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Materials and Sustainability: the residual soil as an optimal construction material

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ABSTRACT
This work aims to demonstrate the application of the process of geopolymerization to the manufacture of the soil-cement block (SCB) in order to obtain a geopolymerized soil block (GSB), since the production of soil blocks, stabilized with Portland cement and compacted manually constitutes an alternative to the construction of low-cost housing projects. Inorganic geopolymers, on the other hand, result from a chemical reaction known as geopolymerization. They are materials of remarkable hardness and mechanical resistance, as well as long-term durability. Geopolymers can be manufactured out of locally available, low-cost raw materials. Hardening a geopolymer compound takes a lot less energy than it does for its counterpart. Geopolymers can harden in a matter of a few hours at temperatures between 50 and 80 Celsius degrees. Besides, the BSG, due to their lower environmental impact, promise to become a key component in the development of sustainable cities, which each time exploit less of their own non-renewable resources.
Keywords - fly ash, geopolymer, soil cement, sustainable construction, habitat.

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I. INTRODUCTION

Ceramic bricks, manufactured out of clay baked at temperatures between 800 and 1 050 Celsius degrees, constitute one of the most ubiquitous building materials in Colombian and Latin American construction. However, a great expenditure of fuel is required for the production of this type of brick; production which also causes the release of an outstanding quantity of CO_2 into the atmosphere.

On the one hand, we're experiencing a steady drop in the availability of good clays and loams for the manufacture of bricks of optimal performance. There's also the dramatic environmental impact to those zones where raw materials are extracted for their production **[1]**.

On the other hand, on multi-story building site and infrastructure works, large quantities of soil are excavated and removed, most of which is later classified as discarded soil refuse. The disposal and transport of this solid waste to a dumping facility incur an additional cost over the project. This cost is later transferred to the owners of finished and commercialized units **[2]**. This view of the process reveals a lineal flow of the consumption of raw materials and the generation of waste from the exploitation of resources, most of which aren't renewable.

The current use of SCBs as an affordable green option in the construction of low-cost housing doesn't require high cooking temperatures and makes use of discarded soil (loam), a readily available, low-cost, eco-friendly construction byproduct **[3]**. These blocks are associated with their non-structural use in construction, as defined by NTC 5324 Icontec standard **[4]**, and there's a growing tendency in their use on residential, office, restaurant and retail facility building projects. However, SCBs are a precast product of slow production that use Portland cement.

Stabilizing the current soil block with a geopolymer would help decrease and even replace the use of Portland cement in its production, turning it into a material with properties similar to those of concrete, expanding the range of possibilities of its application in construction and helping in the solution to problems, such as the depletion of non-renewable resources and the generation of waste **[5]**.

II. METHODOLOGY

The type of research is quantitative. It aims to impact the future legacy of soil-based construction, using scientific techniques to handle the uncertainty posed by the physical and mechanical properties of materials through time. In order to accomplish this, the raw materials included in the research are described in detail; characterizing each one of them, as well as their role in process of manufacture of GSBs. Samples of geopolymer-soil mixes are then taken to the laboratory to test their resistance; once the data is tabulated, the next step is the interpretation of observations. Preliminary conclusions are drawn and recommendations are given in order to establish a scientific methodology that is replicable at a practical scale, one that makes it possible to shift the perception paradigm from soil as solid waste to soil as optimal-performance, low-cost building material.

III. MATERIALS AND CHARACTERIZATION

3.1 The Soil: the soil, extracted from the town of San Antonio de Prado, located in Medellín, Colombia, was characterized through the use of X-Ray diffraction (XRD) techniques, in the materials characterization laboratory of Universidad Nacional de Colombia, in its Medellín site, in order to understand its chemical composition, and to determine the possible design of the mix. (Pictures 1, 2 and 3).

Picture 1. Residual soil in the site.

Picture 2. Selection of the soil sample.

Picture 3. Preparation in the laboratory.

3.2 The Fly Ash: type F (silicon-aluminum) were characterized by members of the cement and construction materials research team of Universidad Nacional in Medellín **[6]**, using XRD techniques and scanning electron microscopy (SEM), to determine its size in microns (Image 1) and its silicon-aluminum composition (Image 2).

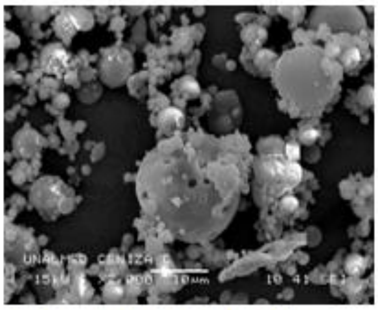

Image 1. Fly ash SEM, 2 000 X.

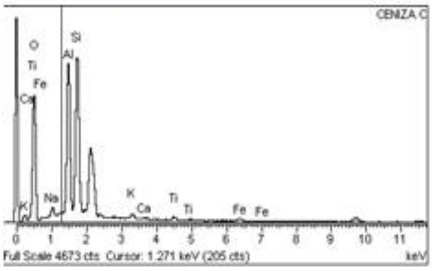

Image 2. Fly ash Chemical probe.

The image 3 shows the presence of chemicals components such as kaolinite, necessary for the process of activation of the cementing components.

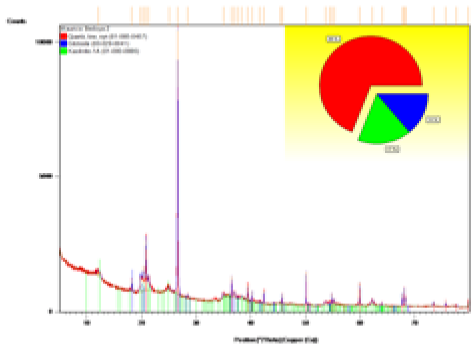

Image 3. X-ray Diffraction of soil.

3.3 The Cement: type I, ordinary Portland cement, in compliance with NTC 121 standard (ASTM C 150), which deals with materials physical and mechanical properties (Table 1).

Specific weight (g/cm^3)	Blaine min. (cm^2/g)	F´c 3 d MPa	F´c 7 d MPa	F´c 28 d MPa
3,10	2 800	8,00	15,00	24,00

Table 1. Properties of Ordinary Portland Cement.

3.4 The Geopolymer: alkaline solution.

RESULTS

Three types of mix were established

S100: mix manufactured out of 100% soil and the geopolymer, without Portland cement or fly ash;

S90Cn10: mix manufactured out of 90% soil, 10% fly ash and the geopolymer;

S90Cn5Cm5: mix manufactured out of 90% soil, 5% fly ash, 5% Portland cement and the geopolymer.

The different mixes were placed and compacted into 10x20 cm metallic moulds, and crushed in an electronic hydraulic compression testing machine in a credited laboratory.

The three samples were crushed at 7 days after manufacture, following the procedure for regular concrete mix, and setting a goal for future resistance at 6.0 MPa after 28 days, with an expected resistance of 65%, in order to be of significance to the research.

Sample + Geopolymer at 5% // Compressive Strength in MPa.

Mix design	Compressive Strength MPa
S100	5,1
S90Cn10	2,9
S90Cn5Cm5	4,0

Table 2. Strength of specimens at 7 days after manufacture.

Sample + Geopolymer at 5% // Expected strength at 7 days in MPa (%) // Observed strength at 7 days in MPa (%):

S100 ... 3.9 (65.0) // 5.1(85.0)
S90Cn10 ... 3.9 (65.0) // 2.9 (48.3)
S90Cn5Cm5 ... 3.9 (65.0) // 4.0 (66.7)

IV. CONCLUSION

After the compression test, it was observed that the cores of the S100 and S90Cn5Cm5 specimens exhibited less erosion than those of the ones manufactured out of the same soil and 10% Portland cement. This characteristic is very important to the preservation of construction units through time and their performance in the presence of outdoors variables, such as wind, sunshine, and friction with airborne particles.

The S100 mix manufactured solely from surplus soil removed from the selected zone, and 5% geopolymer, exhibited the greatest compressive strength, featuring a 100% replacement of Portland cement.

Notes

- Cross-disciplinary action over construction processes takes us to new scenarios where chemistry and materials science are to be considered tools that can afford us a better understanding of natural phenomena, to give answers to the needs of communities **[7]**.
- The geopolymer reaction, known for over six decades and discussed positively among researchers due to its capacity for production of highly resistant compounds from any given material, new or residual, has been demonstrated to be a current answer to the manufacture of new, more durable materials, that can withstand atmospheric, climatic and seismic conditions, which promote a paradigm shift towards bringing together the work of lab technicians and that of builders; a relationship that needs to be taken seriously in order to sustain new, cleaner ways of obtaining raw materials for disciplines like construction.

Possibilities for the SCB and the GSB

The sustainable buildings and houses, both urban and rural. Pictures 4 and 5.

Picture 4. Soil Cement Block made with residual soil.

Picture 5. Housing built with SCB.

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REFERENCES

[1]. J. Gálvez, D. Styles, H. Schoenberger and B. Zescmar, Construction and Demolition Waste best management practice in Europe, Resources, Conservation and Recycling, 136(9), 2018, 166-178.
[2]. H. Yuan and L. Shen. Trend of the research on construction and demolition waste management, Waste Management, 31(4), 2011, 670-679
[3]. S.C. Bestraten, E. Hormias and A. Altemir. Earthen construction in the 21rst century, Informes de la Construcción, 63(523), 2011, 5-20
[4]. ICONTEC. NTC 5324, Soil Cement Blocks for Wall. Ed. Icontec, Colombia, 2004
[5]. J. L. Provis and S. J. van Deventer, GEOPOLYMER. Processing, properties and industrial application, (CRC Press, 2009).
[6]. J. C. Swanepoel and C. A. Strydom. Utilization of fly ash in a geopolymeric material, Applied Geochemistry, 17(8), 2002, 1143-1148
[7]. C. M. Bedoya, Construcción sostenible. Para volver al camino, (Ed. Diké, 2011).

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