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Experimental Characterization of the Thermal Behavior of a Sawdust Mortar

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Abstract**—**Currently, the reduction of energy consumption, through the use of abundant and recyclable natural materials, for better thermal insulation represents an important area of research. To this end, the use of bio-sourced materials has been identified as one of the green sectors with a very high economic development potential for the future. Because of its role in reducing the consumption of fossil-based raw materials, it contributes significantly to the storage of atmospheric carbon, limits greenhouse gas emissions and creates new economic opportunities. This study constitutes a contribution to the elaboration and the experimental characterization of the thermal behavior of a sawdust-reduced mortar matrix. We have taken into account the influence of the size of the grain fibers of sawdust, hence the use of three different ranges and also different percentage in the different confections. The intended practical application consists of producing a light weight compound at a lower cost to ensure a better thermal and acoustic behavior compared to that existing in the field, in addition to the desired resistances. Improving energy performance, while reducing greenhouse gas emissions from the building sector, is amongst the objectives to be achieved. The results are very encouraging and highlight the value of the proposed design of organic-source mortar panels which have specific mechanical properties acceptable for their use, low densities, lower cost of manufacture and labor, and above all a positive impact on the environment.

Keywords**—**Mortar, sawdust waste, thermal, experimental, analysis.

I. Introduction

THE development of modern technologies requires the use of high-performance, biodegradable, recyclable materials and above all with a less prohibitive price. This progress, which aims to improve the performance/mass ratio, has led to a new generation of structures and composite materials. In this context, the field of construction materials uses these new materials in the form of natural fibers, powders and light aggregates. These materials ensure, on the one hand, the durability of conventional natural aggregates, the reduction of certain building elements and, on the other hand, energy saving by reducing thermal conductivity [1]-[3]. Indeed, the weight gain, which can be more or less important depending on the type of concrete, leads to a reduction the sections of the structural elements ensuring the transmission of loads and leads to savings in transport of manufactured items and productivity gains to implementation.

The aim of this study is to understand the behavior of these materials under of different solicitations. Thus, the thermal, mechanical and acoustic properties have been explored. However, some scientific needs and technical difficulties limit the generalization of their use.

In Algeria the building sector is a sector that consumes the most energy, housing consumes a lot between heating, air conditioning, sanitary water, lighting, household chores and others. The most important example is the thermal losses in our homes which result in heat loss through roofs, walls, thermal bridges… As a result, building insulation has become a necessity and is an efficient and cost effective means. Insulation is also beneficial for the environment because, by reducing consumption, it preserves energy resources and limits greenhouse gas emissions [7]. Thus, thermal insulation is interesting in terms of environmental protection, comfort and financial economy. The quality of the insulation to be provided depends mainly on the climate, the exposure of the walls and especially the materials used [5]. The choice of a material as insulation depends naturally on its availability, its ability to respect the environment and its cost. Building materials with low environmental impact that meet the criteria of environmental quality, health, comfort of housing while meeting technical criteria such as mechanical performance, durability, architectural quality and reaction to fire present a perspective of future for the building sector.

Another problem that can be associated with all these problems is the proportion of non-recycled waste, large quantities of waste being thrown into the environment every day and contaminating our environment. By combining these two problems, we can propose an adequate solution to remedy these two phenomena and this offers the possibility of using innovative materials based on recycled materials [4], [6].

The intended practical application in this study is to highlight the thermal behavir of a light-weight mortar matrix of sawdust envisioned for use as a separation wall in the building. Composite specimens developed have both a cost of production far from expensive and a consequent ecological effect and very favorable. Improving energy performance while reducing greenhouse gas emissions from the building sector is among the objectives to be achieved.

In this paper, we studied the influence of sawdust grain fibers' size. Three different ranges were used and different percentages were tested for each class of grain size:

- Range G_1: Sieve 8-12,5;
- Range G_2: Sieve 3.15-6.3;
- Range G_3: Sieve 0,125 -1, 25.

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II. Experimental Protocol

A. Used Materials

Prismatic test specimens were manufactured according to Eurocode 2. A CIMPOR CEM II/AL 42.5R Portland cement, clean dry sand, tap water and a superplasticizer are mixed in a standard 60 L rotary mixer to get a mortar. Particle size analysis yielded three ranges of sawdust from the local carpentry, G_1: 8-12.5 sieve; G_2: sieve 3.15-6.3; and sieve G_3: 0.125 -1.25, Fig.1.

Preliminary compressive and bending tests were performed considering different mass fractions of the components as shown in Table I in order to optimize the proper formulation of the sawdust-based mortar. The best variant will be used in the manufacture of slabs of dimensions 15 x 15 x 3 cm for thermal analysis. Fig. 2 illustrates the different specimens. The physical properties of the different sawdust ranges are summarized in Table II.

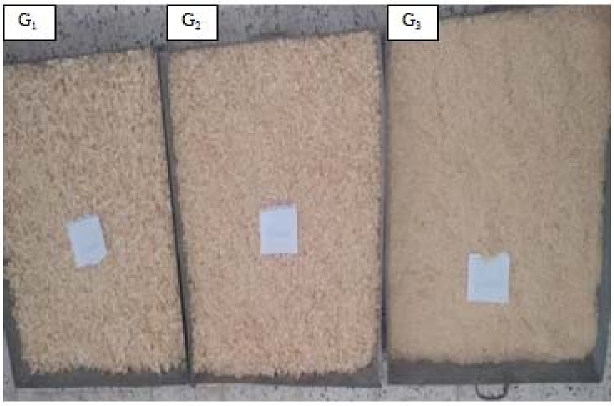


Fig. 1 Different ranges of sawdust

TABLE I
QUANTITIES USED BY SPECIMEN

Material	Range	%	Mass (g)	%	Mass (g)
Sawdust of wood	G_1	40	56	50	70
	G_2				
	G_3				
Mortar	Cement	60	68	50	57
	Sand		237		198
	Water		35		29

TABLE II
PHYSICAL PROPERTIES OF THE RANGES

Sawdust of wood	Characteristics			
Range	ρ (kg/m^3)	ρ_{abs} (kg/m^3)	Compacity C(%)	Porosity P(%)
G_1	41,08	500	8.22	91,78
G_2	54,17		10.83	89,17
G_3	102,5		20.5	79,5

B. Preliminary Mechanical Tests

The compressive and flexural tensile tests on prismatic specimen based on organic source mortar are carried out using an IBERTEST brand machine. The machine is equipped with a maximum force cell of 200 kN, and the software of control and treatment of the results (wintest), which makes it possible to have the force-displacement and force-time diagrams, the histograms, with a good precision. The tests are carried out at an ambient temperature of about 20 °C. The machine is driven at a constant rotation speed of 10 mm/min, 0.1 kN/s. Fig. 3 illustrates the different load-displacement curves in compressive and bending tensile of the best variant composed of 60% M + 40% of SC Type G_3 validated by the physical aspect illustrated in Fig. 2 and in particular the mechanical strengths.

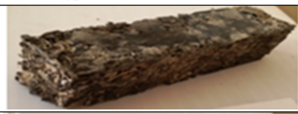
Range	40% sawdust/60% Mortar	50% sawdust/50% Mortar
G_1		
G_2		
G_3		

Fig. 2 Reinforced mortar specimens of different ranges

The test specimens, which are based on different ranges and proportions, have appreciable mechanical properties in terms of compressive and bending. The results obtained show a satisfactory strength to rupture.

As an indication, the variant 60% mortar and 40% sawdust range 3 (MSC-60% 40%-G_3) has the best mechanical characteristics in compressive, compared to other test specimens. The test specimen of 60% mortar and 40% sawdust range 1 (MSC-60% 40%-G_1) has the best mechanical properties in bending. Its flexural strength represents 43.22% of the resistance of the reference mortar. The compressive strength of MSC-60% 40%-G_3 represents 9.4% of the resistance of the reference mortar.

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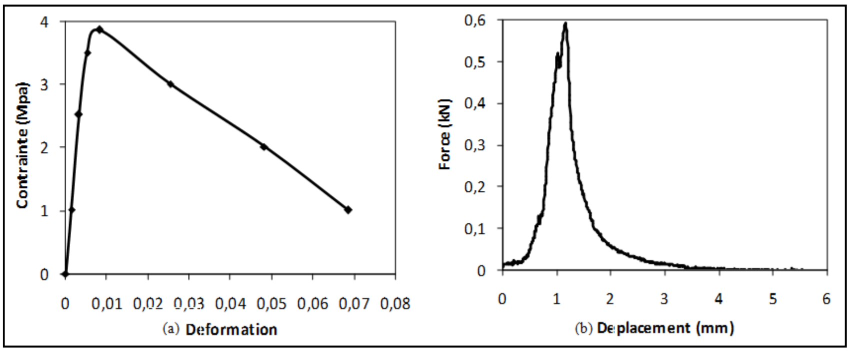

Fig. 3 Stress-strain curves

TABLE III
MECHANICAL PARAMETERS OF THE SPECIMEN 60% M + 40% SC-G_3

Notation	Symbol	Value
Compression stress corresponding to the peak	f_{mc} (Mpa)	3,86
Stress of elastic compression	$f_{mc\ elas}$ (Mpa)	2,51
Corresponding deformation at peak in compression	ε_{mc}	0,0082
Ultimate traction force	F_{mt} (N)	582
Displacement corresponding to the ultimate tensile stress	U_{mt} (mm)	1,1
Young's module	E_m (Mpa)	429
Poisson coefficient	ν_m	0,29

III. CHARACTERIZATION OF THERMAL BEHAVIOR

A. Confection of Specimen

TABLE IV
QUANTITIES OF COMPONENTS 60% M + 40% SC SPECIMEN 15X15X3 CM

Material	Range	%	Mass (g)
Sawdust of wood	G_1, G_2, G_3	40	148.72
Mortar	Cement	60	178.2
	Sand		623.7
	Water		90.024

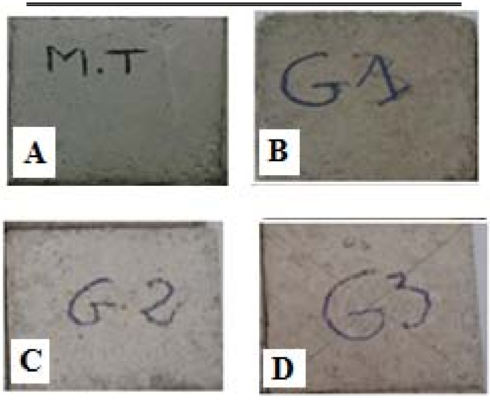

Fig. 4 (A) Mortar test MT, (B) Mortar-60%-sawdust 40%-G_1, (C) Mortar-60%-sawdust 40%-G_2, (D) Mortar-60%-sawdust 40%-G_3

Taking into account all the results obtained during the mechanical characterization of the different percentages and ranges of sawdust, we have opted, for the purposes of our thermal tests, for specimens with the mortar 60% - sawdust 40% for all ranges. All specimens of dimensions 15 x 15 x 3 cm^3 were prepared horizontally, so that the flatness of the surfaces is provided by the formwork itself. Table IV and Fig. 4 illustrate the weighing corresponding to each type of range.

B. Presentation and Analysis of Results

Thermal tests on the test specimen are carried out at the civil engineering laboratory in Reims, France using a NETZSCH brand HFM 436 machine. It is a universal machine that is designed to measure the thermal conductivity of low conductivity materials such as insulators. The test specimens are conserved at room temperature until the day of the thermal tests. The purpose of these tests is to select the type of specimen that has the best thermal properties for use in thermal insulation panels. All the results obtained are reported and represented as tables, curves and histograms for a good interpretation.

TABLE V
THERMAL TESTS FOR MSC AND MT TEST

Specimens	Mass (g)	$\rho_{apparente}$ (g/cm^3)	λ (W/mK)	Thermal resistance (Mpa)
MSC-60%-40%-G_1	1059.36	0,721	0,363	0.08264
MSC-60%-40%-G_2	1185.23	0,81	0,64699	0.04636
MSC-60%-40%-G_3	1244.83	1,015	0,667	0.04497
Mortier (MT)	1364.63	1.73	0,72421	0.04142

The mass and apparent density of sawdust samples have been observed to increase from large diameter to small diameter. This is due to the presence of inter-granular pores in the large diameter. The pores occupy a large space because of the shape of the grains, unlike the reference mortar which remains the heaviest with a higher apparent density.

According to the curve, it is noted that the presence of sawdust in the mortar considerably modifies the evolution of the thermal conductivity so that it is greatly reduced. This reduction is explained by the fact that the sawdust has a low thermal conductivity compared to that of the mortar. Moreover, it is also found that this conductivity is lower when the size of its components (grains and pieces of sawdust) is large, it produces more pore and therefore the porosity in the matrix.

The results obtained confirm the hypothesis that the denser the material, the lower its thermal resistance. It is clear that the determining factor in this decreasing is the porosity of the

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material. The observation is confirmed by the results of the tests. We noticed that for the reference mortar, the value of the thermal resistance is even smaller as the size of the sawdust grains increases. This resistance increases from the small grain size "range 3" to the large size "range 1". The higher the thermal resistance, the more insulating material is. The porosity factor is very important.

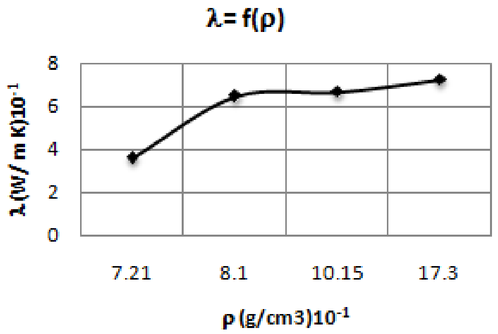

Fig. 5 Thermal conductivity curve as a function of apparent volumetric mass

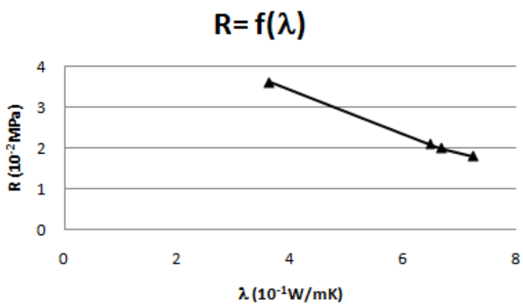

Fig. 6 Resistance curve as function of thermal conductivity

IV. Conclusion

Experimental results allow us to formulate these conclusions:

- Excellent adhesion between sawdust particles and mortar;
- Reduced weight for the MSC-60% -40% -G_1 range by 22% compared to conventional mortar;
- For the same range MSC-60% -40% -G_1 a reduction in thermal conductivity of more than half, it is of the order of 58.32% compared to the conventional mortar, of 29% compared to the MSC -60% -40% -G_3 and 11% compared to the MSC-60% -40% -G_2.
- The size of the sawdust grains influences the thermal resistance.

The overall effect of this mortar has shown good performance as non-structural components, intended for potential use as a partition wall in the building.

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