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RESEARCH ARTICLE

PHYSICAL CHARACTERIZATION OF EXCAVATED SOILS IN DIAMNIADIO-SENEGAL

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Abstract

The building is an object of concern in terms of health, energy consumption and environmental impacts. With more than 40 % of the world's energy consumption and high CO_2 emissions, the building sector is among the most energy-intensive sectors. An in-depth analysis of the building sector shows that Concrete, the material currently most used in Senegal is unsuited to the climatic conditions of Sahelian countries. In addition, cement production consumes a lot of energy and is a source of greenhouse gas emissions. Faced with environmental and energy concerns, the choice of appropriate materials is a key to limiting environmental impact and ensuring a healthy and comfortable indoor environment. This is how a sustainable approach using local clay resources for the production of clay bricks was implemented. However, the use of swelling clays is the source of significant problems in construction. Thus for a good prediction of the mechanical and thermal behavior of a material, it is important to determine its physical properties. This is why our study focuses on the physical characterization of the excavated soils of Diamniadio.

Introduction:-

With more than 40% of the world's energy consumption, the building sector remains one of the most energy-intensive sectors and also one of the most impactful on the environment (nearly 38% of global greenhouse gas emissions in 2019) [1]. An in-depth analysis of the building sector shows that building materials, specifically cement and iron, contribute significantly to the high cost of construction. Concrete, the most commonly used material in Senegal, is unsuitable for the climatic conditions of Sahelian countries. This is due to its poor thermal properties, which offer no guarantee of thermal comfort inside buildings. In addition, cement production consumes a lot of energy and is a source of greenhouse gas emissions. Faced with environmental and energy concerns, the choice of appropriate materials is crucial in order to limit the environmental impact and ensure a healthy and comfortable indoor environment. Thus, Africa, particularly Senegal, aware of the fight to reduce greenhouse gas emissions and for energy efficiency, must offer an alternative to concrete. Thus, research on the use of local clay resources for the production of mud bricks is underway. However, the use of swelling clays is at the origin of important problems in construction. Indeed, due to the phenomena of shrinkage-swelling of these clays, many pathologies at the level of the foundations of the houses located in certain zones are to be noted.

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The earth can be associated with other materials such as cement or hydraulic lime for a greater hardness and resistance but also it can be associated with natural insulators for better insulating qualities. Numerous works have been carried out with laterite in particular.

Waziri et al. [2] worked on cement-stabilized compressed laterite bricks for low-cost housing construction in Nigeria. The samples were stabilized at cement percentages of 0%; 2.5%; 5% and 7.5. Meukam et al. [3] conducted an experimental study on the characterization of local materials used in thermal insulation of buildings. They showed that laterite bricks incorporating natural pozzolan or sawdust have better thermal insulation than simple laterite bricks. Bal et al. [4] studied the valorization of local building materials in Senegal in order to improve their performance in terms of thermal insulation. They used a mixture of laterite and millet pods. Sindanne et al. [5] studied laterite blocks stabilized with cement, sawdust and lime. The evolution of the thermal properties of the earth blocks as a function of the stabilizer rates and their nature was discussed.

As with laterite, clay has also been the subject of several studies.
El-Mahllawy et al. [6] studied the compressive strength of stabilized unfired montmorillonite clay bricks. Quicklime and Portland cement were used as stabilizers. The test results show that cement gives better mechanical properties of the specimens than quicklime. Mounir et al. [7] made a study on a clay-cork composite material. The authors showed that the thermal conductivity of the clay decreases with the addition of cork. Abdessalam [8] made a study on the mechanical and thermal properties of earth bricks (clay). In his study, he mixed clay, dune sand and date palm fibers. The results showed that the increase in % of sand or fiber is beneficial for the improvement of thermal properties with acceptable mechanical strengths. Sutcu [9] studied the influence of expanded vermiculite on the physical, mechanical and thermal properties of clay bricks. The author showed that the brick samples produced by addition of vermiculite can be used as insulating material in construction. Cagnon et al. [10] studied the hygrothermal properties of five extruded clay bricks produced in five brick factories in the vicinity of Toulouse, France. The results of the measurements showed that the hygrothermal properties of the five earth bricks confirmed their ability to regulate the relative humidity of indoor air. Bodian et al. [11] made a study on the physico-chemical characterization of clay raw materials from the Thicky quarry.

According to the results of this review, the bricks are made with either a clay matrix or a laterite matrix. To our knowledge, there are no studies on the swelling clay soils of Diamniadio in Senegal. This is what motivates this research work.

To use a material in construction, it is important to know its characteristics. The raw materials are valued according to their physical and chemical properties, in relation to the available industrial processes.

Materials and Methods:-

The study was carried out on a swelling clay soil (figure1, present on the Urban Pole of Diamniadio. Diamniadio is located in the Dakar region of Senegal at 14° 43′ 13″ north, 17° 10′ 57″ west.

Figure 1:- Clay soil of Diamniadio.

We were mainly interested in the determination of the organic matter content, the natural water content, the apparent and absolute density, the Atterberg limits and the particle size analysis. Some of the measurement devices are shown in Figures 2 and 3.

Figure 2:- Device for Atterberg Limits.

Figure 3:- Device for particle size analysis.

Natural water content (W)

The water content of the various samples was determined by the method of drying in the oven, following the experimental standard [XP CEN ISO/TS 17892-1, 2005] [12]. This involves determining the mass of free water eliminated by drying in an oven at a temperature of 105°C. The determination of the natural water content is based on the following formula:

$$W(\%) = \frac{m_h - m_s}{m_s} \, x100 \qquad (1)$$

with

mh: mass of the soil sample in its natural state;

ms: mass of this soil sample after being oven dried at 105°C for 24 hours;

mh - ms = mass of water [13].

Organic matter (MO) content

The organic matter (MO) content in the soil is equal to the ratio of the difference between the initial sample mass m and the sample mass after the reaction with hydrogen peroxide m' to the initial test mass m (100 grams) [13].

It was determined according to the french standard [NF P94-055, 1993] [14].

The organic matter (MO) content is calculated by the formula:

$$. MO(\%) = \frac{m - m'}{m} x100 \quad (2)$$

Bulk density of raw material

The bulk density of a material is the density of a cubic meter of the material taken in a heap, including both permeable and impermeable voids of the particle as well as the voids between particles. The sample to be tested is placed in a funnel closed by a metal plate. This plate is slid and the aggregates are collected in a cylinder of known volume (V). After removing the excess material, the mass (m) of the material is determined.

The bulk density is given by the following equation:

$$\rho_{app} = \frac{m}{V} \quad (3)$$

Atterberg limits

Atterberg limits are tests that allow to define indicators qualifying the plasticity of a soil, and more precisely to predict the behavior of soils during earthwork operations, in particular under the action of water content variations. The purpose of these tests is to determine the liquidity limit W_L and the plasticity limit Wp of the raw materials. The difference between the liquidity and plasticity limits gives the plasticity index I_P.

The liquidity limit (W_L) was measured by the method of the dish of Casagrande and the plasticity limit (W_P) by the method of the roller. These measures were realized according to the french standard [NF P94-051, 1993] [15].

Particle size analysis

Particle size analysis presents the percentage distribution of solid particles according to their dimensions.

For our raw materials, the particle size analysis was done according to two techniques: the coarser fraction (> 80 µm) was analyzed by wet sieving and the finer fraction (< 80 µm) by sedimentometry according to the standard [NF P 94-057, 1992] [16].

Results and discussion:-

Table 1 presents the results of the water content, the organic matter content, the apparent and absolute density of our sample.

Table 1:- Results of the physical characteristics of the Diamniadio clay.

Sample	Natural water content	Organic matter content	Apparent density	Absolute density
Clay of Diamniadio	3.5 %	1.7 %	1555 kg/m^3	2460 kg/m^3

Our sample has a low natural water content of 3.5 %. This natural water content may be related to the amount of fine or clay elements contained in the sample.

The organic content of 1.7 % shows that our sample is non-organic [17].

The results of the Atterberg limits of our material are shown in Table 2.

Table 2:- Atterberg limits of the sample.

Atterberg limits	Liquid limit, W_L (%)	Plastic limit, W_P (%)	Plasticity index I_P (%)
Clay of Diamniadio	33	13	20

The results show that our material has a liquid limit W_L =33%, a plastic limit W_P =13% and a plasticity index I_P =20%. This shows that Diamniadio clay is a moderately plastic material [18].
The particle size distribution of our material is shown in Figure 4.

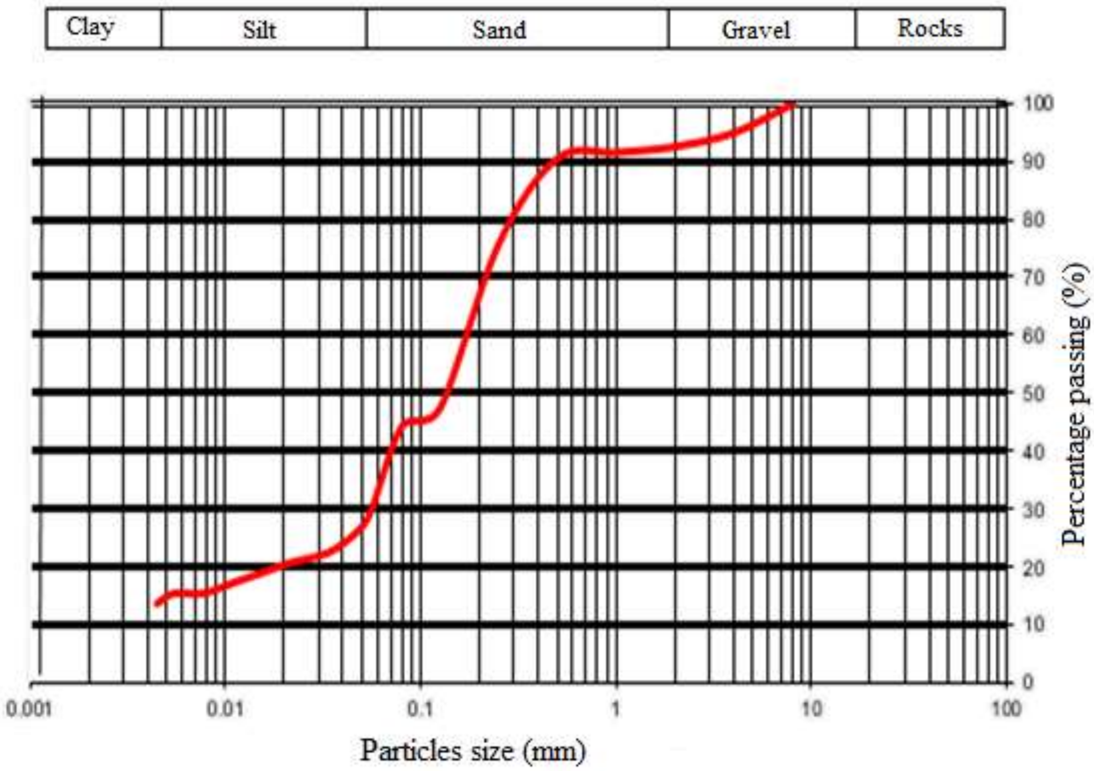

Figure 4:- Particle size distribution curves of the material.

According to the distribution of granular fractions defined by NF EN ISO 14688-1 standard [19], the results indicated that our sample is composed primarily of a fraction of 3 % clay, 23 % silt, 57 % sand and 17 % gravel.

Conclusion:-

In this paper, we determined the physical characteristics of our material.
The water content, organic content, bulk and absolute densities, Atterberg limits and grain size of our sample were determined.
The results of the water content show that our sample has a low natural water content.
The results of the organic matter content show that our sample is non-organic (OM = 1.7 %). Therefore, the negative effect of organic matter in the brick manufacturing processes (stabilization or firing) is negligible.
The Atterberg limits show that Diamniadio clay is a moderately plastic material.
The particle size analysis shows that our sample consists of clay, silt, sand and gravel.

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