado en los materiales de construcción de las viviendas para reducir la humedad y el salitre. Se logró comprobar un desempeño efectivo del impermeabilizante de la mezcla de la prueba 1, con base al mucilago de nopal, agua, piedra de alumbre, cal y jabón, con un 4.33% de absorción en promedio, la prueba 3, incluye mucílago, agua, cal, y sal, el cual presentó un 6.83% en promedio de absorción, la prueba 2 es la que más absorbió agua ya que solo contiene agua, mucílago y piedra de alumbre, con un total de 7.50% de absorción.

Mucílago, Impermeabilizante natural, Prototipo ecológico

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Introduction

The project arises from the Inter-institutional Program for the Strengthening of Research and Postgraduate Studies in the Pacific (DELFIN Program), during the stay of the XXVII Summer of Scientific and Technological Research in the Pacific, at the Technological Institute of Higher Studies of Valle de Bravo (TESVB) , in the Architecture Program, with the participation of students, who helped design and build the prototype of ecological waterproofing with prickly pear mucilage, having as a line of research Alternative Materials and Technologies for Construction and Bioclimatic Architecture.

The UN General Assembly adopted the 2030 Agenda for Sustainable Development, an action plan in favor of people, the planet and prosperity, which also intends to strengthen universal peace and access to justice. The Member States of the United Nations recognize that the greatest challenge in the world today is the eradication of poverty and affirm that without achieving it there can be no sustainable development (ONU, 2015).

Within the 2030 Agenda for Sustainable Development, 17 objectives were established to be met in order to achieve sustainable development, and in this specific case it is intended to collaborate in the development of objective 11: Sustainable cities and communities, which establishes: "Ensure that cities and human settlements are inclusive, safe, resilient and sustainable”.

Rapid urbanization is resulting in a growing number of slum dwellers, inadequate and overburdened infrastructure and services, which is worsening air pollution and urban sprawl (ibid.).

In the search to contribute to the solution to these problems, the aim is to innovate with products for the construction area that, in addition to being functional, also manage to reduce the impact in different aspects in order to be sustainable. In this specific case, one of the alternatives for the waterproofing systems that are currently used will be investigated.

The waterproofing used today usually contains additives, gases and volatile organic compounds that present a great environmental contamination in their manufacture, handling and subsequent permanence in the building. Its permanence in the building is dangerous as it releases volatile products from the film over the years and permanently, causing damage to both health and the environment (Alsina, 2007).

It has become essential to consider all development factors together to achieve sustainability when trying to meet the needs that society presents. Due to the fact that currently the main components of waterproofing agents are chemical compounds that produce a greater environmental impact than that which could be generated by natural components, alternatives have been sought that fulfill the same function that currently developed waterproofing agents intend to fulfill.

In addition, with the implementation of these alternatives, a decrease in investment costs for housing protection is achieved. In this way it is intended that these alternatives to industrialized products are a viable option for the user. Nopal mucilage-based waterproofing is usually one of the most effective natural alternatives, causing less environmental impact than conventional waterproofing.

The nopal has been an important part of the culture and history of Mexico, and not only in gastronomy but also as a fundamental part in the development of various products. Mexico is the world's leading producer of nopal, and for this reason it has been considered the main raw material in the development of waterproofing.

The properties of nopal mucilage have been used since pre-Hispanic times in the country. The mucilage has water retention capacity, interaction with fatty substances and a certain emulsifying power; These properties are still being investigated for their incorporation in food, medical, cosmetic or environmental remediation technology applications, among others (CIAD, 2021).

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Three proposals for the preparation of a waterproofing agent based on nopal mucilage are presented, carrying out the corresponding analysis of each of the proposals to determine the efficiency that is achieved and define the ideal dosages, as well as the situation under which it is recommended. use each one.

Problem Statement

The affectations by atmospheric agents in buildings have been distinguished as one of the main causes that unleash the damage processes in construction materials. Humidity is one of the most important factors considered due to the seriousness of its impact.

Humidity is a measure that indicates the amount of water vapor in the air (Air Things, 2022). This factor increases or decreases its presence depending on the geographical place where the work is located, since it will also be affected by the current climatic conditions. Damage caused by moisture not only affects the safety of the building, but also the aesthetics and habitability of the place.

With the aim of reducing or eradicating the damage present in buildings due to humidity and with the advances that have occurred in the area of the chemical industry, innumerable waterproofing agents have been developed; however, the components of the waterproofing that are usually used today generate considerable environmental damage due to the chemical and toxic substances that make it up.

In ancient times, waterproofing agents of natural origin were already used, so, seeking to cover the need to stop deterioration in construction works and at the same time reduce the environmental damage that is generated, a waterproofing agent is proposed as an alternative to modern waterproofing agents. based on nopal mucilage.

A waterproofing based on natural components, such as nopal mucilage, represents a convenient alternative because it is easy to obtain and can even reduce economic costs for its preparation and application, but without neglecting the effectiveness of providing a coating. that protects from moisture leaks.

Justification

According to data from the National Financial for Agricultural, Rural, Forestry and Fisheries Development (2020), at the national level, the main producers of nopal cultivation are Morelos and Mexico City, who contribute 70.4% of the total volume of nopales; They are followed in level of importance by the State of Mexico, with a participation of 10.2%, and Jalisco, with 4.12%. Being that the place of study, which in this case is Valle de Bravo, is located in the State of Mexico, and taking into account the search for the use of the resources that are available in the region, a proposal is made for a waterproofing nopal mucilage base.

The application of nopal mucilage waterproofing will help reduce the deterioration of construction materials due to humidity, thus reducing maintenance costs.

In addition, it has become necessary to look for alternatives that have the least possible environmental impact, and that in the same way represent an economically sustainable cost. The use of nopal mucilage is usually the most effective natural alternative, since thanks to its origin it does not pollute the environment as conventional waterproofing agents do, in addition to generating lower costs.

Background

As soon as the human being begins to have stable settlements, the need arises to find ways to protect constructions against present damage. This is how waterproofing began to make its first appearances, although not in the industrialized way in which they are known today. Those first waterproofing systems consisted of using less permeable minerals in very inclined positions to deflect rainwater from the roofs (Endurpol, 2022).

The job of waterproofing is the third oldest in the world, dating back to about 13 thousand years, when men had the need to take refuge from the humidity at the end of the Paleolithic. The Egyptians were the first to build monolithic structures by waterproofing them with layer-applied reed fiber-reinforced tar emulsions 3,600 B.C. (Rivera & Benitez, 2022).

With the need to offer better protection alternatives, other types of waterproofing have been developed. Around the 1920s, petroleum derivatives began to be used as a waterproofing method, the most primitive of this type would be known as chapapote. Along with these waterproofing systems, flat roofs began to be created. With the discovery of fiberglass in the 70s, waterproofing membranes began to be manufactured. The breakthrough in chemical research brought about by the space race gave rise to discoveries of more durable and weather-resistant plastic materials (ibid.).

Considering the damage that current industrialized waterproofing can cause, various alternatives have been proposed, among which a natural waterproofing based on nopal mucilage stands out.

According to Gómez (2002), cited by the National Institute of Statistics and Geography (INEGI), 2013:3), the use of nopal dates back more than 25 thousand years ago, when man settled in what is now Mexico. It is probable that, being hunters and gatherers, they included the nopal as part of their diet.

In excavations carried out in Tehuacán, Puebla, prickly pear seeds and shells and fossilized prickly pear fibers were found. It is known that since pre-Hispanic times, Mesoamerican cultures found nutritional and medicinal qualities in the cactus on which they based many of their customs (Saravia, 2022).

Currently the nopal has given rise to the development of innumerable products, thus leading to numerous crops established both for food and medicine and for the development of various products. It has been taken to both the national and international markets and represents a source of income for the rural communities where it is grown.

The Ministry of Agriculture and Rural Development (2020) states that: “The nopal is an endemic product of Mexico where, in addition, it has diversified: of the 200 species of nopales, 101 live in our country. In Mexico, nopal is used in food, livestock, art, construction, the pharmaceutical and cosmetic industry, and more.”

Nopal mucilage and alum are some of the ingredients of the pre-Hispanic conservation and waterproofing techniques that Mexican archaeologists use to prevent the deterioration of ancient convents. The mixture of these materials dates from 900 to 1,500 years before our era in order to waterproof historic buildings (Milenio, 2011). For the restoration of the National Museum of the Viceroyalty, they have been made flattened with nopal slime and lime (Barrera, 2012).

Nopal mucilage is used in the production of ecological paint; At the INAH (National Institute of Anthropology and History), restorers, archaeologists and architects have recently applied prickly pear mucilage as a waterproofing agent for walls and roofs in archaeological zones and historical monuments. The Ministry of the Environment recommends the nopal mucilage as a natural waterproofing agent for walls and roofs of historical monuments (Torres, et al., 2015).

Within the framework of the Engineering Expo 2018, organized by the Technological Institute of Querétaro (ITQ), the Higher Technological Institute of Huichapan (ITESHU) and the Autonomous Metropolitan University (UAM), José Francisco Badillo, José Juan Carranza, José Alfredo Pérez, Jorge Luis Mendoza and Michael Mejía, ITESHU students, presented proposals for waterproofing from nopal slime.

The students noted that:

> “In this first stage we wanted to show the low-income population an alternative to make a waterproofing that could be effective in protecting their homes in the next rainy season. The nopal slime is emptied into a container, then the white cement is applied until it has a thick consistency and then the glue is added to obtain a uniform product. For one liter of waterproofing we use 800 milliliters of nopal slime, 240 grams of pegazulejo and 280 of white cement. It is applied like any waterproofing that exists on the market” (Excelsior, 2018).

In Mexico, nopal mucilage has been used in combination with lime because it increases its adhesive properties and improves its resistance to water. Because of its adhesive properties, it has been used similarly to plaster on adobe and brick walls and also as a water barrier in stucco. A pre-Hispanic technology that contributed to the persistence of Mayan, Aztec and Toltec architectural complexes to this day is in the sights of scientists and it is the use of nopal slime in construction (Cruz, 2014).

Some architects and builders noticed that, in some buildings, mainly tenements, there was humidity in the rest of the house except for the ceilings. They had no water leaks despite the custom of locating the sinks on the roofs. What was found as a common denominator in all cases, were some products used both in the removal of dirt, and to protect the colors of the fabrics, the main components of these being laundry soap and alum (Cordero, 2007). The combination of the mentioned materials supposes as a result an efficient waterproofing to use on surfaces.

Cahuana (2022) in his research determined the variation of the physical and mechanical properties of concrete blocks modified with waracco mucilage. The main results of the investigation tested at 28 days, the absorption percentage reached an optimum value of 3.79% with the addition of 3% waracco mucilage, then the compressive strength reached a value of 80.52 kg/cm2 with the 3 %, which represents an increase of 69.52% more than the resistance of the standard block, finally the permeability with a value of 20.00 ml with 3%, which represents a decrease of 55.65% less than the pattern, as a conclusion it has to be 3% The incorporation of waracco mucilage considerably reduced the absorption and permeability, as well as increased the compressive strength to 76.73% compared to the standard concrete block.

Céspedes and Rivera (2022) point out in their research an average compressive strength in artisanal bricks with nopal mucilage as a natural additive is 98.1083 kg/cm2 while artisanal bricks without additive have an average resistance of 92.0 kg/cm2, which is minor, in comparison of these two results, the handmade bricks with nopal mucilage as a natural additive have greater resistance to compression.

Chávez (2022) studied the effect of adding linseed mucilage to concrete in proportions of 0.5% and 1%, to evaluate its behavior on compressive strength and permeability. Manipulating the flaxseed mucilage, in a seed to water ratio of 1:20. The results of the test tubes with the mucilage, provided an increase in its resistance, where the addition of 0.5% for 7, 14 and 28 days increased by 7.56%, 6.12% and 9%, while with the addition of 1% it increased in 15.02%, 12.94% and 20.62% respectively, in addition the permeability tests also denoted a favorable change, where as a result the samples with the mucilage of 0.5% and 1% yielded values of the permeability coefficient 1.27E-10 and 8, 98E-11 m/s and a penetration of 32.97 and 24 mm, where it was concluded that the mucilage has a positive effect on resistance, increasing up to 23%, and on concrete permeability a favorable reduction was determined for the addition of 1 % considering low permeability concrete.

Ordaya (2022) affirms in his research that with the addition of nopal mucilage in self-compacting concrete in the fresh state are: Improvement in spreading, reduced resistance to blocking, improved self-leveling in relation to the standard sample, concluding that it meets the function of natural plasticizer, on the other hand it was observed that in concrete hardened with the addition of mucilage for all ages in dosages of 0.3%, 0.5% and 0.7%, the resistance decreases in a small percentage compared to the standard sample, but higher to the established design, this natural additive fulfills the function of plasticizer up to a dose of 0.3% and superplasticizer up to 0.5%.

Padilla and Romani (2022) in their research managed to find out that the vast majority of homes are self-built and that people lack economic resources to invest in their construction; This also confirms that the use of bamboo and construction techniques such as thatch are the most suitable for this project.

Prickly pear

The nopal is a succulent plant that measures on average between 1.5 and 3 meters in height. The stems (cladodes or "shovels") are flattened and grayish-green. The flowers are yellow and the fruits vary between yellow, red and purple and contain small seeds that are usually consumed together with the flesh of the fruit.

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The plant reproduces by seed, but can also be propagated relatively easily vegetatively from detached stems (FAO, 2022).

The nopal belongs to the family of cacti, genus Opuntia. Among the cacti, there are plants such as organs, nopales, pitayos, garambullos, biznagas, peyotes, candelabra, cardons, reeds and cardenches, among others (INEGI, 2013).

Geographic location

In the genus Opuntia, 377 species are classified, all endemic to the American continent (that is, they are only found there), of which Mexico has 104 wild and 60 endemic. Cacti grow mainly in arid or semi-arid areas, but can also be found in areas with cold or temperate climates (Novo, 2007).

In Mexico, the genus Opuntia has a wide distribution. The regions with the highest species richness are the center and north of the Altiplano, the northwest, the Bajío, the Neovolcanic Axis and the Tehuacán-Cuicatlán valley. In the dry tropical regions and the northern deserts there is less richness, but endemic species of great importance are usually found. Brought to Europe by the Spaniards, the dispersion of the nopal around the world is very haphazard since the sailors used to take with them a good supply of prickly pears to avoid scurvy (a disease caused by vitamin C deficiency).

Subsequently, selected varieties were brought to establish plantations for various purposes such as stopping the desertification of the soil or producing fodder. Today, in many semi-arid regions of the world there are already naturalized and cultivated wild prickly pears. Some countries even have larger plantations than those of Mexico and with genetic resources that have diversified there (CONABIO, 2021).

Morphological characteristics

Nopales have developed characteristics that allow them to adapt to areas with little water availability and extreme temperatures.

Among others, succulence is its main morphological characteristic, it accumulates large amounts of water in short periods of time and the thick cuticle that they have makes them more efficient to avoid evaporation-transpiration. Due to its crassulacean acid (MAC) metabolism, it carries out a photosynthetic process through which the stomata are closed during the day and open at night, preventing water loss through transpiration.

Nopal mucilage

Nopal leaves excrete a “viscous” substance called mucilage (Opuntia ficus-indica), this is one of the most important components since it is part of dietary fiber. Nopal mucilage is a highly branched, fibrous polysaccharide with a molecular weight of around 13x106 g/mol. It contains approximately 35-40% arabinose, 20-25% galactose and xylose each, and 7-8% rhamnose and galacturonic acid each. Nopal mucilage is considered important for the food industry due to its viscosity properties. It has the ability to form molecular networks and strongly retain large amounts of water, as well as modify properties such as viscosity, elasticity, texture, water retention, in addition to being a good gelling, thickening, and emulsifying agent (Rodríguez, 2019).

Humidity

The author Martines (2007) in his article "Definitions of humidity and its equivalence" says that "Humidity is a property that describes the content of water vapor present in a gas, which can be expressed in terms of various magnitudes. Some of them can be measured directly and others can be calculated from measured magnitudes.

Humidity in the houses

According to Ortega (1994), in his book “construction pathology: dampness in the building”, he exposes four peculiar properties of water that are interesting for the study of dampness. The first is that water has a facility to change state at affordable temperatures; The second, when it solidifies, increases its volume and that causes its density to decrease, so it has the ability to float on its liquid state, acting as an insulating material.

The third, thanks to its polar character and its chemical structure of which it is composed, can be called water, as a universal solvent. And the last characteristic is the surface tension it possesses. Through this characteristic, the water is capable of wetting or bathing the surface, and by modifying its viscosity it can dissolve salts and transport them and deposit them in another place under totally opposite conditions.

Being an element that can easily change its volume, it can cause deterioration or even destruction of various materials, either due to freezing or its solvent capacity, which can cause washing of any surface of the material. In this way, the material is exposed to atmospheric components that, together with water, can cause chemical reactions between them and the particles of the material. The damage is not only superficial, but when the water is in its liquid state it can penetrate any surface, thus deteriorating the material or a construction element, from the inside, such as, for example, reinforced concrete.

It can be said that external humidity is subdivided into three types of humidity: absorption, infiltration and penetration. The three humidities have a different origin, but the same cause appears, which is water.

Absorption humidity occurs when vapor transfer is generated between the external atmosphere and the pores of the materials that make up the enclosure, when these are in the process of reaching equilibrium humidity.

Infiltration dampness originates from water seepage through fissures or cracks in the façade, with the combined or individual action of rain, wind and capillary suction. They usually manifest in the form of spots both externally and internally.

Penetration dampness is the result of poor building maintenance, which allows water to enter freely through unclosed gaps, open joints, etc. which often causes flooding inside the building and causes serious material damage. But they are not usually frequent since with good maintenance and good execution they are avoided without great effort (Pipiraite, 2017).

Saltpeter

One of the main consequences of hygroscopicity is called efflorescence. Saltpeter is a commonly used word to refer to what is technically called efflorescence. Efflorescence or saltpeter is a crystalline deposit on the face of a natural or artificial rocky surface that affects stone walls, brick, block, architectural concrete, plaster and stucco. Saltpeter is an old problem where the immediate affectation is the disfigurement of the stucco or plaster and the spoilage of the finishes.

Additionally, there is the damage caused by the growth of crystals on the surface of the wall. Efflorescence or saltpeter normally forms shortly after construction. New brick soon develops white spots that eventually cause the brick itself and other materials used in construction to disintegrate.

It frequently appears on the surfaces of the walls, both in stone and in brick and concrete block masonry, in plaster and plaster. The causes of these stains are the soluble salts contained in the materials of the wall, the masonry or the nearby ground and the presence of humidity. The water dissolves these salts and carries them with it through the wall. Upon reaching the surface, the water evaporates, leaving recrystallized salts as a residue. These are mostly alkali and magnesium nitrates and sulfates and, less frequently, carbonates. If there are iron salts among them, the spots will appear colored with a yellowish tone (Torres, 2011).

Natural waterproofing

It is an organic compound used as a protector on various surfaces whose characteristic is to prevent the passage of water. They are mainly used in the construction area to protect any property from humidity, waterproofing is used for the insulation of foundations, roofs, slabs, floors, walls, swimming pools, cisterns and deposits. Its effectiveness lies in its proper placement according to the specifications of each product and surface.

Waterproofing is the process that is carried out in all construction to give the elements that compose it the properties of preventing the passage of water through them; that is, it is a system or a series of stages. From the above we can understand that even new constructions must be waterproofed in order to prolong the useful life of the property. In addition to reducing costs by performing preventive maintenance instead of corrective (Valero, 2018).

Hypothesis

The waterproofing made from nopal mucilage will reduce the percentage of absorption in the construction materials of the houses.

Objectives

Create and evaluate a waterproofing prototype made from nopal mucilage used in housing construction materials to reduce humidity and saltpeter.

Materials

The materials that were used for the construction of the prototypes were from the region of the Municipality of Valle de Bravo, State of Mexico.

- Prickly pear.
- Nopal mucilage.
- Hydra lime.
- Alum stone.
- Neutral soap.
- Salt.
- Water.
- Annealed red clay brick (7*14*28) cm

Tools

- Weighing machine
- Test tube
- Brush
- Mesh #8
- Mesh #100
- Gloves
- Cutter
- Plastic buckets

Methodology

The empirical, quasi-experimental quantitative methodology, with a descriptive approach. Rodríguez et al. (2021) in their article "Waterproofing system based on mortar and nopal mucilage (Opuntia ficus-indica)" presents by empirical method the following quantities in table 1 shown, to develop a dosage of waterproofing which was used as guide to subsequently carry out the dosages of this research:

Material	Unit	Quantity (Grams)
Nopal mucilage	Grams	70
Sack lime	Grams	30
Alum stone	Grams	20
Neutral soap	Grams	15
Purified water	Grams	250
	Total	385

Table 1 Base dosage
Source: (Rodríguez Uribe, 2021)

The dosages made of natural waterproofing were applied to construction materials such as annealed red clay bricks, in which absorption tests will be carried out according to standard NMX-C-037-ONNCCE Construction industry - Masonry - Determination of absorption total and the initial absorption of water in blocks, bricks or bricks and bricks - Test method, this in order to know the amount of absorption and later tests are carried out to know the amount of humidity.

Experimental development

The experimental process consists of four stages which allow the elaboration of the waterproofing, from the extraction of the nopal mucilage to the realization of different dosages and mixtures of waterproofing, as well as analyzing the behavior of the bricks before absorption.

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Stage 1. Mucilage extraction

- Figure 1 shows the selection of nopal leaves from which the thorns and impurities were removed to later rinse and leave them clean.

- When weighing the nopal leaves on the scale, 3,141.5 grams were obtained.

- The leaves were cut into squares, later they were deposited in a bucket with water at room temperature. The amount of water is with a Nopal-Water weight ratio of 1:2, leaving the mixture to rest in a container for 48 hours.

- After the time, with the help of a number 8 sieve, the leaves were separated from the mucilage. Finally, to remove any solid that the mucilage had, a sieve was used again, this one was number 100 and thus the mucilage was obtained free of impurities and ready for use.

Figure 1 Nopal extraction process
Source: Own elaboration

Stage 2. Preparation of waterproofing mixtures

For the design and realization of the different mixtures, different dosages and materials were used, 3 different tests were elaborated in which 750 ml were obtained in each one, these will be described below:

- **Test 1.** Figure 2 shows that this consists of 300 ml of water, 200 ml of mucilage, 100 grams of lime, 70 grams of alum stone and 60 grams of neutral soap. The alum stone and neutral soap were diluted with the aid of boiling heat with 100 ml of water in each case of the 300 ml mentioned.

Figure 2 Process of elaboration of test 1
Source: Own elaboration

- **Test 2.** Figure 3 shows that it contains 300 ml of mucilage, 400 ml of water and 70 grams of alum stone. It is worth mentioning that the alum stone was diluted with the 400 ml of water contained in this mixture.

Figure 3. Process of elaboration of test 2
Source: Own elaboration

- **Test 3.** Figure 4 shows that it contains 300 ml of mucilage, 400 ml of water, 150 grams of lime and 60 grams of salt.

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Figure 4 Process of elaboration of test 3
Source: Own elaboration

Stage 3. Absorption analysis of bricks

In order to analyze the behavior of the bricks against absorption, the following tests were carried out:

- Before applying the waterproofing to the bricks, they were left to dry in the sun for 3 consecutive days in which they would be in the sun for 4 hours each day, this allowed us to minimize the humidity that they already contained. Subsequently, figure 5 shows the bricks that were left to rest in water, the 9 bricks as follows: from 1 to 4 12 liters were used, from 5 to 7 in 8 liters and from 8 to 9 in 8.5 liters, these amounts were determined to fully cover the faces of the brick. With this, it was possible to obtain the amount of water absorbed by each brick in relation to its weight.

Figure 5 Bricks immersed in water for absorption test.
Source: Own elaboration

Stage 4. Application of waterproofing tests

Figure 6 shows the three tests carried out that were applied to 3 annealed red clay bricks each, therefore we work with 9 bricks to observe the behavior and if there is any variation between bricks even with the same test. For its application, the following procedure was carried out:

- First, the bricks were dried in the sun to work with them with the minimum amount of moisture that they could contain.

- Each test was applied with a brush, covering all the faces of the brick, in order to fully cover the brick with the waterproofing mixture.

- It was left to dry for 10 minutes in the sun, being that way, it is a first layer. Finally, a second layer of waterproofing was applied, which was subsequently taken out in the sun to dry.

- The placement of tests was carried out as follows: from brick 1 to 3 test 1 was used, from brick 4 to 6 test 2 was used and finally, from brick 6 to 9 test 3 was used.

Figure 6 Application of waterproofing in brick
Source: own elaboration

- With the application of the waterproofing in each brick, a test is carried out to determine the percentage of absorption that each one has and thus be able to evaluate which waterproofing is more effective. Figure 7 shows the test that consists of placing 1 liter of water in a bucket and leaving each brick for 10 minutes, so what it managed to absorb in that time is taken into account to see the amount of water absorbed by each brick with its respective waterproofing.

Figure Absorption test process with waterproofing
Source: Own elaboration

Results

It was possible to obtain the amount of water that each brick absorbed in relation to its weight, these data are before applying the waterproofing, in Table 2 the amounts corresponding to each brick are presented, it can be observed that brick 6 with the difference of weighing 97.2 gr, it is the one that absorbed the least water and brick 8 with a weight difference of 180.2 gr, is the one that absorbed the most water.

Brick	Initial dry weight (gr)	Wet weight (gr)	Weight difference (gr)
1	1937.9	2092.1	154.2
2	1946.8	2103.8	157.0
3	2001.3	2129.1	127.8
4	1983.5	2102.5	119.0
5	1998.8	2127.4	128.6
6	1980.1	2077.3	97.2
7	1932.5	2055.2	122.7
8	1854.5	2034.7	180.2
9	1937.1	2069.8	132.7

Table 2 Registration of brick weights.
Source: Own elaboration

To determine the effectiveness of the tests carried out, the test with the waterproofing applied to the bricks was taken into account. Table 3 shows the (ml) of water absorbed by the bricks, with 1 and 2 being the ones with the least absorption of 40 ml and the one with the highest absorption being 5 with 85 ml.

Brick	Test applied	Water absorption in (ml)
1	Test 1	40
2	Test 1	40
3	Test 1	50
4	Test 2	70
5	Test 2	85
6	Test 2	70
7	Test 3	55
8	Test 3	65
9	Test 3	85
10	No test	130

Table 3 Water absorption of each brick
Source: Own elaboration

The percentage of absorption was calculated with the following equation:

Absorption = ((wet sample weight - dry sample weight)) / ((dry sample weight)) x 100

Table 4 shows the results obtained from the absorption percentages of the different tests applied to the bricks.

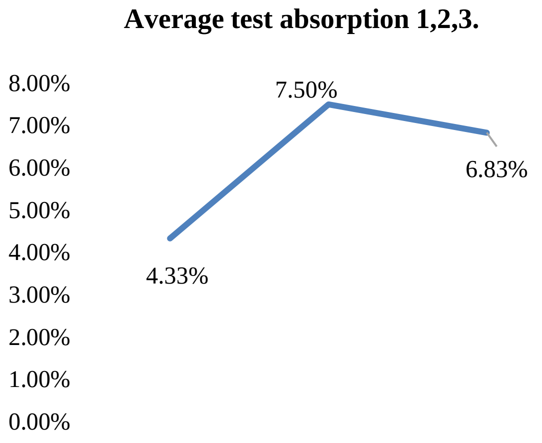
Brick	Test Applied	Absorption percentage
1	Test 1	4%
2	Test 1	4%
3	Test 1	5%
4	Test 2	7%
5	Test 2	8.5%
6	Test 2	7%
7	Test 3	5.5%
8	Test 3	6.5%
9	Test 3	8.5%
10	No test	14%

Table 4 Absorption percentage of each brick
Source: Own elaboration

With this, it was determined that test 1 is the most efficient, since it is the one that yields the best results in terms of water absorption. This result is due to the fact that tests 2 and 3 contain greater amounts of water and the absence of alum stone as well as neutral soap that works as a waterproof rubber, it is worth mentioning that test 1 was the only one that was not allowed. apply a second layer, unlike the other tests, since the mixture slips and does not allow its adherence.

In the same way, brick number 10 that does not contain a waterproofing mixture was put in the test in order to have a reference regarding the function that the waterproofing would have, this gives us as a result that there is a great difference in absorption between the application of waterproofing and the use of a brick without it, since the table alludes to how it counteracts absorption by using some natural waterproofing agent, the difference between a brick without water and with the waterproofing agent that presents the least percentage is 10%.

In graphic 1, it can be seen that the first waterproofing test is the one that presented the lowest absorption on average in the three specimens, with a value of 4.33% absorption, followed by the third test with a value of 6.83% and finally the second with a value of 7.50%.



Graphic 1 Average of absorption tests
Source: Own elaboration

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Conclusions

The problems of water filtration and humidity are related and their causes are usually natural aspects, even economic ones, helping to solve this problem leads to the creation of a protection system, however, from an economic point of view, Many times there is not enough budget. For this reason, this research was carried out to analyze the economic differences and effective alternatives to moisture treatment and the implementation of natural, traditional and environmentally friendly waterproofing.

It was possible to verify an effective performance of the waterproofing of the mixture of test 1, based on nopal mucilage, water, alum stone, lime and soap, the pores of the brick were better sealed, which reduced the filtration of water in the bricks. , test 3, includes salt in the mixture but does not contain alum stone, which was the second best waterproofing agent, test 2 is the one that absorbed the most water since it only contains water, mucilage and alum stone.

Of the 9 bricks to which 3 different tests were applied with the nopal mucilage and without the inclusion of mucilage, it is concluded that, in the face of water exposures that can occur in constructions such as: rains and other external agents, it is verified that the traditional annealed red clay bricks that are frequently used today have a high vulnerability to humidity.

Finally, it was possible to demonstrate the previously proposed hypothesis which states that "The waterproofing made from nopal mucilage will reduce the percentage of absorption in the construction materials of the houses of Valle de Bravo, Mexico". Obtaining in the future bricks covered with natural waterproofing with less absorption capacity and more resistant to erosion caused by prolonged exposure to water. Waterproofing is essential for the protection of buildings against climate change.

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Seismic evaluation of asymmetric reinforced concrete buildings using methods based on the performance design philosophy

Evaluación sísmica de edificios asimétricos de concreto reforzado utilizando métodos basados en la filosofía de diseño por desempeño

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Abstract

This article presents an approximate Performance-Based Seismic Design and its application to medium-rise buildings, characteristic of the Valley of Mexico and its metropolitan area. The proposed procedure considers the participation of the higher modes. This method considering displacements as damage indices and controls the global damage of the structure. To show its application and the validity of its results, 2 reinforced concrete buildings of medium height (8 and 15 stories), asymmetrical in plan were designed and evaluated. To avoid the uncertainties of the modal combination rules, a response spectrum was used as seismic demand. The seismic demand was applied orthogonally and simultaneously. The results obtained from the proposed approximate procedure were compared with those obtained from a step-by-step non-linear dynamic analysis, observing a congruence between both (displacement profiles and drift).

Torsion, Seismic evaluation, Damage control

Resumen

En este artículo se presenta una metodología de diseño sísmico aproximado, basado en la filosofía de diseño por desempeño y su aplicación a edificios de mediana altura, característicos del valle de México y de su zona conurbada. El procedimiento propuesto considera la participación de los modos superiores y tiene un control de daño global de la estructura, considerando los desplazamientos como índices de daño. Para mostrar su aplicación y la validez de sus resultados se diseñaron y evaluaron de 2 edificios de concreto reforzado, de mediana altura, asimétricos en planta de 8 y 15 niveles. Para evitar las incertidumbres propias de las reglas de combinación modal se utilizó como demanda sísmica un espectro de respuesta. La demanda se aplicó de forma ortogonal y simultánea. Los resultados obtenidos del procedimiento aproximado propuesto se compararon con los obtenidos de un análisis dinámico no lineal paso a paso, observándose una congruencia entre ambos, perfil de desplazamientos y desplazamientos relativos.

Torsión, Evaluación sísmica, Control de daño

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Introduction

At present most seismic design codes include torsional effects, with certain restrictions in the static method and none in the dynamic method, either spectral or dynamic modal analysis. In both cases the existence of asymmetries in plant is penalized by an increase in the spectral ordinate. Recent research has shown the limitations of these methods, particularly when used in the seismic design of buildings for boundary states where significant damage is accepted. Because of this, in recent years earthquake engineering has oriented part of its research to understand the nonlinear behavior of structures, particularly those considered irregular, using robust procedures. However, of these efforts, there is still no methodology, easy to implement, to ensure performance consistent with that established in the design.

Some "recent" research by different authors recommends the use of displacement-based procedures, since the effect of resistance distributions on the nonlinear torsional behavior of asymmetric buildings is explicitly considered. Paulay (2002) conducted research on the influence of torsion effects on the seismic performance of structures and proposed to reduce these effects through adequate control of stiffness and resistance distributions. However, most of these works have been validated in structures that do not enter the nonlinear range.

Due to the above, this article presents an approximate procedure for seismic design of buildings based on displacements and damage control, defined from the distribution of the resistances of the structural elements in plan and elevation. The results of this research emphasize the influence of torsion effects on the seismic performance of buildings, particularly in mezzanine drifts. The proposed methodology is based on the hypothesis that it is possible to approximate the seismic performance of a structure of multiple degrees of freedom (MDOF), through the response of a bilinear oscillator of a degree of freedom (SDOF), associated with a reference system, where the oscillator is defined by the properties of the modal form that contribute most to the inelastic response of the structure.

The fundamental principle of the proposed methodology is the validity of the capacity curve of the structure, which can be approximated by a curve bilineal, characterized by 2 stages and defined by the principle of equal energies between the "real" and bi-linear curves. From this one can construct the behavior curve (Sa-D) of the reference system of an oscillator (SDOF), using concepts of structural dynamics, and extract the seismic performance of the structure to a given seismic demand.

Background

Different investigations have shown that there is enough evidence to think that one of the main causes that cause severe damage to a structure after an earthquake of considerable magnitude are excessive rotations of the diaphragms. During the earthquake in Alaska (1964) damage was generated that reached the collapse of important buildings, e.g., J.C Penney building. In Mexico City, the 1985 earthquake caused severe damage to many structures, 42% of the buildings that collapsed or suffered serious damage were corner, which are susceptible to excessive rotations in the rigid diaphragms.

In the last 4 decades many investigations have been developed on the effects of torsion in the nonlinear response of buildings; However, there is still no single and/or accepted conclusion on how to consider its effects on the seismic design of structures. The progress of understanding the seismic behavior of asymmetric structures has been slow, which manifests itself with a paucity of methodologies and general conclusions, which makes us question. Do we really have a deep understanding of the behavior of ductile torsion systems? Are our element modeling hypotheses and therefore that of structural systems close enough to reality?

Paulay and currently some of his collaborators have shown a particular interest in understanding the seismic response considering the effects of torsion, particularly in ductile buildings. His contributions and views on this problem have been of great help in understanding the seismic response of asymmetric buildings. The following paragraph describes some of his contributions and comments:

The eccentricity of the rigidity is the parameter that most influences the response of the elastic systems, on the contrary, the eccentricity of the shear force is one of the parameters that most influences the response of ductile systems. Paulay (2002) showed that strength and stiffness systems are not independent parameters and that nominal yield displacements are a geometric property of materials, which is independent of force. He introduced the idea that the ductility displacement capacity of a system is based on the displacement capacity of its critical elements. He suggested that the elimination or reduction of system rotations, due to torsional effects, should not have to be the main design objective, instead system rotations should be accepted, when it is demonstrated that the displacement ductility criteria, for the different translation elements, are not violated. In this way we would have a greater dissipation of energy and consequent a more effective damping, among others.

Force-based seismic design method

This design philosophy has been adopted by most of the current regulations and consists of designing the structural elements using the results obtained from a linear elastic analysis, associated with a seismic demand characterized by a spectrum of elastic design smoothed and reduced by a ductility factor, R and / or Q. In this methodology, displacements are a secondary parameter that are only reviewed at the end of the design process, assuming that the rule of equal displacements is met for all cases. When the estimated displacements exceed the displacements established by the regulation then the rigidity of the structure is adjusted.

However, of the shortcomings observed in the application of this design philosophy, most current seismic design regulations continue to propose the use of force-based methods, accepting the validity of many assumptions, which do not have a rigorous foundation. The main inconsistencies found in the force-based method are related to the correlation between stiffness and strength, the relationship between strength and ductility, the choice of ductility of the structural system as the most important performance index, the validity of the equal displacement rule, among others.

Recent research has shown that any of these factors can lead designers to results inconsistent with those obtained from step-by-step nonlinear dynamic analysis.

Performance-based seismic design method

Due to the deficiencies observed in the force-based philosophy, some authors have directed efforts to develop "new" methods of seismic design, placing particular emphasis on the performance-based philosophy, which has as its main objective to design economical, safe structures with a seismic behavior consistent with the damages observed in previous experiences. This philosophy seeks to guarantee the stories of damage estimated in the structural design. It is established that in the event of a severe earthquake and with a low probability of occurrence, collapse must be avoided, but it is accepted that damage to the structural elements occurs, while for moderate earthquakes that have a high probability of occurrence, damage of any kind should be avoided, mainly in the main structural elements.

In recent years, many approximate methods based on the performance-based philosophy have emerged, mainly using displacements as a performance index, mainly because "recent" research has shown that displacements are the efficient way to assess damage to a structure, since the deformations produced by these displacements are directly related to the damage. Among the seismic design procedures based on displacements most referenced in the specialized literature are those proposed by Moehle (1992), Priestley et al., (2007), Ayala et al., (2012), among others.

Direct method based on displacements.

Priestley et al., (2007) proposes a direct method of seismic design (DDBD), based on the concept of the substitute structure proposed by Shibata and Sosen (1976). In this method, a structure of multiple degrees of freedom (MDOF) is idealized as an elastic system of an equivalent degree of freedom, which is associated with a viscous damping equal to the sum of the viscous damping of the system of multiple degrees of freedom and the hysterical corresponding to the non-linear behavior, and to a secant stiffness associated with a maximum displacement.

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Method based on the validity of the capacity curve

Ayala et al., (2012) proposes an approximate seismic design method based on the assumption that the performance of a structure of multiple degrees of freedom can be approximated by the performance of a reference system, associated with the fundamental mode of the structure. The capacity curve of the structure is approximated by a bilinear capacity curve generated using the principle of equal energies. From this bilinear curve a capacity curve is defined in spectral coordinates (Sd-Sa) called the behavior curve, which offers the parameters for the seismic design of the structure.

The slope of the elastic branch of the behavior curve represents the rigidity of the structure in the elastic range while the second branch represents the post-yield or inelastic stiffness. Post-yield stiffness is defined using a structure with a damage distribution associated with a predefined maximum displacement, based on a performance index obtained from some regulation. The steps of the method (Ayala et al., 2012) are described in the following paragraphs.

1. Perform a preliminary design of the structure using a force-based method
2. Propose harm sharing
3. Define the dynamic properties of the structure without damage and the structure with damage
4. Define the target displacement of the structure
5. Calculate the yield displacement of the structure
6. Determine ductility, the relationship between initial stiffness and post-yield stiffness
7. Verify that the target displacement is consistent with an inelastic displacement, obtained from an inelastic spectrum
8. Calculate the resistance, Ry/m and Ru/m, of the capacity curve
9. Construction of the capacity curve
10. Obtain the design forces for the structural elements through spectral modal analysis
11. Design the structural elements

Formulation for estimating the reference system

The dynamic equilibrium equation, for a three-dimensional structure of multiple degrees of freedom, representing a building, subjected to a seismic demand at the base, is given by the following equation:

$$\{f_I\} + \{f_A\} + \{f_E\} = 0 \quad (1)$$

where:

$\{f_I\}$ = Inertia forces

$\{f_A\}$= Damping forces

$\{f_E\}$= Static forces

$$\{f_I\} = [M]\{\ddot{u}^t\} \quad (2)$$

$$\{f_A\} = [C]\{\dot{u}\} \quad (3)$$

$$\{f_E\} = [K]\{u\} \quad (4)$$

Substituting 2, 3 and 4 into equation 1:

$$[M]\{\ddot{u}^t\} + [C]\{\dot{u}\} + [K]\{u\} = 0 \quad (5)$$

$$\{\ddot{u}^t\} = \{\ddot{u}\} + \{\ddot{u}_g\} \quad (6)$$

Where the matrix of mass, damping, rigidity and the vectors of displacements, velocities and accelerations are formed by submatrices which group all degrees of freedom of the structure:

$$[M] = \begin{bmatrix} M_x & 0 & 0 \\ 0 & M_y & 0 \\ 0 & 0 & I_0 \end{bmatrix}$$

$$[K] = \begin{bmatrix} K_{xx} & K_{xy} & K_{x\theta} \\ K_{yx} & K_{yy} & K_{y\theta} \\ K_{\theta x} & K_{\theta y} & K_{\theta\theta} \end{bmatrix}$$

$$[C] = \begin{bmatrix} C_{xx} & C_{xy} & C_{x\theta} \\ C_{yx} & C_{yy} & C_{y\theta} \\ C_{\theta x} & C_{\theta y} & C_{\theta\theta} \end{bmatrix}$$

$$\{u\} = \begin{Bmatrix} u_x \\ u_y \\ u_\theta \end{Bmatrix} \qquad \{\ddot{u}\} = \begin{Bmatrix} \ddot{u}_x \\ \ddot{u}_y \\ \ddot{u}_\theta \end{Bmatrix} \qquad \{\ddot{u}_g\} = \begin{Bmatrix} \ddot{u}_{gx} \\ \ddot{u}_{gy} \\ 0 \end{Bmatrix}$$

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Substituting 6 in 5

$$[M]\{\ddot{u}\} + [M]\{\ddot{u_g}\} + [C]\{\dot{u}\} + [K]\{u\} = 0$$

$$[M]\{\ddot{u}\} + [C]\{\dot{u}\} + [K]\{u\} = -[M]\{\ddot{u_g}\} \quad (7)$$

Returning to the previous equation, the following modal coordinate transformation is applied:

$$\{u\} = [\Phi]\{v\}$$

$$\{\dot{u}\} = [\Phi]\{\dot{v}\}$$

$$\{\ddot{u}\} = [\Phi]\{\ddot{v}\}$$

The differential equation of motion of a system of various degrees of freedom can be expressed as "n" independent equations for systems with the properties of each of the modes. So, for the total response of the structure, we have:

$$[M][\Phi]\{\ddot{v}\} + [C][\Phi]\{\dot{v}\} + [K][\Phi]\{v\} = -[M]\{\ddot{u_g}\} \quad (8)$$

Multiplying both terms by $[\Phi]^T$

$$[\Phi]^T[M][\Phi]\{\ddot{v}\} + [\Phi]^T[C][\Phi]\{\dot{v}\} + [\Phi]^T[K][\Phi]\{v\} = -[\Phi]^T[M]\{\ddot{u_g}\} \quad (9)$$

Since vectors of modal forms are normalized to the mass, we have:

$$[\Phi]^T[M][\Phi] = [I] \quad (10)$$

$$[\Phi]^T[K][\Phi] = [\omega^2] \quad (11)$$

$$[\Phi]^T[M] = [\Gamma] \quad (12)$$

$$[\Phi]^T[C][\Phi] = [2\zeta\omega] \quad (13)$$

Substituting 10 to 13 into equation 9:

$$[I]\{\ddot{v}\} + [2\zeta\omega]\{\dot{v}\} + [\omega^2]\{v\} = -[\Gamma]\{\ddot{u_g}\} \quad (14)$$

Then the decoupled equation of motion for mode *i* is:

$$\ddot{v}_i + 2\zeta\omega_i\dot{v}_i + \omega_i^2 v_i = -[\Gamma_{xi}\ \Gamma_{yi}\ \Gamma_{\theta i}]\begin{Bmatrix}\ddot{u}_{gx}\\ \ddot{u}_{gy}\\ 0\end{Bmatrix}$$

$$\ddot{v}_i + 2\zeta\omega_i\dot{v}_i + \omega_i^2 v_i = -\Gamma_{xi}\ddot{u}_{gx} - \Gamma_{yi}\ddot{u}_{gy}$$

If for validation purposes, it is considered $\ddot{u}_{gx} = \ddot{u}_{gy} = \ddot{u}_g$ then:

$$\ddot{v}_i + 2\zeta\omega_i\dot{v}_i + \omega_i^2 v_i = -(\Gamma_{xi} + \Gamma_{yi})\ddot{u}_g \quad (15)$$

The decoupled equations of motion corresponding to systems of a degree of frequency freedom ω_i damping ζ_i, subject to a demand $\ddot{u}_g$ is given by:

$$\ddot{D}_i + 2\zeta\omega_i\dot{D}_i + \omega_i^2 D_i = -\mathrm{m}\ddot{u}_g \quad (16)$$

Comparing equations 15 and 16 gives the following relationship between v_i and D_i :

$$v_i = (\Gamma_{xi} + \Gamma_{yi})D_i \quad (17)$$

Where D_i is the displacement of the oscillator in response to demand $\ddot{u}_g$, then the spectral shift of the oscillator $Sd(T,\zeta)$, It is directly related to the maximum modal shift of the structure, so the above equation can be written:

$$v_i = (\Gamma_{xi} + \Gamma_{yi})Sd(\mathrm{T}_i, \zeta_i) \quad (18)$$

The displacement in the three directions in the center of mass of the roof of the building will be given by:

$$u_{iax} = \varphi_{iax}(\Gamma_{xi} + \Gamma_{yi})Sd(\mathrm{T}_i, \zeta_i) \quad (19)$$

$$u_{iay} = \varphi_{iay}(\Gamma_{xi} + \Gamma_{yi})Sd(\mathrm{T}_i, \zeta_i) \quad (20)$$

$$u_{ia\theta} = \varphi_{ia\theta}(\Gamma_{xi} + \Gamma_{yi})Sd(\mathrm{T}_i, \zeta_i) \quad (21)$$

To find the structure reference frame for a mode i has:

$$\mathrm{Sd}_i = \frac{u_{iax}}{\Phi_{ix}(\Gamma_{xi} + \Gamma_{yi})} \quad (22)$$

$$\mathrm{Sa}_i = \omega_i^2 Sd_i \quad (23)$$

Proposed method

The seismic design method proposed in this article is an extension and/or modification of the procedure proposed by Ayala et al 2012 and is based mainly on the validity of the capacity curve, from which it is possible to extract the performance of the structure by constructing the behavior curve of the reference system expressed in spectral coordinates. The initial branch of the behavior curve represents the properties of the structure in the elastic range, and the slope of the second branch represents the properties of the structure in the inelastic range.

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The characteristics of the second branch are defined from a damage distribution proposed by the analyst. The yield strength per unit mass (Ry/m) is associated with the story of demand for the structural elements that are assumed to have damage to design demands. The ultimate resistance per unit mass (Ru/m) is the story of demand for the structural elements that must remain elastic to such demands. Based on these fundamentals, the following paragraphs describe in detail the steps of the proposed design method to design asymmetrical buildings:

1. Build an elastic model and perform a pre-design of the structure. The pre-design is obtained according to a current force-based regulation either by static analysis under gravitational loads and equivalent lateral loads or by spectral modal analysis under the same demands.

2. Define the performance objective associated with a current seismic design regulation.

3. Propose a configuration of damage of the structure. The structural elements and sections in which damage resulting from the design demand is accepted to occur. The damage is characterized by plastic ball joints. This model is called "damaged".

4. Obtain the dynamic characteristics of structural models without and with damage. Modal analyses of both models are performed, from which the periods and modal forms are obtained and, from each of these analyses, the periods of the modes that most influence the response of the structure, T1 and T2, are selected. These periods define the branches of the behavior curve of the reference frame of a degree of freedom; one for the elastic range and the other for the inelastic range, Fig. 1.

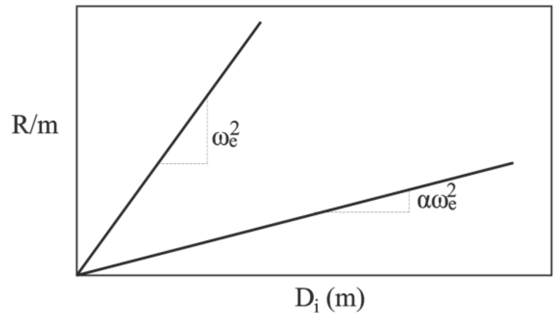

Figure 1 Branches of the behavior curve of the reference frame

5. Calculate yield displacement, $\overline{D_{i1}}$ of the behavior curve of the reference frame from the yield distortion of the structure, using expressions proposed by Priestley, (2000) that are a function of the geometry of the structure and the properties of the materials.

6. Get the target offset of the reference system. This offset is defined according to the maximum permissible values of the mezzanine drifts, corresponding to the design performance story. To calculate the objective displacement of the behavior curve, the following is used:

$$\delta_{dj} = \delta_{1dj} + \delta_{2dj} \quad (24)$$

where δ_{1dj}y δ_{2dj} They correspond to the mezzanine distortion of story j where it occurs, subscript 1 represents the elastic stage and subscript 2 represents the post-yield stage.

The contribution of the ith mode for each of the stages is defined by the following expressions:

$$\delta_{1dji} = \rho_1 \delta_{1j} \quad (25)$$

$$\delta_{2j} = \delta_{disj} - \delta_{1j} \quad (26)$$

$$\delta_{2dji} = \rho_2(\delta_{disj} - \delta_{1j}) \quad (27)$$

Where δ_{disj} is the objective design distortion.

$$\rho_1 = \frac{\delta_{1ji}}{\sum_{i=1}^{n} \delta_{1ji}} \quad (28)$$

and

$$\rho_2 = \frac{\delta_{2ji}}{\sum_{i=1}^{n} \delta_{2ji}} \quad (29)$$

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To calculate rooftop displacements for the mode that contributes most to the response (Δ_{A1i} and Δ_{A2i}), corresponding to each of the stages, the following equations are used:

$$\Delta_{A1i}=\frac{\delta_{1dji}}{\delta_{1ji}} \quad (30)$$

$$\Delta_{A2i}=\frac{\delta_{2dji}}{\delta_{2ji}} \quad (31)$$

Finally, the displacements of mode i (Projection X) are obtained for each of the stages

$$\overline{D_{11x}}=\frac{\Delta_{A1i}}{\phi_{iAx}(\Gamma_{xi}+\beta\Gamma_{yi})} \quad (32)$$

$$\overline{D_{12x}}=\frac{\Delta_{A2i}}{\phi_{iAx}(\Gamma_{xi}+\beta\Gamma_{yi})} \quad (33)$$

7. Obtain the ductility corresponding to the design displacements. The ductility (μ), is calculated from the displacements defined in step 6.

$$\mu=\frac{\overline{D_{12x}}}{\overline{D_{11x}}} \quad (34)$$

8. Calculate the offset of the reference system. From an inelastic spectrum of displacements, associated with the α value defined by the eq. 40 and from the ductility, μ, calculated in the previous step, the spectral displacement is obtained (Dux), corresponding to the fundamental period of the elastic model, T1 (Fig. 2) of the reference system. This offset is compared to the target offset ($\overline{D_{12x}}$); if they are equal, the process continues; If not, the initial structure and/or the proposed damage distribution is modified and step 2 or 3 is returned, depending on what is decided to change, until the equality between these displacements is satisfied.

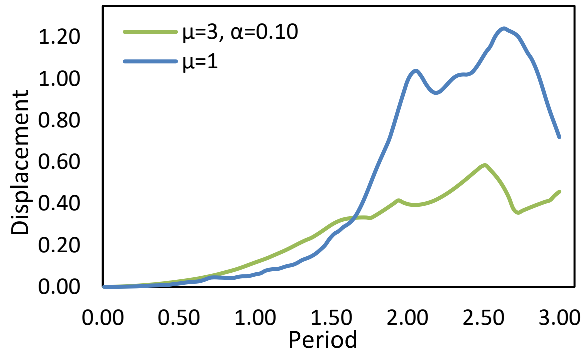

Figure 2 Elastic and inelastic displacement spectra

9. Construct the behavior curve. With the parameters obtained in the previous steps, i.e., yield displacement, ultimate displacement, yield resistance, ultimate strength, initial stiffness, post-yield stiffness, ductility and the ratio of post-yield stiffness to initial stiffness, the behavior curve of the reference frame is constructed (Fig. 3).

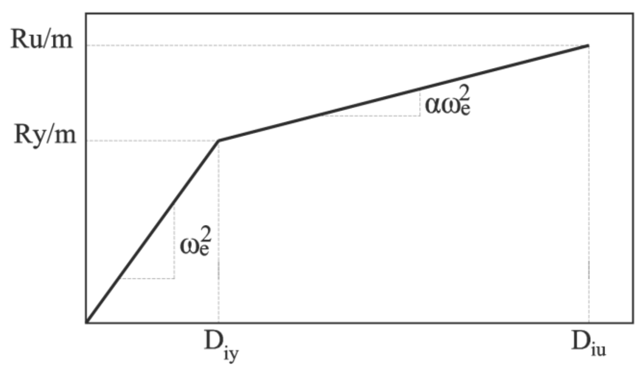

Figure 3 Behavior curve of the building reference system

10. Calculate design forces. To obtain these forces, two spectral modal analyses are performed, one for the elastic model, which includes gravitational loads, and as seismic demand a spectrum scaled by the factor λ1 is used, calculated as the quotient between the yield displacement of the oscillator and the maximum elastic displacement. The second analysis is performed for the model with damage, using as seismic demand the record scaled by the factor λ2, calculated as the quotient between the target displacement and the maximum elastic displacement corresponding to stage 2. The design forces for the elements that accept and do not accept damage are obtained by adding the two previous analyses.

$$\lambda_1=\frac{\overline{D_{11x}}}{D_{1x}} \quad (35)$$

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$$\lambda_2 = \frac{D_{12x}}{D_{2x}} \quad (36)$$

Application example

To illustrate the application of the proposed procedure, two reinforced concrete buildings of 8 (B1) and 15 (B2) stories were designed, with 10% eccentricity in masses, using as demand, for comparative purposes, the records of a real earthquake. The results obtained were compared with those obtained from a nonlinear dynamic analysis step by step before the same seismic demand used in its design. For the structures used, the following considerations were considered:

1. Story diaphragms are considered infinitely rigid in their plane, i.e., three degrees of freedom per floor, two horizontal displacements and one rotation around the vertical axis are considered and the beams are considered as infinitely rigid for axial deformation purposes.

2. It is not considered damage to the base of the columns of the first story and nor to the beams of the last stories, 2 (B1) and 4 (B2).

Buildings B1 and B2 are rectangular with three bays of 7 m in direction X and four bays of 8 m in direction Y. The X1 and Y1 bays of the building. The thickness of the slab is 0.12 m, the height of all mezzanines is 3.3 m. In Fig. 4 The standard floor of the building is shown.

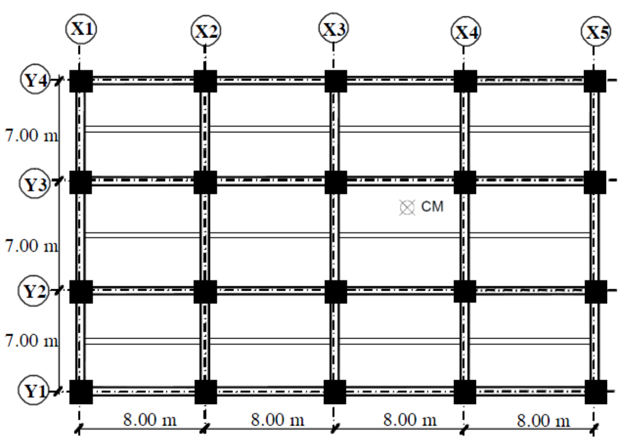

Figure 4 Story plan of the building with an eccentricity of 10% in each of its main axes

Analysis of results for building B1

For this example, a drift story of 0.02 and a design offset of 23 cm yield displacement (0.076), yield resistance (1.65 m/s^2), ultimate resistance (2.029 m/s^2), post-fluence ratio (11.3%) and a ductility of 3.

The mechanical design elements were calculated by 2 modal analyses in time, the first for the structure without damage (fact, λ1 = 0.54) and the second for the damaged structure (fact, λ2 = 0.32).

In Figure Fig. 5 The mezzanine distortions are observed in the "X" and "Y" directions of the frames that make up the building, as well as those of the center of mass. It is observed that the mezzanine distortions calculated with the proposed method are approximate to those obtained from a step-by-step dynamic analysis.

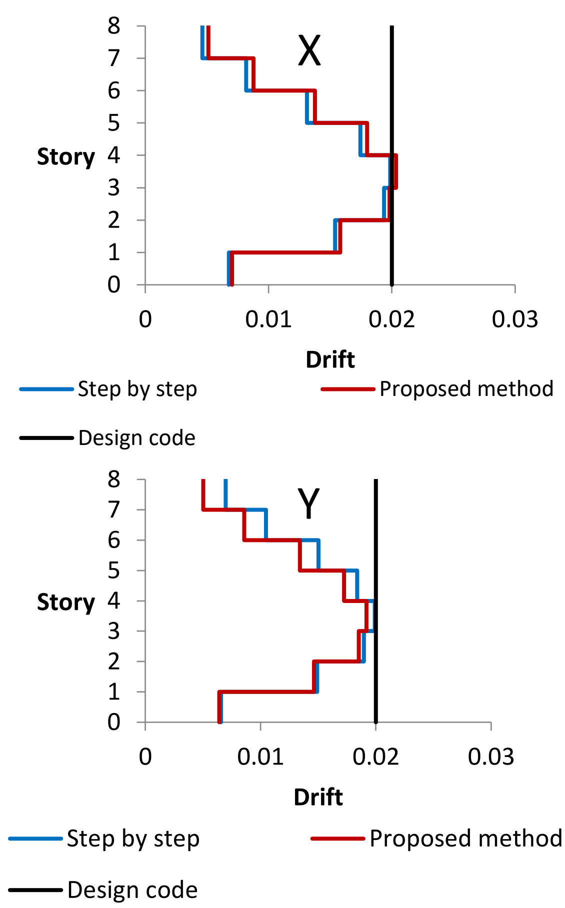

Figure 5 Drift story of building B1.

Analysis of results for building B2

The properties of the behavior curve of this structure are as follows:

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Yield displacement (0.165), yield strength (1.438 m/s^2), the ultimate resistance (1.774 m/s^2), the post-fluence ratio (α=16.34%) and a ductility of 2.4.

The mechanical design elements were calculated by 2 modal analyses in time, the first for the structure without damage (fact, λ_1 = 0.171) and the second for the damaged structure (fact, λ_2 = 1).

Figure 6 shows the mezzanine distortions in the "X" and "Y" directions of the strongest frame. It is observed that the mezzanine distortions calculated with the proposed method are approximate to those obtained from a step-by-step dynamic analysis.

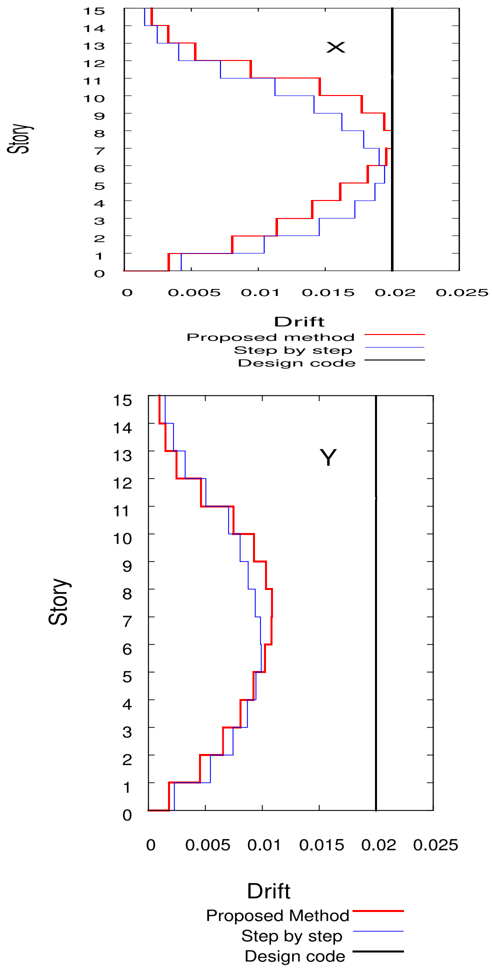

Figure 6 Drift story of building B2

Conclusions

From the results obtained in the 2 designs, where the application of the proposed adaptation to the original method of seismic design by displacements proposed by Ayala et. al (2012) and the estimated results of a step-by-step nonlinear dynamic analysis were compared, the following conclusions were obtained:

1. Archived good structural damage control. The differences between the damage distributions in the structures assumed as a design objective in the application of this method and those obtained from the nonlinear dynamic analysis step by step for the same seismic demand for which it was designed, are not significant.

2. The method proposed and/or modification of the original proposal in this research offers results comparable to those obtained from a step-by-step nonlinear dynamic analysis. This method guarantees that the estimated performance, derived maximum from mezzanine, using a reference system associated with the fundamental mode is consistent with that calculated of a numerically "accurate" method, under certain circumstances associated mainly with the influence of the higher modes on structural performance.

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To the University of Guanajuato.

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Comparative study of 6 types of lime for use in construction and architectural heritage restoration

Estudio comparativo de 6 tipos de cal para su uso en la construcción y restauración del patrimonio arquitectónico

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Abstract

All materials, to a lesser or greater extent, when in contact with the environment, undergo changes in appearance or in their properties. The sun, the rain, the winds, in general the weather causes the constructions to expand, contract, move and suffer deformations which causes their deterioration. The Architectural Heritage has great cultural importance due to the information it contributes to the historical study of society, it is a faithful reflection of the History of a place and for this reason it must be restored for its conservation. Quality assurance in any process is the total effort necessary to plan, organize, direct and control quality. In the construction industry, it is necessary to verify the characteristics of the materials used to guarantee improvement in their properties. This study aimed at the physicochemical characterization of 6 types of lime used in construction. The methodology used was based on the comparative determination of density, morphology and elemental composition. This study contributes to the knowledge of the characteristics of the different types of lime and serves as a basis for other studies related to the subject**.**

Lime (Calcium oxide), Restoration, Architectonic patrimony

Resumen

Todos los materiales en menor o mayor medida al estar en contacto con el medio ambiente sufren cambios en la apariencia o en sus propiedades. El sol, la lluvia, los vientos, en general el clima hace que las construcciones se dilaten, se contraigan, se muevan y sufran deformaciones lo cual provoca el deterioro de las mismas. El Patrimonio Arquitectónico tiene gran importancia cultural por la información que aporta al estudio histórico de la sociedad, es fiel reflejo de la Historia de un lugar y por eso se debe restaurar para su conservación. El aseguramiento de calidad en todo proceso es el esfuerzo total necesario para planear, organizar, dirigir y controlar la calidad. En la Industria de la construcción se vuelve necesaria la verificación de las características de los materiales empleados para garantizar la mejora en las propiedades de los mismos. Este estudio tuvo como objetivo la caracterización fisicoquímica de 6 tipos de cal utilizada en la construcción. La metodología empleada se basó en la determinación comparativa de la densidad, morfología y composición elemental. Este estudio contribuye con el conocimiento de las características de los diferentes tipos de cal y sirve como base para otros estudios relacionados con el tema.

Cal (Óxido de calcio), Reconstrucción, Patrimonio arquitectónico

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† Researcher contributing as first author.

Introduction

Architectural heritage is of great cultural importance for the information it contributes to the historical study of society and for what it represents for people as a whole. It is a faithful reflection of the history of a place and for this reason it must be preserved. Heritage is a topical issue and is present in various fields, whether cultural, social or scholarly. Until well into the 20th century, heritage was the monopoly of the social elite, as was education. In the 21st century, in the context of a democratic and mass society, heritage is an element of consumption and an educational tool. The different public institutions, civil society and school curricula are responsible for the dissemination of heritage, recognizing its educational value, its capacity to generate wealth and create knowledge. In the construction industry, it is necessary to verify the characteristics of the materials used to guarantee the improvement of their properties.

Lime is one of the materials used in construction, which is used in the preparation of mortars or masonry mixtures to join the materials used to build walls, foundations, slabs, as well as to finish walls and ceilings (I, II, III). Lime is a material that has many advantages, as well as a great variety of applications, which makes it an indispensable element in construction and restoration works (IV).

Lime is a generic term that designates all the physical forms in which calcium oxide and magnesium oxide, (CaO and MgO) and/or calcium hydroxide and/or magnesium hydroxide, ($Ca(OH)_2$ and $Mg(OH)_2$) can appear (V, VI). The standard that defines the specifications, definitions and conformity criteria for construction lime is UNE EN 459.

This standard classifies lime into two types:

Class I lime or quicklime, Q, consisting mainly of calcium oxide (CaO), and magnesium oxide (MgO) produced by calcination of limestone.

Lime class II or slaked or hydrated limes, S, resulting from the slaking of quicklimes composed mainly of calcium hydroxide. [$Ca(OH)_2$]. The raw material used for the manufacture of lime is limestone or dolomite extracted from quarries, with a carbonate content of over 95%, which are decarbonated by calcination in kilns at 975ºC + 25ºC to produce the corresponding lime. Tables 1 and 2.

Characteristics	Grain
Calcium and magnesium oxide content in calcined sample (1)	> 90% by weight
Finesse, Accumulated percentage retained on Sieve UNE 6,3 mm Sieve UNE 0,2 mm	0% Less than 10%.
Reactivity. Minimum temperature Quicklime with MgO < 5%. Dolomitic lime MgO > 5%. The maximum time to reach the minimum temperature is, in both cases, 25 min. both cases, 25 min.	> 60% > 50%

Table 1 Class I quicklimes
Source: Own elaboration

The determination will be carried out on a sample previously calcined in an electric furnace at 975ºC + 25ºC.

Characteristics	Grain
Calcium and magnesium oxides content on calcined sample	> 90% by weight
Carbon dioxide content, at the point of manufacture	< 5% weight
Fineness. Accumulated percentage retained on UNE 0.2 mm sieve.	< 10%

Table 2 Slaked or hydrated limes
Source: Own elaboration

The determination will be carried out on samples previously calcined in an electric furnace at 975ºC + 25ºC. The objective of this work was to characterize the physical and chemical properties of the different samples as a contribution to scientific knowledge and as a contribution to the conservation of the architectural heritage of the country. This study is presented in 6 sections, section 1 deals with the Introduction. Section 2 deals with the Methodology to be developed. Section 3 deals with the Results of the Study. In Section 4 the Acknowledgements. In Section 5 the Conclusions. Section 6 contains the References consulted.

Methodology to be developed

1. The specific mass was determined according to the method of the pycnometer Standard (NMX-C-165-ONNCCE-2004).Table 3

2. The morphology, as well as the elemental composition was determined with a scanning electron microscope JEOLJSM IT-100. Tables 4 and 5.

Analysis of results

As can be seen in Table 3. The density of the lime ranged from 1.05 to 4.53 grams per cubic centimeter, which indicates a great variety of chemical composition of the material, which is understandable since it depends on the origin of the rocks from which the lime was extracted.

It was also observed that the stone slaked lime compared to the slaked purchased natural lime showed a small variation in density, due to the fact that the slaked purchased natural lime has a higher percentage of calcium compared to the stone slaked lime.

The unslaked purchased natural lime has a higher amount of magnesium compared to the other types of lime. Powdered slaked lime, on the other hand, has calcium and magnesium in its composition.

Textlex lime has the highest density, which may be because it contains calcium, sodium, magnesium and also the highest carbon content compared to all the other samples studied. On the other hand, the slaked Textlex lime had the lowest density, which may be due to the fact that it did not contain carbon compared to when it was not slaked.

No. of sample	Type of lime	Density g/cm^3
1	Slaked lime (in stone)	2.586
2	Natural Lime (purchased, not slaked)	1.168
3	TEXTLEX lime (not turned off)	4.53
4	Lime (powdered slaked)	1.13
5	Natural lime (purchased, slaked)	2.64
6	TEXTLEX Lime (Off)	1.05

Table 3 Density of the different types of lime in g/cm^3
Source: Own elaboration

%	1	2	3	4	5	6
Ca	81.81	0	35.06	81.81	94.86	26.21
S	1.12	0	0.62	1.12	1.18	0
P	0	6.62	0	0	0.61	0
Si	0	82.96	0.82	0	3.35	0.76
K	0.6	0.87	0	0.6	0	0.54
Na	0	4.73	0.22	0	0	0
Mg	1.85	4.73	0.82	1.85	0	0.72
O	13.61	42.73	0	13.63	0	0
C	0.99	0.08	20.54	0.99	0	0

Table 4 Elemental chemical composition of the 6 types of lime
Source: Own elaboration

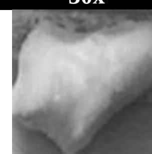
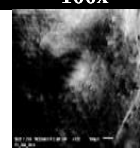
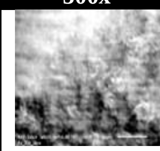
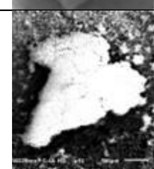
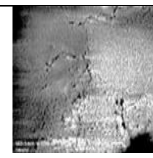
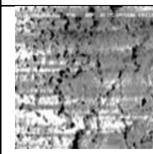
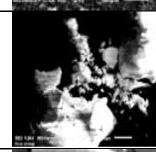
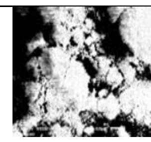
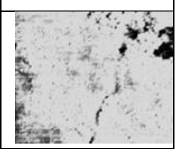
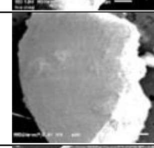
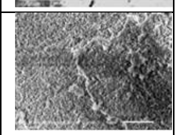
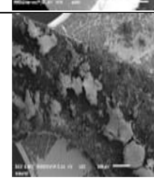
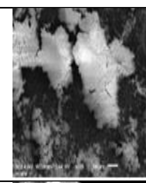
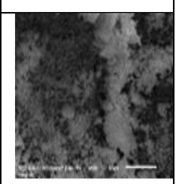
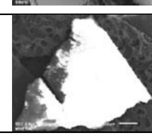
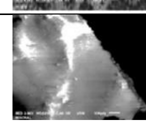
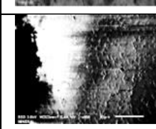
Samples	30x	100x	500x
Slaked lime 1 (in stone)			
Natural lime 2 (purchased, not slaked)			
TESTLEX lime (not off) 3			
Lime (slaked powder) 4			
Natural lime (purchased slaked) 5			
Cal TESTLEX (off) 6			

Table 5 Morphology of the 6 Cal samples at 30, 100 and 500 magnifications (30X, 100X, 500X)
Source: Own elaboration

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Conclusions

As can be observed in Table 3, the slaked lime in stone and the purchased slaked natural lime showed similar densities of 2.59g/cm^3 and 2.64g/cm^3 due to their chemical composition.

Textlex lime was the one that gave the highest density 4.53 g/cm^3 because it has carbon in its chemical composition.

The slaked Textlex lime gave the lowest density, which may be due to the fact that during the slaking process the carbon was converted into CO_2, so it no longer had carbon in its elemental composition.

In calcium content, sample 1 and sample 4 had the same content, while sample 5 had the highest calcium content, sample 3 and sample 6 had the lowest calcium content.

Table 6 shows that all types of lime presented fine grain, which is good because the homogeneity of the grain is of vital importance for a good performance of the material when it is mixed with other construction materials.

This study will help those working in the construction and restoration process to see the need to ensure the quality of the materials they buy by verifying their chemical composition in order to reduce variability in the product of the works they carry out. This study also lays the foundation for subsequent studies.

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Vernacular architecture as heritage and its materials

Arquitectura vernácula como patrimonio y sus materiales

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Abstract

The objective of this research is to recognize vernacular architecture as heritage architecture from the cultural approach developed as a constructive knowledge. The method applied to this research is qualitative-inductive, whose objective is the description of the characteristics of the object of study. The work has been developed for at least 4 years and has been done in a study is on a small scale and through proximity to empirical reality. The research exposes examples that were made through interaction with the inhabitants and as a result of direct observation. The stages of the research were: fieldwork relating access in the Sierra del Estado de Puebla, Chietla and Teziutlán where productive data collection was carried out; the analysis consisted of reducing the information, disposition, transformation and obtaining results and verifying them to reach conclusions. The contribution of this work is that it allows the dissemination of the concept of vernacular architecture as heritage with its antecedents that facilitate the understanding of the transformation of this concept.

Background, Cultural asset, Materials

Resumen

El objetivo de esta investigación es reconocer a la arquitectura vernácula como arquitectura patrimonial desde el enfoque cultural desarrollado como un saber constructivo. El método aplicado a esta investigación es de carácter cualitativo-inductivo, cuyo objetivo es la descripción de las características del objeto de estudio. El trabajo se ha desarrollado durante al menos 4 años y se ha hecho en un estudio es en pequeña escala y a través de la proximidad a la realidad empírica. La investigación expone ejemplos que se hicieron a través de la interacción con los habitantes y como resultado de la observación directa. Las etapas de la investigación fueron: el trabajo de campo relacionando el acceso en la Sierra del Estado de Puebla, Chietla y Teziutlán donde se procedió a la recolección productiva de datos; el análisis consistió en reducir la información, disposición, transformación y la obtención de resultados y verificación de estos para llegar a conclusiones. La contribución de este trabajo es que permite la divulgación del concepto de la arquitectura vernácula como patrimonio con sus antecedentes que facilitan la comprensión de la transformación de este concepto.

Antecedentes, Bien cultural, Materiales

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† Researcher contributing as first author.

Introduction

This architecture has had many names such as folk, autochthonous, popular, traditional, picturesque, folkloric or architectural heritage. The concept of heritage has changed, initially conceived as a right of the elite to express their power, to become part of culture under an anthropological approach where tradition and heritage interact. This fact favoured the inclusion of vernacular architecture as heritage, considered as that architecture that is produced by the people and for the people, which corresponds to its contextual and environmental situation, as it uses materials from the region, takes into account the climatic conditions and is based on traditional knowledge.

The theme is important because it is part of the constructive identity and the cultural past that reinforces the current culture. It is important to preserve construction know-how and to recognise vernacular dwellings as cultural heritage. The problem facing vernacular architecture is its gradual disappearance for various reasons, one of which is the lack of knowledge of the value of this architecture by users and architects. For this reason, it is considered that one of the strategies to preserve vernacular architecture is to disseminate and recognise its value as heritage architecture.

The sections included in this work are: the background where concepts that will be used throughout this work are defined. The second section is called cultural property, this section defines concepts that form the concept of heritage, its approach and the condition in which vernacular architecture is found. The third section attempts to describe some of the materials most commonly used in vernacular architecture.

Background

The origin of the word "vernacular" comes from the Latin word vernaculus, which refers to "native" or "slave". The "Charter of Built Vernacular Heritage" of 1999 describes its characteristics, where it emerges from the community itself, under a regional nuance as it relates and responds to the conditions of the environment, coherence of form, style, and appearance, with architectural types arising from the building tradition transmitted in an informal way.

From social anthropology and ethnography, a definition of the term vernacular related to rural or semi-rural communities and community production was developed, Amos Rapoport (1969) relates it to socio-cultural and environmental factors. Early work on vernacular architecture was initially opposed to modern architecture and the concept of modernity. This is because vernacular housing represents building tradition, which is handcrafted as opposed to modern materials whose production is industrial (R. Ettinger, 2010).

Vernacular architecture, as already mentioned, has been assigned different names, the most common terms being "popular" or "traditional" with a difficult precision in its contents and meanings, as the term popular is determined by the use assigned to it and not by its origin. The ambiguous term "popular" emerged with the romantic-folklore approaches of the late 19th century. As for the term "tradition", it is a concept that refers to the cultural values that are integrated through the variable "time" and is seen as a dominant reference value, knowledge inherited from the past and which remains in the present (Martín Galindo, 2006).

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However, there is a term for vernacular architecture that is a relative of the popular term and is called picturesque, which is used to define cultural elements of little value or things that cannot be defined. The origin of the word picturesque derives from the Italian word pittore, which in English means painter. In England it was associated with paintings depicting nature or views of growing cities. It is located, the term picturesque arises in romanticism and costumbrismo, and it can be said that its beginning can be found in the books of William Gilpin, and the thought developed by the English empiricism of the early nineteenth century (Calderón, 2010).

Although the concept of picturesque begins in painting, it transcended to attitudes, popular customs, activities or clothing; nowadays it is an emotional concept to which a value is inferred. In the case of architecture, picturesque is the use of everyday or common constructive forms and elements for a community, which has also been called traditional, to which Calderón (2010) mentions that it is a spiral of links established between place-individual-community where social activity defines the space where architecture arises.

Later, in the second half of the 18th century, the archaeological approach appeared, in this approach the ancient monument is valued and this aspect will be in force for at least a hundred years; it will be transformed by the discoveries of new civilisations and the notion of artisticity is developed, it is the historical and artistic values. From the 19th century onwards, the national monument is considered as a common heritage, which is considered for its value of antiquity, however, in this same century, important destructions of the heritage took place. The 20th century saw the creation of the League of Nations, which came into being at the Paris Conference on 24 April 1919, based on the Treaty of Versailles, which put an end to the First World War, where heritage ceased to be a matter for individual states and became a universal heritage. The Second World War produced a devastating destruction of European historical heritage, destroying urban centres and historical architectural monuments, provoking a crisis in the value of monuments due to their antiquity and rethinking approaches to the concept of heritage (García, 2012).

The concept of cultural heritage of vernacular architecture is based on the International Charters and specifically with the Charter of Venice in 1964, which is still in force today and which synthesises the conclusions drawn at the 2nd International Congress of Technical Architects of Historic Monuments and led to the foundation of ICOMOS (International Council on Monuments and Sites).

> "It is also understood that a historic monument is more than a testimony with documentary value and that cultural property is not only of artistic and historical value, but also of cultural value, so that the idea of cultural property and cultural heritage is assumed". (García, 2012, p.30)

Within this framework, in the 1980s, efforts were made to recognise vernacular architecture as heritage, and despite not being endorsed by any international body, the Charter of Cuba, the product of the First Meeting on Vernacular Architecture in 1988, stands out.

> "We define vernacular architecture as a spontaneous product that symbolises and crystallises the idea of the world held by the group that produced it. The elements that define it are precisely its manufacture - without the intervention of professionals - and the fact that the structures, forms and materials it uses are determined by the local climate, geography, geology, economy and culture, as well as the fact that it is highly integrated with the context and the surrounding landscape, while fully maintaining its identity. Vernacular architecture is either isolated or forms ensembles in historic centres and in urban and rural settlements" (Martín Galindo, 2006, p. 43-44).

This approach and the concepts of the Athens Charter were taken up by the 1999 ICOMOS General Assembly in Mexico, where the Charter of Built Vernacular Heritage was ratified in relation to vernacular/traditional architecture and heritage and identities. In this document vernacular architecture ceases to be "modest architecture" or "picturesque architecture".

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It is introduced as part of the ethnological heritage which is based on tradition, and therefore becomes heritage in use and tangible heritage which is the construction itself and ways of life or intangible heritage as it responds to the way in which housing arises and the way it is used (Martín Galindo, 2006).

Cultural property

According to Molano (2007), the concept of culture originated in Europe in the 18th century, as an expression of superiority that sought to explain the political and social order where everything that did not fit into the canons established by the dominant sectors was excluded. Anything that did not fit into the dominant parameters of the time was considered rustic, popular or picturesque.

> "The term culture comes from the Latin term cultus and although it initially referred to agricultural activity, we now understand it as the cultivation of the human spirit, of man's intellectual faculties, and its definition has changed throughout history" (García, 2012, p.13).

With the advent of the Enlightenment, European philosophy focused on the idea that nature and culture were opposites, so the further away communities were from the cities, the more uneducated they were considered, as they did not have the benefits of culture.

Thus, Europe was the cradle of culture and civilisation, and only its products were valid. Nowadays, the concept of culture is broader and depends on the area of knowledge or approach, but culture is defined as all the information and skills that human beings develop and that allow them to form collectives. According to the UNESCO Declaration of Mexico (1982), culture is defined as the instrument that allows human beings to reflect on themselves, to discern values, to seek new meanings and to create. Culture also has a symbolic code called language, there are no rules that force people to choose a model, they are learned, not genetic or instinctive (García, 2012).

UNESCO has defined cultural property as movable, immovable, works of art, manuscripts, books and other objects of historical, artistic or archaeological interest, scientific collections and important collections of books, archives or reproductions of property that are of great importance for the cultural heritage of peoples. Culture is seen as the body of knowledge, ideas, traditions and customs that characterise a community.

> "UNESCO first used the expression "cultural property", with the intention of giving a broader and more updated vision to the concept of historic and artistic heritage, including in this category both movable and immovable property of great cultural importance, as well as buildings whose purpose is to conserve or exhibit this movable property, and monumental centres that include a considerable number of the above elements" (Llull, 2005, p. 197).

Based on Josep Ballart's (1997) classification, the types of values that can be attributed to cultural assets are divided into three categories: use value, formal value and symbolic-significant value; this is one of the most widely accepted, as there are many classifications according to the place from which they originate.

"Public institutions at both regional and international level have proposed successive classifications and denominations, contained in laws that do not always coincide, for the elements that are considered to be part of cultural heritage" (Llull, 2005, p. 179).

In this way, objects are assigned superior characteristics that justify their conservation so that they can be observed by future generations. Institutions have had to modify their criteria throughout the twentieth century to be inclusive.

"The notion of cultural property has been progressively broadened to include not only historical monuments and works of art, but also folkloric, bibliographic, documentary, material elements, etc., whose significance need not be only historical or aesthetic, but which are valuable because they are manifestations of human activity in general, even if they are very recent" (Llull, 2005, p. 180).

It is striking that the population's notion of what a cultural good is, changes from one community to another, as the patrimonial is fused with the everyday and these communities downplay the value of their objects, however, it is precisely this everydayness that allows these cultural goods to remain with the subsequent hybridisations. The concept of cultural property is related to the concept of heritage.

The Diccionario de la Lengua Española defines patrimonio as follows: "From the Latin patrimonium, estate that a person has inherited from his ascendants" and also the Ideological Dictionary of the Spanish Language defines it as: "own goods acquired by any title"" (García, 2012, p.17).

The current concept of Heritage begins in the Enlightenment in the 19th century, under a political-legal approach until it came to produce socio-political theories that lead to the definition of the Democratic Welfare State that lasted until the 1930s. In this decade it was strengthened in Europe until the 1930s with the emergence of International Architectural Conferences, the Athens Charter and the forums where the new international thinking was developed with a historiographical dialectic and the inclusion of new disciplines. This process was interrupted by the Second World War (Ruiz, 1997).

It is worth noting that the territory is related to the concept of heritage because it is the meeting point of man, since for his survival he required the resources that it provided him, which is why the territory is given a cultural value, since it influences the culture and its creative capacity, and therefore, its economic development. However, it has also been related to collecting, as for a long time the concept of heritage was linked to museology and the conservation of cultural goods. These objects and buildings were created to transmit ideas or feelings and were expected to be timeless, without considering that time modifies culture, therefore, these objects lose their symbolic value. Therefore, heritage conservation is fundamentally a cultural act, which has the conscious and voluntary intention of preserving that heritage and that it transcends through time (García, 2012).

As for the definition of "own property acquired by any title", it refers to the fact that heritage is currently as diverse as the number of communities that exist, since in a single country or municipality there are different notions and examples of cultural heritage.

> "The cultural heritage of a people includes the works of its artists, architects, musicians, writers and scholars, as well as the anonymous creations, arising from the popular soul, and the set of values that give meaning to life, that is, the material and non-material works that express the creativity of that people; language, rites, beliefs, historical places and monuments, literature, works of art and archives and libraries" (García, 2012, p.17).

The concept of heritage emerged with a meaning of personal wealth, where war campaigns were initiated to appropriate precious objects as a way to show off prestige, luxury and power. No classification was established, the enjoyment of which was individual and private, which is why many of these objects were destined for grave goods. Later, the Romans gave heritage a pedagogical significance, as the Greek objects taken by the Romans and later used in the Renaissance became a reference model... "The monuments of the past began to be appreciated as testimonies of history, which visually explained the passing of the centuries, and also endorsed the information acquired from the written texts of ancient cultures" (Llull, 2005, p. 185).

However, at this time, the conservation and observation of historical heritage facilitated a critical look at the artistic historical past and some strategies were established to protect that heritage, among them the construction of museums. The French Revolution brought about a change in the valuation of historical heritage, as cultural property was technically and legally institutionalised with a public character. However, it was restricted to minorities who sought to find their identity in the past, which is why nationalism appeared in Romanticism, with the inclusion of historical models from the past (Llull, 2005).

Currently, the objective of heritage is to facilitate access to culture for all sectors of the population; this allows not only to preserve national identity, but also to support education by promoting knowledge and social identification. For this reason, laws have been established that allow for the care and conservation of cultural assets, as well as the creation of bodies that ensure compliance with these laws. The concept of heritage with a fundamentally aesthetic sense was affected by the massification of culture through adult literacy programmes, the creation of study centres and Universities and the inclusion of pedagogical models (Llull, 2005).

Therefore, new criteria are established considering the nature of cultural assets, the categorisation of Immovable Heritage, Movable Heritage, Intangible Heritage and the Law for the protection of Monumental and Archaeological Heritage, Bibliographic and Documentary Heritage and Ethnological Heritage. Thus, Historic Sites are defined not only as a unit, but also as the interaction of the homogeneous grouping of constructions defined under criteria of coherence. In the case of historic gardens it is restrictive, as other characteristics such as their origin, aesthetic, sensory or botanical values must be included. In the case of historic sites, they are those places as a place that has historical memory before the community, as well as cultural memory where its artistic, social, ethnological, natural or landscape values are included. It should be noted that the concept of heritage acquires an integrating approach of Cultural Anthropology in which beliefs, art, morals, customs, and human expression are circumscribed (Ruiz, 1997).

For all of the above, it can be said that the object of current Historical Heritage becomes Cultural Heritage, which is more totalising, in the sense that not only the object is observed, but also the conditions where this object arises or, in the case of architecture, the site where there are one or more buildings that have basic characteristics that group them together.

Cultural heritage is the result of human production, it is a historical heritage that forms the identity of a people (Llull, 2005) and the heritage object acquires a representative significance of the culture of a community. This is more tangible in objects such as monuments, because although they are only the creation of the dominant classes, they also reflect the predominant ideology (Ruiz, 1997).

This is why vernacular architecture, not being a monumental product of societies, was despised because it was seen as a vulgar product that did not need to be protected and is still seen today as synonymous with poverty. This was encouraged by the fact that for a long time heritage assets were taken as singular and monumental works: since vernacular housing is not monumental, it was not considered as heritage.

> "Among the multiple models of character and destination with which factories are made is vernacular architecture, understood as: the projection and construction of buildings and installations in a specific area; with techniques that have crossed the threshold of time, or that have been acquired by the relationship with other cultures. And which arises as a response to a series of social and economic needs, to which it adapts and with which it relates, forming its own cultural landscape, understood as a physical and social space" (Martín Galindo, 2006, p. 801).

In Mexico there are 5 zones or regions, which are: Northern Mexico, the Pacific coast and the Gulf of Mexico, Central Mexico, the southern Mayan zone, and the cold and mountainous zones. In each zone different materials are produced and therefore vernacular dwellings will have some significant variations. It is common that in forested areas, wood is used as the main construction material for walls and roofs, in areas where there are no trees, mud, stone or reeds are used, and in areas where there are forested areas, stone and mud, there are combinations of these materials. Some materials are presented below.

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Materials

In areas where there are not enough resources to build houses, it is more practical to use the materials of the region, elaborated through vernacular construction processes, generating spaces to live in that are not only economical and comfortable, but also use bioclimatic design. This makes vernacular architecture a strategy that favours sustainability, produces a homogeneous typology and allows the transmission of technical and social knowledge that strengthens the identity and cultural heritage of the communities where it exists.

Vernacular architecture has the particularity of using the materials of the region, selecting and elaborating them to create a habitat adapted to the socio-economic needs of its inhabitants.

> "The first step in the construction process is the choice of the site where the house will be built. The materials must be ready and have been collected according to the projected dimensions of the house" (Sánchez, 2000, 84).

In vernacular housing, construction processes and the materials used in them were transmitted orally, explaining the process and doing it at the same time (Carranza, 2010, p. 17). Thus, the builder relied on his intuition and experimentation (Piralla, 2002).

As can be inferred, when the user observed a construction that resisted natural actions such as wind and earthquakes, the basic principles that have proven to be successful were generated (Carranza, 2010).

That is why in all cultures the preservation of the construction processes and materials that were best adapted to local conditions was encouraged; those that provided better conditions of habitability and use of available materials (Peñaranda, 2011).

In other words, the entire structure must respond to the climatological conditions and the functional conditions of the space, which is why it is necessary for the materials to be able to withstand seismic effects and for their deformations to produce a redistribution of forces in the structure (Carranza, 2010).

It should be noted that a large part of architectural theory has been based on the evolutionary idea of building culture, based on "trial and error". The foundations of architecture and the development of architecture have been based on a system of evaluation where it was determined that, when a construction element could no longer be part of the system, it was replaced by elements with more resistant forms and materials (Peñaranda, 2011).

In the case of vernacular architecture, this situation can be observed in the case of reed, wood, tile or tejamanil roofs replaced by metal sheets. Currently, metal sheets are replaced by reinforced concrete slabs that require the installation of reinforced concrete chains and castles. The combination of different materials and construction systems generates a physical and visual degradation of the construction.

Figure 1 Vernacular dwelling of adobe, stone, block with concrete frames in Tochimilco, Puebla
Source: (Vázquez, 2019)

It is also the case that another floor is built on top of the vernacular dwelling and has to be reinforced to support the weight of the building.

Figure 2 Vernacular housing transformed with prefabricated construction systems in Tochimilco, Puebla
Source: (Vázquez, 2019)

Most of the materials used in the construction industry come from the earth's crust and in the case of vernacular architecture the materials have the possibility of being reused and recycled from waste. Stone is a design element and construction material that has been used in vernacular and traditional architecture; the latter is predominant in the construction field in Mexico. This material extracted from nature can have a significant impact on people's quality of life, as it is an element that allows for the solidity of dwellings and when used in walls it integrates any urban architectural typology (Mendiola et al., 2014).

Stone is used in new or old buildings as it facilitates its use in architecture of good constructive quality due to its resistance and is aesthetic when integrated into different typologies, this is a material that is used to restore heritage or to develop contemporary architecture. Stone that is extracted from quarries using explosives also has great properties such as durability, fire resistance, thermal movement, structural strength and good appearance.

> "It’s aesthetics is capable of causing hermeneutic phenomena related to social identity, as well as connoting a superior value of constructive quality related to vernacular architecture" (Mendiola, 2007).

Figure 3 Vernacular house with stone walls, adobe and roofs of wooden beams and tiles in Teziutlán Puebla
Source: (Garate, 2016)

In areas where adobe is used, it is common to place an overlay that prevents subsoil moisture from deteriorating the adobe, which is why steps are observed in the access to the house.

Figure 4 Vernacular house with concrete frames and cement cladding in Tochimilco, Puebla
Source: (Vázquez, 2019)

Wood is a plant material, compact and fibrous, obtained from trees or woody plants, whose resistance is variable and depends not only on the type of tree it comes from, but also on the direction of the fibres. Wood is a hygroscopic material that always contains water, so moisture must be removed from felled trees in order to reach its maximum strength and prolong its useful life (Gallardo and Robles, 2011).

When wood is used outdoors, it is affected by weather conditions, its characteristics are modified and it suffers deformations, especially if the humidity of the element is not controlled and it is degraded by the biological elements that attack it. Climatic conditions affect its physical characteristics, and it is common for sudden changes in the environment to cause severe damage. For example, ultraviolet radiation affects the surface; infrared radiation heats the surface, causing cracks, but the humidity inside remains the same. It should be noted that the hardness of wood is a highly variable property and cannot be controlled (Gallardo and Robles, 2011).

In vernacular dwellings, wood deformation is visible, as when it is outdoors, it undergoes changes that affect its volume due to humidity, and when it withstands radiation, shrinkage occurs and, as it is flexible, it can change its shape and therefore its load-bearing capacity (Gallardo and Robles, 2011).

Figure 5 Rural vernacular wooden dwelling with morillos, no windows, wooden door frames with wooden beams and half-round roof tiles
Source: (Hernández, 2018)

Reed (Phragmites australis, Cav., Trin. ex Steud) is a naturally spreading, warm-season, wild plant that grows in temperate to tropical zones in the vicinity of wetlands, drainages and wet headwaters. Reed can be two to four metres tall, with smooth, flat leaf blades, 1 to 5 cm wide and 15 to 45 cm long.

> "It is an ecological and sustainable material that is low cost, aesthetically acceptable, easy to obtain [...] frost resistant and a good thermal insulator due to the large number of air-filled hollows in the stems" (Withney, 2014, p. 2).

Its growing season is continuous and uninterrupted, making it a material that is constantly renewed. It thrives in places with optimum temperatures between 30 and 35° C. It is a resistant material that grows best in firm clayey soils with mineral content and tolerates moderate salinity, but it is possible to grow in very salty water. In Mexico it grows almost everywhere in the country, but mainly in Chihuahua, Jalisco and Michoacán (Gerritsen, Ortiz and González, 2009).

In the construction industry in Mexico, reed is used to make vernacular constructions where walls and roofs are woven with fibres and sometimes pieces of wood are added to give it greater solidity, it is also used as a mesh for walling and as reinforcements in the construction of adobe houses. However, it is commonly used to build windbreaks on their plots and at the same time reduce soil erosion.

Figure 6 Vernacular dwelling with reed walls and roof in Tochimilco, Puebla
Source: (Vázquez, 2018)

Adobe is a material that is found almost everywhere on the planet and this material predominates in vernacular constructions due to its easy acquisition of the material, it was used by different cultures at different times and without an apparent relationship between them. It is a material made from a mass of clay and sand, mixed with different elements that ferment and prevent cracking during drying, and natural fibres such as straw, grass, horsehair, dried hay, agave, and even synthetic fibres are added. The most commonly used mixture for adobe production contains 20 per cent clay and 80 per cent sand and water, with a drying time of 25 to 30 days.

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Adobe has been "defined" in various ways, among the most common: (1) "earth that has been thoroughly stripped of all impurities"; (2) "clay mass" moulded into a brick shape and dried in the sun; (3) "brick formed from a mass of clayey earth, water and some additive, dried in the sun and air" (Gendrop, 2001, p. 238).

Adobe constructions in non-seismic zones can maintain their characteristics, but in seismic zones, being a massive material that works very well in compression, but weak in tension, it can be severely damaged when subjected to the action of earthquakes. Adobe is a material with a high thermal inertia, which is why it has been used in different climates, as it becomes a regulator of the internal temperature. However, it is susceptible to humidity, which is why it is recommended that exterior walls be plastered with two layers; the first layer with mortars based on slaked lime paste, clay and sand for the first layer, and in the second, a mortar of lime paste and sand. In the case of interiors, they can be left apparent or mortar can be applied with a mixture of clay, sand and water (Carranza, 2010).

Figure 7 Vernacular housing in Teziutlán Puebla
Source: Garate, A. (2016)

One of the first sheet metal roofs was built in Warsaw, Poland in 1701, and since then they have been used to cover spaces in different parts of the world. In the case of Mexico, sheet metal roofing has lightened roofs, allowing families to protect themselves with a resistant and relatively low-cost element. Metal roofs are effective for heat conduction, so in very hot areas they are inoperative. However, in warmer areas, shingles are placed on top to protect against the temperature that can occur inside the space and to eliminate noise from rain or hail. The sheets also reflect the sun's rays and are painted or shingled over to reduce this.

Durability in low quality metals can last for more than 20 years.

Figure 8 Vernacular dwelling with adobe walls and tin roofs in Chietla, Puebla
Source: (Garate, 2017)

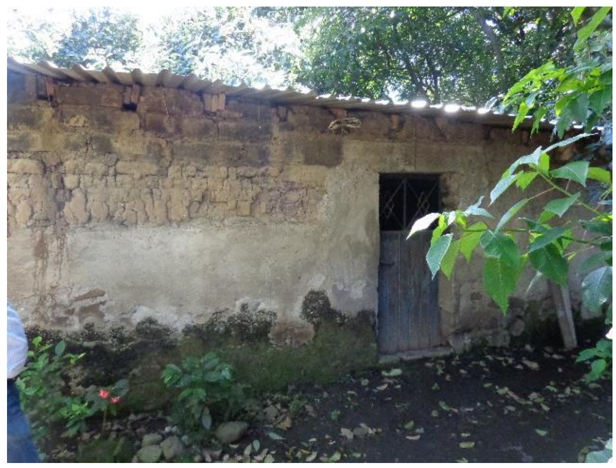

Figure 9 Adobe wall and roof with wooden beams and corrugated sheeting in Tochimilco, Puebla
Source: (Vázquez, 2019)

The tile is a material that is believed to have been developed in 640 BC for the Greek temple of Hera in Olympia and the first tiles were made from fired clay and in the form of arches. Different materials have been used to make them and in different shapes. In Mexico, it was introduced by the Spanish during the colonial period between the 16th and 18th centuries. The terracotta tile is a resistant material that is placed on top of the stringers that rest on wooden beams or morillos, supported and fastened to the walls. There are different types of roof tiles, although the most common is the half-round roof tile, which is combined in two positions so that they are fastened together and function as an overlap, which does not allow water to penetrate, as they function as channels that transport water out of the interior of the house (Cabrera, López, & López, 2015).

In the northern Sierra of the State of Puebla, the application of half-round clay tiles and wooden tiles can be observed in the houses. In the case of Puebla, the half-bed tile predominates, and currently flat and figured tiles are being applied, as shown in image 10.

Figure 10 Adobe wall and prefabricated clay tile roof in Tochimilco, Puebla
Source: (Vázquez, 2019)

Although the material does not determine the form, it does establish limitations, as some characteristics depend on the size of the materials used to build rooms. That is why, by changing the construction materials, some characteristics of the space are also modified, this situation is evident when restorations of the built heritage are made; because, the closer they are to the original materials, they have a better structural behaviour and therefore retain their value. It is common to favour the conservation of the material over the conservation of other values, as the material is linked to the value of antiquity and this is linked to authenticity. It should be noted that for it to be authentic, it is not related to antiquity but to its being regional and handmade, never industrial. This situation is in direct opposition to modernity, as vernacular architecture becomes an architecture of the past (R. Ettinger, 2010).

However, it should be noted that industrialised materials have permeated vernacular constructions, modifying not only their appearance, but also their structural behaviour. An example of this is the substitution of tejamanil by corrugated sheets, or the incorporation of castles, chains and/or concrete slabs to reinforce vernacular dwellings.

Conclusions

Vernacular architecture arises in different regions, because in a certain way it is an architecture that takes materials from the context, making it accessible to rural communities. In other words, it was born as a response to housing needs and each region or culture maintains its formal and constructive characteristics. The use of materials and construction systems within the region obeys the environmental or bioclimatic conditions; however, there are areas that obey socio-cultural conditions.

It can be said that vernacular architecture is the result of social participation, the product of its physical context and the knowledge of the community that makes up its building tradition.

It is common to confuse vernacular housing with housing that uses traditional materials. Vernacular architecture is that which is built by the inhabitants of the dwelling themselves, whose construction processes are the product of socialisation. In many places there is still the tequio, which is a group of family members who participate in the construction of the house, which is why it is called a social and environmentally friendly product, as most of its materials are taken from nature and once its usefulness is over, they can be returned to it. Therefore, it is important to focus on the preservation of this architecture as it is not only cultural heritage, but also addresses real needs and reduces environmental impact. On the other hand, traditions are preserved and this type of architecture can be enriched with new technologies that allow for a longer period of usefulness.

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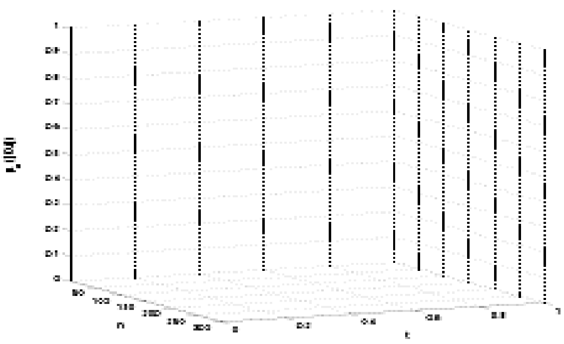

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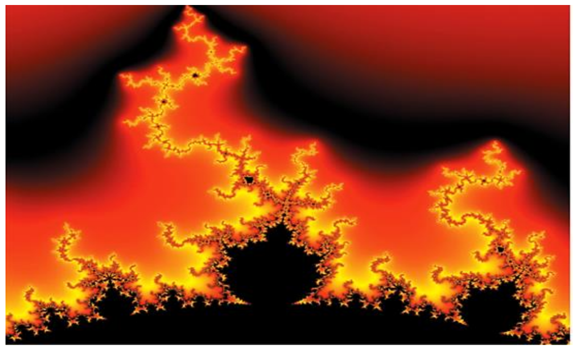

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