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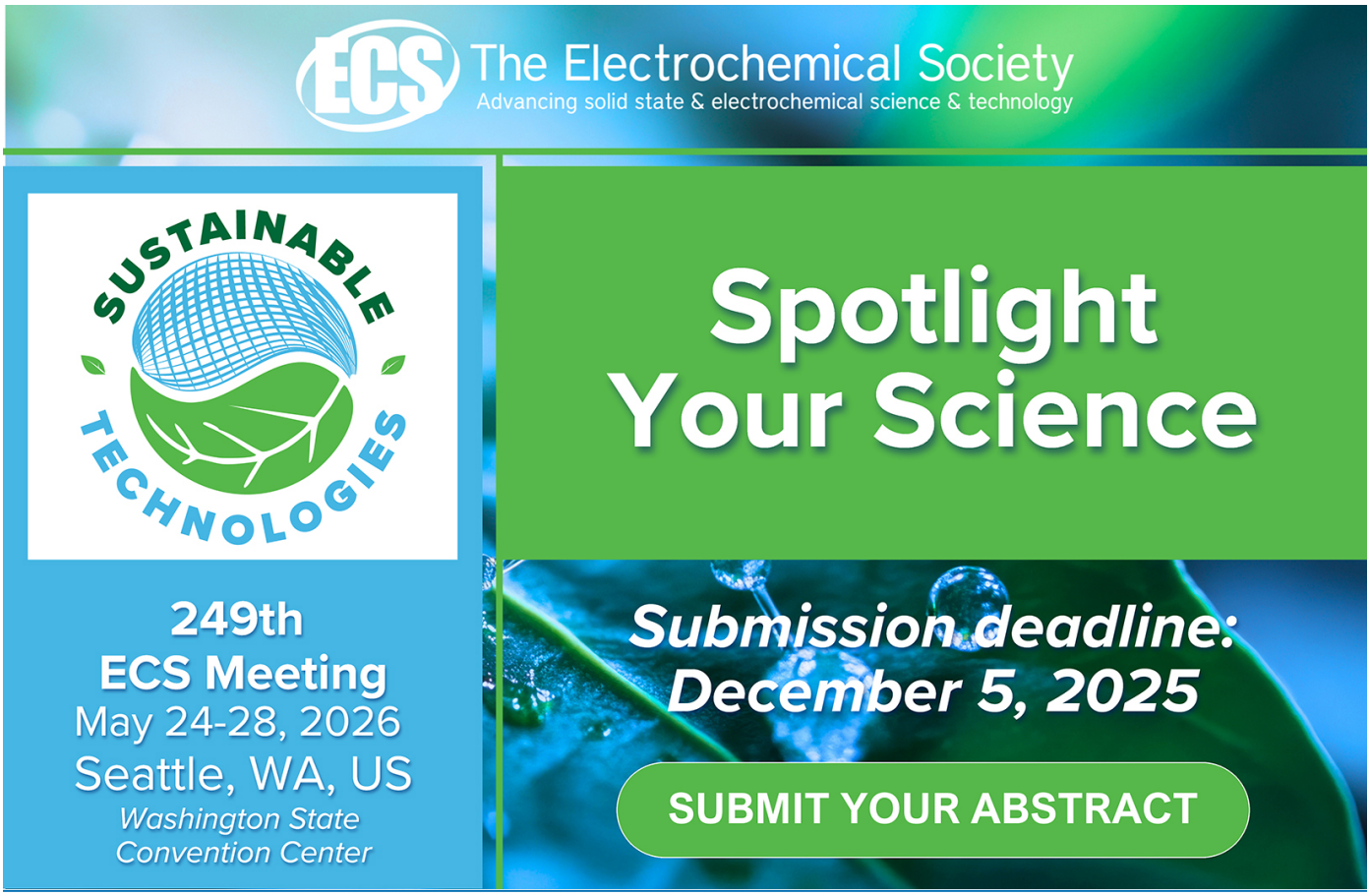
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Physical analysis of building materials with soil

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Abstract. Industrialization in construction has allowed the use of materials such as concrete and steel, these being essential for the construction of large buildings and structures, however, in some vulnerable areas, using this type of techniques and materials represents a high cost, due to which the traditional or vernacular architecture is a sustainable alternative. This research carries out a physical analysis of the materials used in the constructions on land that are developed in the municipality of Ocaña, Norte de Santander, Colombia. The results obtained indicate that the soil used in the analyzed structures has a maximum density of 1.41 g/cm3 with a humidity percentage of 32.55%; likewise, in natural condition these soils have a liquid limit of 67.85 a limit plastic of 45.72 and a plasticity index of 22.13. In other words, the soil has characteristic plastic characteristics of a fine soil. This corresponds to the granulometric classification of the soil, which corresponds to a high plasticity Silt, which has sands with diameters between 395 µm and 76.1 µm. It also has a specific gravity of 2.65 g/cm^3.

1. Introduction

One of the most serious problems facing Colombia and other developing countries is the issue of poverty. The world bank [1]. He made a publication where an analysis of the evolution of poverty in Colombia is made; additionally, a strategy is proposed to reduce it, with policies that promote rural development, social improvement and infrastructure. Likewise, in the 2014 national agricultural census, statistics show that almost 50% of peasants live in multidimensional poverty, which in practical terms means that this population is three times poorer compared to inhabitants of urban sectors. This situation motivates the development of sustainable construction techniques, using artisanal techniques and taking advantage of the local resources [2].

This research carries out an analysis of conventional and industrialized construction techniques, from a physical analysis of the materials, to identify the characteristics they describe and their impact on the possible pathologies that they may present. Since at present the use of concrete and steel is usually used as essential materials for the construction of large structures, however in some areas using this type of techniques and materials represents a high cost, for which traditional or vernacular architecture is an alternative to these construction systems [3], having a direct relationship with the place where it is developed and taking advantage of existing resources [4]. In this sense, the use of alternative materials such as earth acquires relevance and a constructive value, since it has both physical and mechanical characteristics that make it a material suitable for the development of buildings, such as resistance to impacts, manageability, thermal absorption, in addition to being non-combustible to fire and facilitates the reduction of CO_2 emissions [5].

The construction systems on land, with a low technological load, manage to optimize natural resources by being adapted to the climate of the region, allowing to regulate water vapor, heat and favoring the state of comfort [6,7]. among the energetic advantages of applying this construction system

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today, in contemporary architectures they mention the following: (i) thermal inertia has the ability to store energy in its interior to return it later, which favors its successful use in different climatic conditions [8]; (ii) acoustic insulation earthen walls do not transmit sound vibrations well, becoming a barrier against unwanted noise, having much more favorable acoustic properties than those of conventional walls [9]; (iii) sustainability, being a natural material, it can be reduced to its original state and deposited anywhere without any inconvenience, just as they do not generate any environmental degradation problem or alter bioclimatic conditions [10,11].

Accordingly, this research proposes an analysis of the construction systems on land, from the determination of the properties of the materials used as raw materials, analyzing, among other aspects, the natural conditions of the soil and from there a rural housing model is proposed with architectural features that take advantage of and maximize their properties.

2. Materials and methods

The research was developed by proposing a set of four stages, which are described in Figure 1. The research methodology is based on the analysis of specific homes in Colombia, Norte de Santander, in the town of Pueblo Nuevo and the Municipality of Playa de Belén. Documentary methods used to review information; this was obtained directly from technical visits made to different homes, in the same way an extensive bibliographic and documentary review has been carried out.

Data collection and information management were carried out using technical sheets, which in an objective and systematic way allow a partial recognition of the buildings, identifying the construction materials, the construction system, age and pathologies present in the structure. Additionally, field tests and laboratories necessary for the characterization of the materials were carried out, such as particle size tests, specific density, plasticity limits, and proctor and scanning electron microscopy. Finally, an architectural model for rural housing is established, considering the physical properties of the raw materials analyzed, to satisfy the needs of the population's analyzed resources.

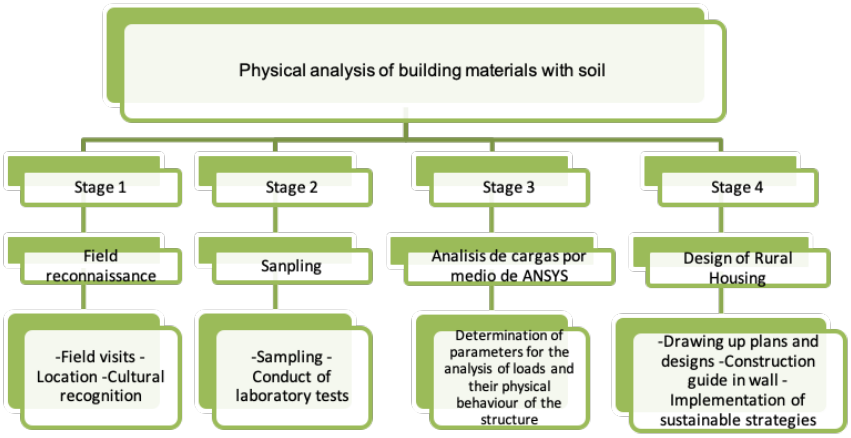


Figure 1. General diagram of the methodology adopted in the research.

3. Results

In Colombia, specifically in the department of North de Santander there are a large number of constructions on land; in this research, buildings in the town of Pueblo Nuevo and the central area of the municipality of Playa de Belén have been analyzed. When analyzing the data obtained from the different buildings in the field visits, it is identified that the wall is the predominant technique in the construction of houses.

3.1. Characterization of raw materials

For the town of Pueblo Nuevo, Norte de Santander, Colombia, different potential areas were identified to obtain material for the construction of brick walls, collected along the access road to the town; A

characterization of the clays was carried out, initial with a granulometric analysis, as can be seen in Figure 2, following the procedure of [12] with an array of square sieves from ¾ to 200.

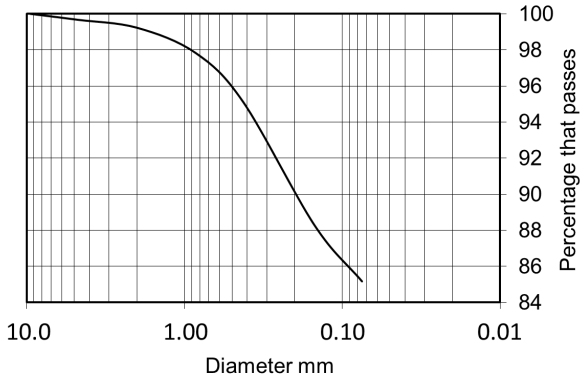


Figure 2. Granulometric curve of the material.

As can be seen in the figure, the granulometric curve of the soil indicates a percentage of fines present in the soil in natural condition that exceed 85%, whereas only 0.33% gravel and 14.5% particles were found the size of sands. In addition to this, a scanning electron microscopy analysis was also carried out, with which the size of the soil particle could be established, in this case the sands have sizes between 395 µm and 76.1 µm. These results mainly indicate that the soil in question corresponds to a fine material, with plastic characteristics. Which were determined by calculating the plasticity limit based on the procedure described in [13], and the results are shown in Table 1. With respect to the limits of plasticity and as can be seen in the Table 1, the soil has high values that are characteristic of highly plastic soils. This type of soil is suitable for the construction of wall structures, since the clay content and the plasticity they present give it an adequate consistency.

Table 1. Atterberg limits.

	Soil in natural condition		
Condition	Liquid limit	Limit plastic	Plasticity index
Natural	67.85	45.72	22.13

3.2. Mechanical characteristics

Regarding the mechanical characteristics of the soil, the proctor test was carried out as indicated in Figure 3, to determine the maximum compaction density of the soil and the optimum humidity, these results are of great relevance since they establish the amount of water which must be added to the soil in order to create a compact paste with the greatest resistance.

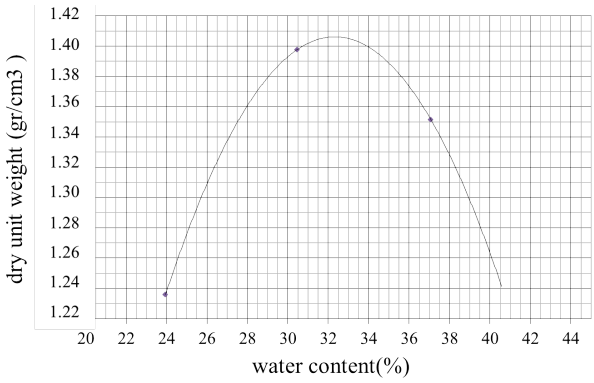


Figure 3. Compaction curve.

According to the graph, the maximum density is 1.407 g/cm^3 with a humidity percentage of 32.55%, this indicates that in the case of brick walls, they require at least a water percentage of 33% to achieve maximum compaction. of the material. That said, specimens of the material were made with the indicated amount of water, and some tests were carried out to determine the resistance, the results are indicated in the graph of Figure 4.The maximum stress achieved was 3.56 MPa and 3.84 MPa, acceptable values for a brick wall, for which the material under study is suitable for the construction of structures on land, which is now considering the design of a typical single-family home.

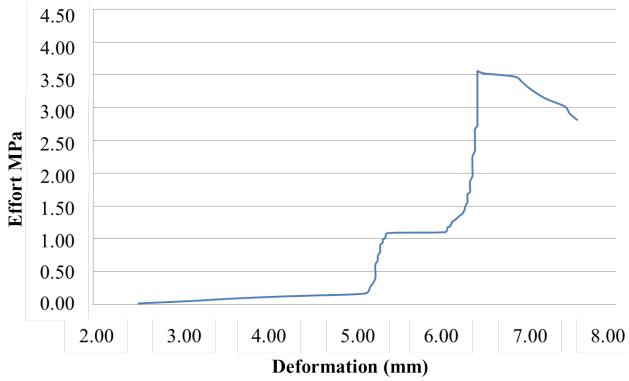


Figure 4. Granulometric curve of the material.

3.3. Housing design

Once the field visits were made to collect information on the historical context and the current state of the dwellings, the main needs of the population were identified. Initially and understanding that the target population of this research corresponds to inhabitants of these municipalities.

According to the historical legacy of the two settlements under study, both the village of Pueblo Nuevo and the municipality of Playa de Belén, Norte de Santander, Colombia, it was sought that the constituent materials of the houses were coupled to the existing ones, taking advantage of a material from the area that It also embraces the philosophy of sustainable constructions, that is, the construction of housing in Tapia is intended [14]. A first phase was proposed that corresponds to the elaboration of the designs that contemplate this type of housing, which, in addition to seeking the recovery of vernacular techniques, is also intended to be a sustainable project with the implementation of a rainwater harvesting system, water recycling and green facades.

The wall in Tapia as seen in Figure 5 has a thickness of 0.50 m, manufactured from the compaction of the earth inside a form also called mud, which consists of two wooden boards 1 m high and 2 m long, and two side gates that give the width of the wall, the process consists of introducing the earth brought to the desired condition, in layer thicknesses of 0.10 m later with a "Ram" the process of compaction, then the mud is dismantled and moved horizontally to continue with the process.

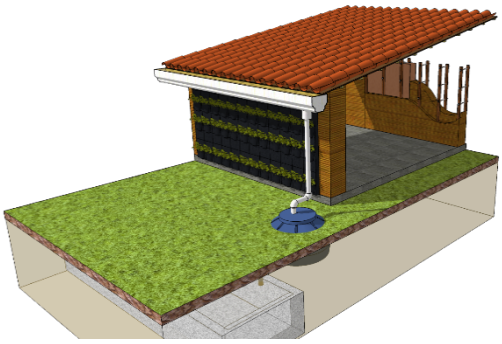


Figure 5. General scheme of rural housing.

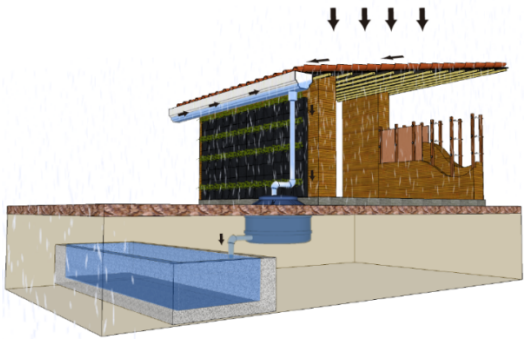


Figure 6. Diagram of the water collection and use process.

Regarding the green façade, it was thought of a kind of garden with aromatic seedlings, this allows the use of space, in addition to providing a thermal regulation inside the house, decreasing 5 degrees in times of intense heat, and in cold periods it conserves the heat inside. Figure 6 shows a general diagram of the main elements that make up the design of the house.

Figure 6 shows how it is rainwater collection and utilization system was designed taking advantage of the roof area, which acts as a collector, during rainy periods the water that falls on the clay tile roof descends on this given its slope until it reaches a gutter that later leads to a downspout, until reaching a first PVC tank that with the help of filters retain the larger polluting elements such as leaves, then the water is led to a larger tank that stores the water, and from which the water is pumped. Figure 7 shows a general diagram of the process, allowing this to be reused to be used in irrigation systems.

3.4. *Analysis of the brick wall in ANSYS*

Figure 7 and Figure 8 show as part of the analysis developed to the rural housing proposal, a finite model was developed for the analysis of the behavior of the tread wall, in a wall 0.8 m thick and 2.4 m high and 2.0 m high. Width It was modeled considering the load of the wall's own weight and the pressure generated by a clay tile roof that is taken as 1.2 kPa in the upper part of the wall, which was assumed to be embedded in the base for simulation purposes. As can be seen in Figure 8, the greatest deformation occurs in the upper part of the wall where the shit was applied; said deformation corresponds to 2.5 mm.

Regarding the values of the maximum normal stress and the maximum shear force, as shown in Figure 8, we see that the maximum nominal stress corresponds to 5.3 MPa at the base where the wall rests; likewise, the shear stress has a value of 2.1 MPa, this makes it possible to determine that its structural behavior must be articulated with rigid systems such as gantries, which contribute to better seismic performance and thus improve its resistance to compression and flexion of the wall in wall.

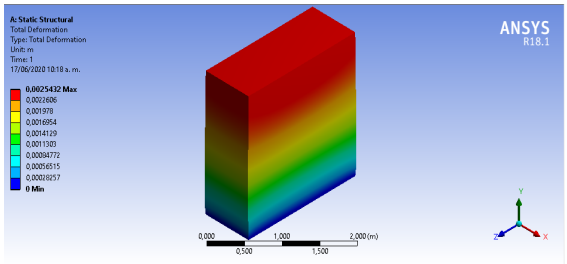


Figure 7. General scheme of rural housing.

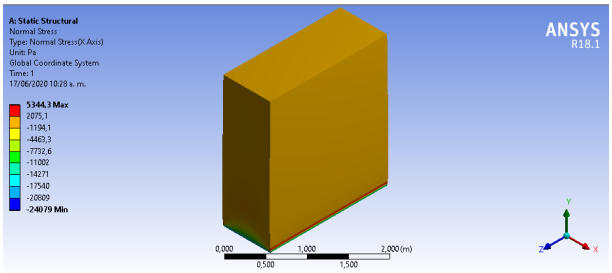


Figure 8. Diagram of the water collection and use process.

4. Conclusions

Vernacular architecture forms a great heritage in the department of Norte de Santander, Colombia, with a strong presence in different municipalities and townships, however the buildings on land are beginning to disappear when they are replaced by a type of construction that has been planted at an industrial level, as is concrete and masonry with ceramic bricks. The use of the wall technique at present is very limited, it is difficult to find people who handle this construction system, this is largely due to the standardized construction and new materials that displaced and caused a loss of the technique.

The analyzed material has typical characteristics of a fine soil of high plasticity, with a percentage of fine that exceeds 80% of the total fraction of the soil, in addition to a small minor percentage of sand and gravel that make up 20% of the sample. The sizes of the sands range between 395 µm and 76.1 µm, this coarse fraction is the one that supports the soil and allows the development of a granular matrix that supports and regulates the deformations and stresses to which the walls will be subjected. These conditions indicate that the soil in question is suitable for use in earth construction techniques such as ramming and the manufacture of BTC if a cementing agent is used. From the analysis in ANSYS it is concluded that it is necessary to carry out a reinforcement of the structure, with a porch that allows it to articulate and comply with Colombian regulations, to be implemented in sustainable rural housing

Finally, the implementation of a rural house configures an alternative that faces the displacement of architecture on the ground, being also a solution to the housing problem that vulnerable populations present in isolated areas, giving rise to a dignified space and that is also emerging within sustainable construction, by using materials with a low pollution load, and in addition to integrating systems such as green facades and rainwater catchment.

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