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Thermo-mechanical characterization of a building material based on Typha Australis

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ABSTRACT

This paper is a contribution to the valorization of Typha Australis as building material. To do this, the crushed fibers of Typha have been agglomerated using clay as binder. The weight percentage of binder is found to be at least 75% to obtain stable materials. The influence of binder content on mechanical and thermal insulation properties was examined. The mechanical properties were evaluated by using a mechanical press. The measurements of thermal effusivity and thermal conductivity of samples have been performed using the transient hot-plate method. Compression and tensile strengths respectively varies from 0.279 to 0.796 MPa and from 0.340 to 0.969 MPa when the weight percentage of binder range from 77–85%. This values have a strong linear correlation with the weight percentage of binder. The thermal conductivity of dry materials varies from 0.117 to 0.153 $W.\ m^{-1}.\ K^{-1}$ while the thermal effusivity rises from 228.9 to 300.0 $J.\ m^{-2}.\ °C^{-1}.\ s^{-\frac{1}{2}}$. The results show that the thermal conductivity and thermal effusivity increases with increasing moisture content of materials.

1. Introduction

The building industry is the main energy consumer in Senegal with 54.7%, according to the Energy Information System of SENEGAL. According to the data base of the Typha-based thermal insulation materials production project in Senegal, in West Africa, 25–30% of the electric produced is consumed by this sector. In addition to energy consumption, it is noted that the most important part of the CO_2 emitted comes from houses (49%). Building represents a key sector for the reduction of greenhouse gas emission. Using concrete without insulation increases building energy consumption. Thermal insulation is an important factor for reducing energy consumption as well as reducing CO_2 emissions [1–3]. The insulation materials available (polystyrene, polyurethane, glass and rose wool etc.) are mainly imported and are very costly [4]. It is therefore necessary to find insulation materials based on vegetable fibers as an alternative to imported insulation materials. This study deals with the use of *Typha australis* fibers to make a building material. *Typha australis* is an aquatic plant which is found on wetland and belongs to the Typhaceae family. This plant which can reach a height up to 3 m [5] is particularly widespread on the valley of Senegal River. *Typha australis* is nowadays considered as a harmful plant. Indeed, the proliferation of this plant on the valley of Senegal River affects its ecosystem and reduces the socio-economic activities of populations living along the river. The global objective of our study is to transform the harmful *Typha australis* as an opportunity by its transformation as a building material.

This paper aims to do a mechanical and thermal characterization of building materials based on *Typha australis* fibers. Several research works have been carried out in order to develop vegetal product based on local materials [1–4]. Meukam et al. [1], in his work, shows that the use of sawdust improves the thermal performances of stabilized earth bricks. The cannabis fibers influence on the physical and mechanical properties of BTC (compressed earth bricks) were studied by Millogo et al. [2]. The authors show an improvement on mechanical performance of the BTC. Bal et al. [3] studied the influence on thermal properties of laterite bricks with millet waste additive. The investigation of the mechanical properties and hygroscopic behavior of compressed earth block filled by date palm fibers was done by Taallah et al. [6]. The thermal behavior of hollow clay bricks made up of paper waste has been studied by [7]. The authors showed that the thermal conductivity of the brick materials with additives reduced from 0.68 W/m K to 0.39 W/m K compared with that of the sample without additives. Cherki et al. [8] studied the thermal behavior of an ecological composite material based on granular cork embedded in plaster. Their

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findings indicated that the composite is better than plaster without cork in term of thermal insulation and lightness. Belkarchouche et al. [9] determined the influence of adding natural fibers (olive pomace) on concrete thermal and mechanical properties. Their results showed that the addition of fibers improve slightly the thermal and mechanical performance. Benmansour et al. [10] evaluate the possibility of using a new material, composed with natural cement, sand and date palm fibers, as insulating building materials. Toguyeni et al. [11] focus their study on the thermal characterization of an insulating board made with lime and vegetable fibers of the Hibiscus sabdariffa. Palumbo et al. [12] studied the possibility of developing insulation materials for the construction sector made of non-industrial crop wastes and natural binders. The authors assessed the thermal behavior, equilibrium moisture content and water vapor permeability of experimental insulation panels obtained. Their results showed that crop wastes can perform adequately as insulation materials. Efendy et al. [13], in their study, performed a physical and mechanical characterization of untreated and chemically treated harakeke fibers. These fibers were compared with those of hemp to assess their use as potential reinforcements in composite materials. Other studies were carried out on concrete materials reinforced with *Typha australis*. Diatta et al. [14] showed that thermal insulation of concrete materials has been improved with additives. Diagne et al. [15] showed that the mechanical properties of concrete materials are improved by combining Typha, sisal pulp and polypropylene fibers. Georgiev et al. [16] report qualitatively the results of testing different combinations of clay with *Typha latifolia* fibers for their suitability as a universal plaster. Their authors demonstrated clearly the superior properties of Typha fibers as a reinforcement material for clay plaster mortars. Luamkanchanaphan et al. [17] studied study physical, mechanical and thermal properties of insulation boards prepared from narrow-leaved cattail fibers by using Methylene Diphenyl Diisocyanate (MDI) as a binder. Their test results showed that the insulation boards had good physical and mechanical properties and thermal conductivity values of the board with a density of 200–400 kg/m^3 were less than that of fibrous materials and cellular materials.

In this paper, the potential of the use of clay as binding material to make Typha fibers panels was assessed. In this order, the influence of binder content on mechanical and thermal properties of panels with and without humidity were studied. Mechanical properties into investigation were compression and tensile resistances and thermal properties concerned conductivity and effusivity.

2. Materials and methods

The test panels were made with fibers obtained from crushed Typha leaves and clay as binding material.

2.1. Materials

2.1.1. Binder

The clay used was produced from local quarries and do not need any transformation. The results of the granulometric analysis of the clay are illustrated in Fig. 1. These results showed that this clay is mostly made up of close grains with a 1.015 good – quality module. The binding material was composed with equivalent masses of clay and water mixed until a sticky viscous liquid was obtained. The mixing was done in a stainless steel beater having specific speed of 62 or 125 rpm and a capacity of 5 l. The mixing time was about 5 min.

2.1.2. Fibers

Fibers were from *Typha australis* leaves extracted and sun dried before being crushed by means of a hammer grinding machine. The fibers obtained are presented in Fig. 2. The fibers length ranged from 1 mm to 42 mm with a mean value of 13 mm. The fibers density value was determined by calculating the mean value for five measurements is 86.5 kg/m^3.

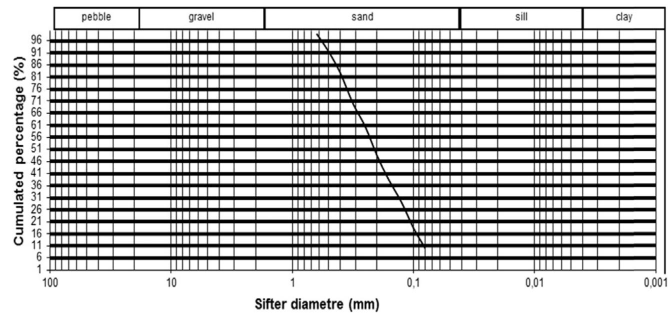

Fig. 1. Granulometric graph of clay used.

Fig. 2. Crushed Typha fibers.

2.2. Sample preparation

Samples were made by mixing typha fibers with the binder material in the beater during 5 min. The mixture was malaxated using a mixer type E095. The mixer had specific speed of 62 or 125 rpm and a capacity of 5 l. The mass composition of the different samples is given in Table 1.

For mechanical tests, a mould of dimensions 4×4×16 cm^3 was used to prepare samples and for the thermal test samples were prepared in a mould of dimensions 10×10×2 cm^3. The material obtained by mixing fibers and clay was poured in the moulds and tamped. After 24 h in an indoor environment of about 27 °C, the moulds were removed and test specimens were cured in air about 14 days. Figs. 3 and 4 show respectively a sample for the thermal test and a sample for the mechanical test. The density and the porosity of the specimens are presented in Table 2.

2.3. Mechanical characterization

Mechanical characterization consists in the determination of the compression resistance and the tensile strength. Test was performed with three specimens for each mix. This characterization was done using a E0160 type mechanical press with a maximum force of 250 kN. The specific speed of the force application was 2 kN/sec. For the

Table 1
Masses of the different compounds.

Samples	Binder percentage (%)	Binder mass (g)	Crushed typha mass (g)	Water mass (g)
E_1	77.13	102.87	30.5	87.63
E_2	78.11	108.81	30.5	92.69
E_3	81.48	134.19	30.5	114.31
E_4	84.22	162.81	30.5	138.69
E_5	84.90	171.45	30.5	146.05