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RESEARCH ARTICLE

PHYSICO MECHANICAL CHARACTERISATION OF ECOLOGICAL COATINGS BASED ON CATTAIL AND TURF

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Abstract

Coating mortars are subjected during their use to several external stresses, which can negatively affect their durability and lead to a loss of adhesion between them and the support. This study focuses on the development of an ecological coating based on clay and cattail fibers, aimed at improving the energy performance of buildings. The materials used are locally sourced and have been carefully characterized to appropriate standards. Several formulations were tested, combining clay with cattail and/or laterite, but only three showed satisfactory adhesion and absence of cracking, all containing a high proportion of cattail fibers.Mechanical and thermal tests revealed thermal conductivity ranging from 0.4 to 1.4 W/m. K and compressive strength ranging from 0.605 to 1.252 MPa. The optimal formulation, consisting of 25% clay and 75% cattail, showed a thermal conductivity of 0.46 W/m. K, which increased to 0.6878 W/m. K with the addition of 15% sand. Following the application of a coat of waterproof paint, this coating showed good resistance to rainwater after exposure to bad weather for a period of two months.To go further, studies on the adhesion and mechanization of the application of coatings are recommended, in order to optimize implementation and reduce costs while improving durability. This study represents a significant step forward towards more sustainable and economically viable construction solutions.

Introduction:-

Over the past few decades, the scope of environmental issues has expanded considerably. In addition to questions of managing and improving the living environment, global problems related to climate change, biodiversity loss, desertification and persistent sources of pollution have emerged. Data production and environmental information management have become essential tools for defining, implementing and evaluating environmental and sustainable development policies [1].

In a context where environmental preservation is a central concern worldwide, the use of ecological and sustainable materials in the construction sector has become a priority. Among these materials, eco-friendly coatings offer

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environmentally friendly alternatives to conventional chemical products, while providing performance levels that meet modern requirements. However, despite their undeniable advantages, these coatings still have limitations in terms of durability, adhesion and resistance to varying climatic conditions [2].

Understanding the adhesion properties between mortar and substrate is a major challenge for manufacturers who are attempting to improve the performance of their products through increasingly complex formulations. Beyond the affinity of a mortar for a substrate (chemical and physical compatibility of two materials), it is the durability of the bond between the materials that is sought. However, mortars are subjected to sometimes severe external stresses during their service life (drying, freezing/thawing, carbonation, etc.), which can lead to a loss of adhesion [3].

Materials and Methods: -

Raw Materials

Thicky Clay

Thicky clay is a promising material for industrial applications. It has a compact texture and is composed of flat sheets superimposed in a turbostratic disorder, characterised by random rotations and translations (see Figure 1). Microscopic observations show that this matrix has pores and microcracks, as well as a random orientation of the sheets, resulting in voids and a network of discontinuities. In terms of chemical composition, the clay consists mainly of quartz, kaolinite, illite and calcite [4].

Figure 1: Thicky clay quarry

Laterite of Thicky

Thicky laterite is characterised by a compact texture, similar to that of clay, with flat, superimposed layers and a turbostratic disorder. However, the laterite matrix is denser than that of clay, also featuring pores and microcracks. The random orientation of the layers creates voids, contributing to a network of discontinuities. In terms of physical and chemical properties, laterite has a very low organic matter content. Like clay, laterite is classified as non-marly, with a calcium carbonate content not exceeding 10%. Mineralogically, laterite consists mainly of silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3), while other oxides are present in smaller quantities. These properties make laterite a material that is also suitable for industrial applications, particularly in brick manufacturing [4].

Figure 2: Thicky Laterite Quarry

Typha Nguinth

The cattail used in this project is harvested in Nguinth (see Figure 3). Nguinth is a neighbourhood of Thiès located near the northern suburbs of Thiès and the town of KeurMame El Hadji. Harvesting consisted of cutting the stems approximately 15 cm above water level to allow for regrowth.

Figure 3: TyphaNguinth

Thies Limestone

The Paleocene limestones of Bandia, Thiès, and Pout, which are highly titrated in their upper horizon (+95% $CaCO_3$), are very suitable for lime production. Opportunities exist to meet the rapidly expanding national and subregional demand driven by the development of the gold mining industry. Limestone is a sedimentary rock that is easily soluble in water and consists mainly of calcite or calcium carbonate (at least 50% $CaCO_3$) and magnesium carbonate ($MgCO_3$). Depending on its location, limestone may also contain dolomite and clay (aragonite or marl). Figure 4 shows a photo of the Thiès limestone quarry.

Figure 4: Thies Limestone

The lawn

Turf, also commonly referred to as lawn, is a surface sown at high density with selected seeds, mainly grass varieties. It is mowed regularly during growth periods and often watered and fertilized to make it denser and keep it that way. Figure 5 shows turf in wet and dry conditions.

Figure 5:Lawn

Materials and Methods: -

Materials

There are various tools for applying plaster, but the most common ones used to create the different layers are shown in the following figures.

• The honeycomb roller or oak leaf roller: used to create a textured finish on the plaster;
• Trowel: used to manually spray the plaster onto the facade;
• Sprayed: using a spraying machine makes the task easier and faster, allowing larger areas to be covered.
• Tyrolean: also known as Tyrolean plaster, it is suitable for decorating exterior and interior walls on plastered masonry.
• The rule: made of wood or aluminum, it is used to adjust the thickness of the layers and to shape the final appearance of the plaster;
• The trowel: used to compact the plaster and give it a sprayed-crushed appearance
• Nail board or scraper: used to give the plaster a scraped appearance thanks to its rough underside.
• Shovel: a tool consisting of a more or less hollow plate attached to a handle, used to pick up or move granular, lumpy, pasty materials, etc.
• Sponge: a substance full of holes, soft when wet and capable of absorbing a lot of liquid, used for washing and cleaning.
• Gloves: a covering that fits the shape of the hand and fingers and is used as an accessory to clothing or as protection in various activities.
• Wheelbarrow: a mobile container, carried on one or more wheels, equipped with two handles for the human transport of small loads, usually over short distances.
• Putty knife: this is one of the essential tools for finishing your glasswork. It is used to coat the substrate with putty, ensuring that the glass is held perfectly in place. It is a special tool for mirror work.

Methods: -

The preparation of the substrate also depends on the age of the wall. In this case, the wall must first be cleared of all traces of old, crumbly, or non-adherent coatings such as plaster, surface water repellents, paint, etc. In some cases (presence of whitish calcite stains on concrete walls), it may be necessary to brush with a wire brush or wash with pressurized water [5]. Thorough preparation of the substrate involves not only brushing and careful cleaning (see Figure 6) to remove all impurities, but also precise leveling to correct any irregularities that could compromise adhesion. The latter was particularly effective in our tests with coatings made from clay, cattail, and sand. By ensuring that the physical and chemical properties of the different materials are harmoniously compatible, we have significantly improved the adhesion between the plaster and the substrate.

Figure 6: Cement support wall

The formulation studied is based on a combination of five main components: limestone, clay, cattail, turf, and sand. Limestone and clay act as mineral binders, ensuring the cohesion and strength of the coating. Plant fibers, such as cattail and turf, are incorporated to improve certain physical properties such as flexibility, lightness, and insulating capacity, while reducing the risk of cracking (Figure 7). Sand acts as a mineral filler, contributing to the dimensional stability and mechanical strength of the mixture. The balance between these elements results in a formulation that offers high adhesion performance and is suited to the thermal and mechanical requirements of coatings in a sustainable construction context.

Figure 7: a- Mixture before adding cattail and grass; b- Mixture after adding cattail and grass

Table 1 shows four plaster formulations made from mixtures of limestone, clay, cattail, turf, laterite (used as sand), and water, expressed as percentages. These formulations were selected for their good adhesion performance.

Table 1: Formulation: Limestone + Clay + Cattail + Turf + Sand

N°		Quantity of materials as a percentage				
	Water	**Limestone**	**Clay**	**Cattail**	**Lawn**	**Laterite**
Formulation 1	16%	20%	15%	25%	10%	14%
Formulation 2	17%	23%	13%	20%	15%	20%
Formulation 3	15%	15%	15%	20%	20%	15%
Formulation 4	19%	25%	20%	10%	5%	21%

Figure 8 below shows the application of different types of formulated coatings.

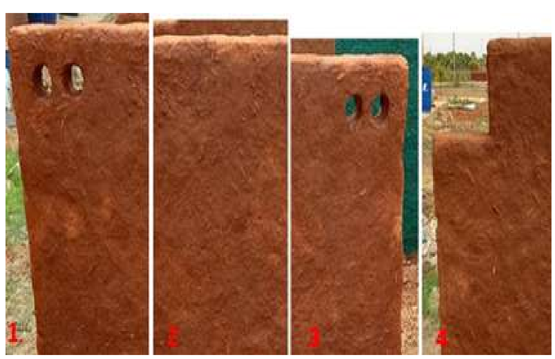

Figure 8: Application of the 4 types of coating to the substrte

Result: -

Withdrawal measure

The pellet test allows the dry strength of the soil to be tested and also determines the percentage shrinkage of clays. The percentages of soil shrinkage are summarized in Table 2.

Table 2: Percentages of soil removal during the pellet test

	Hbefore	Hafter(7days)	Vbefore (cm3)	V after (cm3)	% Withdrawal
Clay	2cm	2cm	249,38	144,413	42%
Laterite	4cm	3,8cm	680,94	618,36	9%
Limestone	3cm	3cm	487,33	112,086	23%

After 8 days if shrinkage is significant: There is a risk of cracking in the plaster; it is therefore necessary to add a lot of sand to make the plaster. On the contrary, if shrinkage is low after drying: There is little risk of cracking in the plaster; it is therefore necessary to add little sand to make the plaster. Conclusion: The soil taken from the Thicky clay quarry has a high shrinkage percentage, as shown in Table 3. Therefore, our plaster is at risk of cracking.
The clay and laterite soils tested both have a fairly high clay content, which makes them suitable for use in plaster. In addition, laterite fines have an average clay content: they are suitable for use in plaster or cob with the addition of sand or plant fibers.

Water content

The results for the natural water content of our samples are presented in Table 3 below.

Table 3: Natural water content of samples taken

Samples	Wetweight	Dry weight	Weight of water	Water content
Laterite	506g	502g	4g	0,80%
Clay	694g	677g	17g	2,51%
Limestone	821g	799g	22g	2,75%

Both samples have low natural water contents. However, the clay sample has a higher natural water content than the laterite sample, which has a water content of 0.80%. Variations in natural water content may be related to the amount of fine or clayey elements contained in the samples analyzed.

Thermal testing

The asymmetric hot wire method is a transient measurement method used to characterize the thermal conductivity and thermal capacity of a material based on the temperature change measured by a thermocouple placed near a resistive wire for a period of 400 to 600 seconds.

- **Principle of the Method**

The method consists of inserting a thin heating wire between the sample to be characterized (see Figure 11) and the 5 cm thick polyurethane. A type K thermocouple consisting of two thin wires is placed next to the heating element and glued to the side of the polyurethane in contact with the element. The device is completed by another block of polyurethane placed above the sample. The whole assembly is placed between two aluminum blocks of known thickness, as shown in figure 9.

Figure 9: Samples tested

Table 4 shows the thermal capacity and conductivity values for formulations made solely from clay, cattail fibers, turf, limestone, and sand.

The formulation 3 is composed of (12% clay + 25%typha + 10%sands + 10% limestone + 28% turf) and the formulation 4 consists of (15% clay + 20%typha + 15% sand + 20% limestone + 15% turf).

Table 4: Thermal conductivity for formulations

Formulation	λ (W/m. K)	f_c (J/kg. K)
Formulation 3	0,003	794,3157
Formulation 4	0,015	918,0855

For all these results, the residual curve is good (see Figure 12). The highest thermal conductivity value is obtained with formulation 3 (λ = 0.003 W.m^{-1} K^{-1}) and the lowest thermal conductivity value with formulation 4 (λ = 0.015 W. m^{-1} K^{-1}).

• Summary of results

For formulations (1, 2, 3, and 4), both thermal conductivity and thermal capacity decrease as the percentage of typha in the mixture increases.These changes is shown in Figures 10.

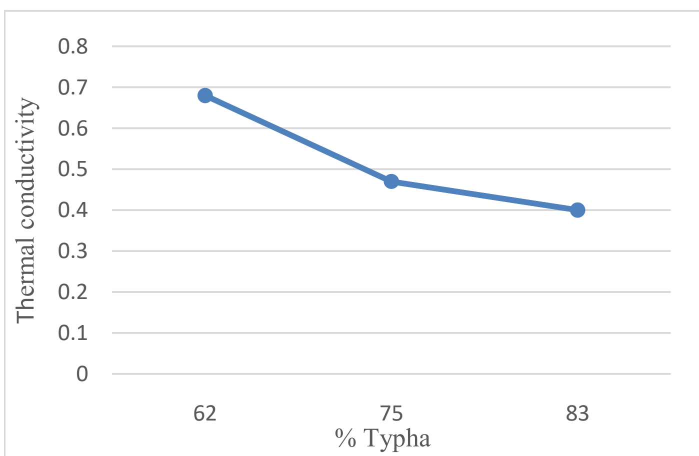

Figure 10: Variation in thermal conductivity as a function of Typha percentage

In composite materials, heat is mainly transferred by conduction. Materials with a porous structure slow down this process by increasing the amount of air, which does not conduct heat well. The decrease in conductivity shown in Figure 11 can be explained by the fact that cattail is a lightweight, porous material. Adding more cattail to the mixture increases the overall porosity of the composite [6]. The pores introduce air spaces that are poor heat conductors, reducing the material's ability to transmit heat.

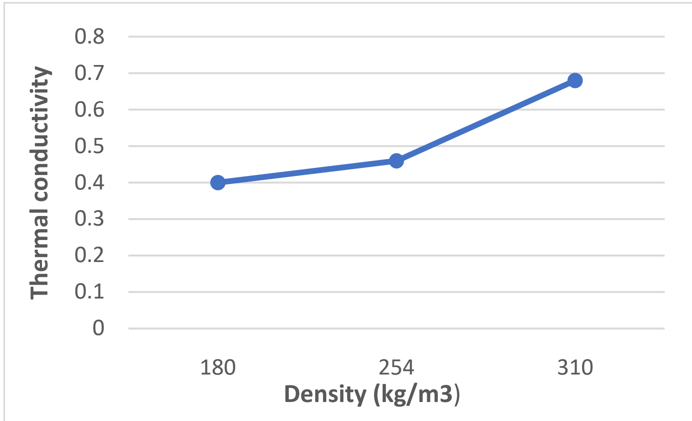

Figure 11: Variation in thermal conductivity as a function of the density of formulations without laterite

The observation that thermal conductivity decreases as the density of the composite decreases means that the lighter the composite (i.e., the less dense it is), the less able it is to conduct heat. This is related to the internal structure of the material; low density indicates a greater amount of air in the material, which acts as an insulator [7].Furthermore, as porosity increases with the addition of cattail, the volume of clay (which has a higher heat capacity) in the composite decreases, resulting in a reduction in overall heat capacity.

Mechanical testing

Most insulation materials intended for use in homes are not designed to support the structure of buildings. Depending on their use (slabs, walls, attics, panels), the mechanical stresses required will differ. In the case of insulating coatings, the material must at least support its own weight. The German standard DIN 4108-10 for manufactured thermal insulation materials sets the required simple compression stress at 0.02 MPa [7].

The results of the compression test for all coating formulations are shown in Figure 12 below.

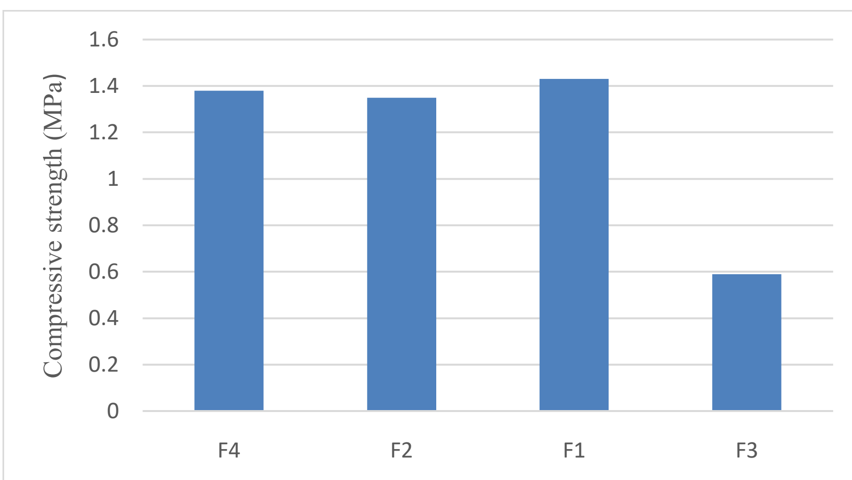

Figure 12: Compressive strength of different types of formulations

After the initial addition of cattail fibers, a slight increase in strength is observed. However, it is noted that these strength values decrease when the amount of cattail used in the formulations is increased.
In fact, depending on the compressive strength of the soil and the internal friction between the fibers and the soil, good compressive strength can be achieved thanks to the fiber reinforcement put in place [8][9].

To obtain good final strength of the composite, adhesion between the matrix and the fibers is essential. This is because, during loading, once the matrix is exceeded, it transfers the load to the reinforcements (fibers).
In turn, the fibers maintain the balance of the whole by supporting the load for a considerable amount of time. The adhesion between the reinforcements and the matrix determines the overall stability of the composite. Poor adhesion (due to a lack of cohesion, for example) between the reinforcements and the matrix is a source of weakening over time.

Conclusion: -

In this study, we successfully developed a formulation for an eco-friendly plaster mortar made from natural bio-based materials. All of the materials selected were sourced locally and characterized according to the appropriate standards. Comprehensive testing was carried out, including field analyses and laboratory tests. These evaluations focused on the formulations as well as the mechanical and thermal characterizations of the earth-based plasters. The results show that only three formulations were free of adhesion and cracking problems. These formulations all contain a significant volume of cattail fibers and clay, which required an evaluation of their thermal and mechanical characteristics. Thermal characterization revealed thermal conductivity ranging from 0.40 to 1.40 W/m. K, while the heat capacity ranged from 200,000 to 1,800,000 J/kg.K. In addition, these formulations offered acceptable compressive strength, with values ranging from 0.605 to 2.252 MPa for compression. These results comply with the German standard DIN 4108-10 for thermal insulation materials, which stipulates that an insulating coating must at least bear its own weight, with a simple compressive stress set at 0.02 MPa.

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