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RESEARCH ARTICLE

THERMOMECHANICAL STUDY OF TYPHA-BASED PARTICLEBOARD PANELS

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Abstract

This study focuses on the use of cattail in building construction. The overall objective of this study is to contribute to the preservation of our natural resources, which are threatened with depletion, by combating the proliferation of cattail while facilitating the acquisition of affordabl e housing for all citizens. Specifically, the aim is to design agglomerate d cattail panels in order to study their thermomechanical properties. Panels were made using cattail and welded mesh, and structural concret e was sprayed onto the panel at different thicknesses to determine which thickness offered the best value for money. Mechanical (compre ssion) and physical (heat transfer) tests were carried out on the samples. The results obtained are satisfactory overall: mechanical strength of the panels up to 2.81 MPa, which is higher than 2 MPa, the minimum strength required by standard NF DTU 20.1, and thermal conductivity varying between 0.119 and 0.034 W/m.K. Comparative studies have shown that the panels offering the best value for money are those with a typha density of 67 kg/m3 and a concrete thickness of 3 cm, which pro vides savings of more than 15% compared to conventional construction

Introduction:-

The use of raw materials such as earth and plant fibers, either alone or in combination, in construction is part of a long tradition on every continent. Men and women have developed various techniques for exploiting these resources depending on the geological, geographical, climatic, and cultural context, as well as the resources available on site.

Today, the use of fossil fuels must be drastically reduced due to their impact on greenhouse gas (GHG) emissions and the resulting global warming. Faced with the current urgency to reduce the environmental impact of the construction industry, the world is increasingly interested in materials that consume very few non-renewable resources in their manufacture, implementation, and use[1]. A particular focus on “low-carbon” materials goes hand in hand with improved energy efficiency during the building's use, particularly through good insulation. From this point of view, it has been proven that the use of bio-based materials can very effectively influence the energy consumption of buildings. In addition, a return to wall structures that regulate thermal comfort and consume less energy is also important, as this will be one of the responses to changing current thermal comfort requirements and, more generally, to the need for a healthy building environment[2]. Typhas australis, also known as cattails or bulrushes abroad, are monocotyledonous plants typically found along calm waters, ditches, lakes, marshes, and more generally in wetlands [3].In Senegal, the Typha australis reed has become an invasive species, particularly in the

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rivers and lakes of the north of the country. Until now, it has been rightly considered a nuisance. Rationally exploiting this plant, transforming it into a raw material and contributing to the sustainable local development of Senegal[4]. Our study focuses on the use of typha in construction. It is a project to produce typha-based insulation using cattails to manufacture panels. These panels will be used as walls (exterior and interior) and floors. This model must be adapted globally to the scale of the dwelling (for example, it must include consideration of sun protection, ventilation, and humidity management).

This study on the production of typha-based chipboard panels was therefore conducted with the following objectives in mind:

- To reduce the socioeconomic impact of the proliferation of typha in Senegal.
- Seeking economical construction methods,
- Using materials that are less dependent on fossil fuels,
- Taking advantage of the thermomechanical properties inherent in natural raw materials.

Material and Methods:-

The panels are made up of 25 kg of cattail, which is placed in a wooden crate. They are laid in layers that are bound together. Once filled, they are compressed to ensure that everything is compact. Next, the frame is put in place, which is made up of galvanized welded mesh with a diameter of 1.5 mm and a mesh size of 9 cm x 9 cm. This mesh acts as reinforcement for the concrete, connecting the panels together and also allowing the electrical and water supply networks to be attached. The dimensions of the panels vary according to requirements. Our prototype has the following dimensions: height h = 3 m, thickness e = 12 cm, and width l = 0.90 m.

(a)

(b)

Figure 1. Samples of typha chipboard panels seen in profile (a) and from the front (b)

Specific weight:- The results of tests to determine the bulk density of solid grains γs of KeurMorry sand are shown in Table 2.

Table 1. Specific gravity test results

Designation	Average values
Pycnometer volume (ml)	250
Weight of material	50
Weight of pycnometer P1 (g)	111.35
Weight of pycnometer + water P2 (g)	358.87
Weight of pycnometer + material P3 (g)	161.46
Weight of pycnometer + material + water P4 (g)	389.88
Density d	0.99
Temperature Tc	25
Specificweight	2.62

The bulk density of the sand used is equal to 2.62. The$\gamma s \geq 2.6$, which allows us to say that it is composed of heavy particles [5].

Sand equivalent:-
This test, as shown in Figure 2, makes it possible to highlight the relative proportion of harmful fine dust or clayey elements in soils or fine aggregates.


Figure 2. Equivalent sand test

It consists of separating the fine particles contained in the soil from the coarser sandy elements. A standardized procedure is used to define a sand equivalent coefficient that quantifies the cleanliness of the sand. The test is performed on the 0/5 mm fraction of the material. The sample is washed and left to settle for 20 minutes[6]. The height h2 is then measured visually or using a piston to determine the sand equivalent: ESv (visual) or ESp (piston). This test was carried out on sand from KeurMory. The results are shown in Table 2.

Table 2. Sand equivalent test results

Test parameters		Average values
Flocculateheight h1 (cm)	h_1 (cm)	15.5
Sand height at sight h2 (cm)	h_2 (cm)	9.6
Sand height at piston h'2 (cm)	h'_2(cm)	1
Sand equivalent on the test sample	ES (%) at sight	62.5
	ES (%) at piston	6.5

The analysis shows that although the sand is clayey, it can be used for standard concrete.

Grain size analysis of sand and basalt:-
Grain size tests were performed on sand and basalt to determine the percentage of different grains in the samples. The grain size curves for sand and basalt are shown in the figure. These curves were used to determine the characteristics of the materials used. These characteristics are listed in the table below:

Table 3. Characteristics of the aggregates used

Materials	Coefficient of uniformity (Cu)	Coefficient (Cc)	Fineness modulus (Mf)
KeurMory sand	2.36	1.39	1.33
Basalt 3/8	2.41	1.15	--

The results in the table show that the sand used has a narrow particle size distribution and poor grading. The fineness modulus value corroborates the results of the particle size analysis of KeurMory sand. The respective values of 2.41 and 1.15 for the uniformity and curvature coefficients show that 3/8 basalt has a uniform and graded particle size. These results were used to formulate the shotcrete.

Study of the compressive strength of concrete:-

Test principle:-

Mechanical tests were performed using a 2.000 kN mechanical press following a standardized protocol, as shown in Figure 3. The samples are placed and centered on the machine's platform. A mechanical press applies increasing loads over time to the surface of the sample until it breaks.

Figure 3. Compressive strength measurement.

Thermal study:-

Test principle:-

Thermal inertia is the ability of a material, or more generally a building, to maintain a certain temperature regardless of the external environment (temperature, air humidity, etc.) and thus provide good thermal comfort (in terms of humidity, a pleasant environment, and ambient temperature). Thermal inertia depends mainly on the heat flux and thermal diffusivity, which in turn depends on conductivity and heat capacity[7]. The thermal plane method is a transient measurement method used to characterize the thermal conductivity and heat flux of building materials and insulation over a period of 10 to 22 mn. With this method, one side of the material is heated, allowing the temperature change over time to be monitored using appropriate equipment. The experimental setup is described in Figure 4.

Figure 4. Experimental thermal testing setup

Résultats et Discussion:-

Compressive strength:-

After the sample broke during the 28-day compression test, the average values obtained were recorded in Table 4.

Table 4. Compressive strength as a function of concrete thickness

N° Sample	Thickness	Strength	Surface	Stress
	(cm)	(N)	(mm^2)	(MPa)
1	1.5	64 032	60 000	1.07
2	3	168 432	60 000	2.81

Analysis of the table shows that the maximum compressive strength of the panels increases as the thickness of the concrete varies. This strength reaches 2.81 MPa for a thickness of 3 cm on each side, meaning that these panels can be used as non-load-bearing walls.

Thermal resistance:-

The results of the thermal tests are summarized in the following figure.

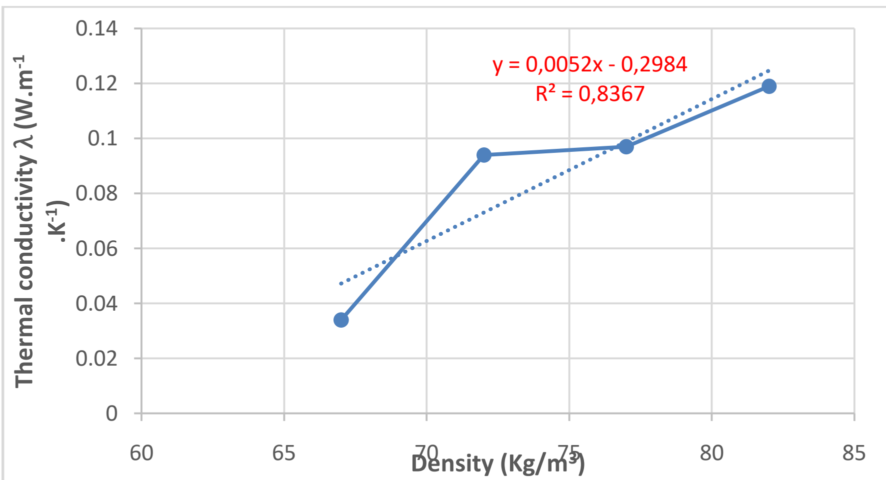

Figure 5. Thermal conductivity as a function of sample density.

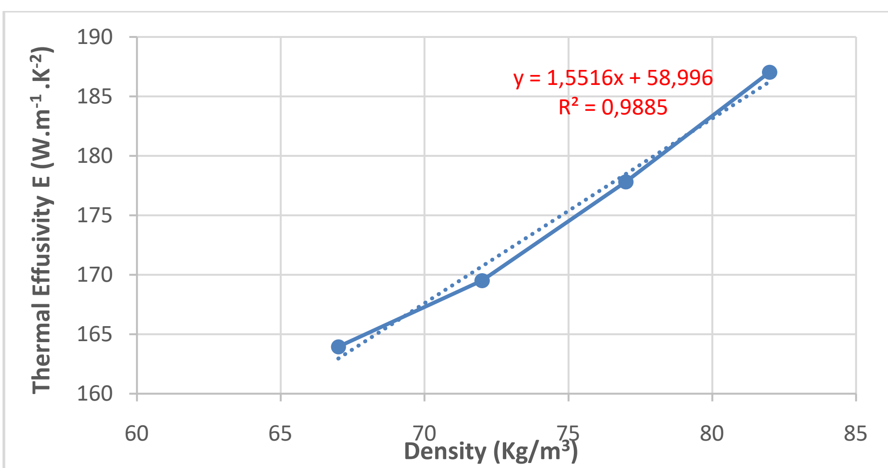

Figure 6. Thermal effusivity as a function of sample density.

Analysis of the curves in Figure 5 and Figure 6 shows that the lower the density of the cattail, the lower the thermal diffusivity and thermal conductivity. By varying the density, we see an increase in the voids between the stems. Typha is an organic material with pores, so the more voids there are between the stems, the greater its insulating capacity. Thermal characterization shows that the conductivity of all samples (thermal conductivity λ=0.119 $W.m^{-1}.K^{-1}$to 0.034 $W.m^{-1}.K^{-1}$ is very low, so their thermal resistance is high. These panels are inert and have low thermal conductivity, so using them in a building limits heat transfer and provides good thermal comfort. With a thermal conductivity of 0.034$W.m^{-1}.K^{-1}$, the panel with a density of 67 kg/m^3 is the ideal choice for ensuring good thermal comfort in buildings. For all samples, the standard deviation values are close to 1, indicating a slight dispersion in the measured values. Thus, the results confirm that the predictive equations are reliable for estimating the thermal conductivity of typha-based materials.

Conclusion:-

The proliferation of cattails in Senegal poses a major environmental problem due to their negative impact on the environment and socio-economic activities in the areas affected by this scourge, which lacks appropriate means of elimination. One way to combat this proliferation is to use them in construction as partition walls in the form of chipboard panels. This study therefore aimed to determine the mechanical and thermal characteristics of typha chipboard panels. The results showed that a density of 67kg/m^3 of typha has a thermal conductivity of 0.034W. m/K and 3cm of 18MPa concrete as a structural coating gives the boards optimal mechanical and thermal properties and a 16% saving in the total cost of structural work and a reduction of more than 60% in the energy consumption of a villa with a reinforced concrete structure. These panels could therefore be suitable for building single-family homes and classrooms, cold rooms for fishing, livestock and agriculture, and poultry farms. The materials used in this study are artisanal, so improving them would enhance the properties of the panels, which could reduce the cost of structural work. Consequently, the introduction of this type of material in the building sector could be a promising prospect, provided that further studies on durability (aging and fire resistance tests) are carried out.

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