



## EFFECT OF THE TYPE OF BINDER ON PHYSICO-MECHANICAL AND THERMAL PROPERTIES OF MORTARS WITH A BASIS OF COIR

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### ABSTRACT

This paper aims to study the effect of type of binder on properties of mortars with coir. Two types of binders were used for the manufacturing of mortars containing coir: lime is used as binder for mortar n°1 (Mortar 1) and cement is used for mortar n°2 (Mortar 2). The measurements of the physical, mechanical and thermal properties of the specimens show that Mortar 1 has higher water absorption values than those of Mortar 2 and consequently has the lowest values of thermal conductivity. The results also indicate that dry density of the specimens has more important role than the type of binder on mechanical properties. Relationships were established between mechanical properties and dry density of these mortars. These relationships are independent to the type of binder. The mortars also satisfied most recommended thermal insulation standards.

**Keywords:** coir, binder, thermal conductivity, dry density, mechanical properties, water absorption.

### INTRODUCTION

In the field of building materials, the waits toward materials are in a constant evolution. If previously, these materials were mainly desired only for their mechanical properties, the current tendency is to encourage the use of multifunctional composite materials in terms of mechanical properties, thermal and acoustic insulations. At the present time, due to environmental and energy problems, increasing attention should be paid to material with low environmental impacts (eco-material) with a view to conserving energy and protecting the environment. So, materials with natural fibers are actually the subject of a particular attention. Several research projects have been conducted on the use of natural fibers (rice straw, wood, bamboo, sisal, hemp, etc.) in cement composite [1-11]. In any case, the results show that the use of natural fibers in cements composite increases flexural strength and offer significant cost reduction as compared to synthetic fibers. Savastano *et al.* [12] showed that the use of sisal waste as reinforcement in concrete improve the mechanical properties of these concrete. The works of Asasutjarit *et al.* [13] on the use of coir in concrete indicated that the best pretreatment of these fibers was to boil and wash them as it can enhance some of their mechanical properties. Merzoud and Habita [14] elaborated mortar with a basis of 'diss' (*Ampelodesmos mauritanicus*). The results indicated an increase in mechanical properties of these composites when the fibers are boiled. In Europ and in Canada, many research works [15-22] are conducted on the use of hemp fibers in cement composites. The results indicated various advantages among them the following: increased in mechanical properties, acceptable thermal and acoustic insulating properties compared to the traditional materials (concrete, fiberglass, wool of rock, etc.).

In Côte d'Ivoire, the annual production of coir is approximately estimated at 80000 tons among which 70% are recycled and the others 30% constitute waste and are consequently rejected in the environment [23]. The

literature concerning these fibers seems to indicate an insufficient technological valorization, particularly in the field of cement composites.

The purpose of this article is to determine physical, mechanical and thermal properties of mortar casting with coir. The type of binder and the effect of composites density are also discussed.

### MATERIALS AND METHODS

#### Materials

#### Coir

Coir can present different properties according to their origin, the mode of culture and the treatment undergone by the walnut from which they arise. In this study, coir sourced from the same farm were rinsed and beaten by wooden roller in order to separate the ligneous material from particles which remain hung on there. They were afterward crushed and dried in the steam room at a temperature of 50°C. This operation allows obtaining rotproof fibers. The material appears in the form of fibrous elements 30 mm in length, 2 mm in width and 1.5 mm in thickness (Figure-1). Table-1 indicates the physical and mechanical properties of these fibers.



**Figure-1.** Coir crushed and dried used in this study.

**Table-1.** Physical and mechanical characteristics of coir.

Density (g/cm <sup>3</sup> )	Water absorption (%)	Tensile strenght (MPa)	Modulus of elasticity (MPa)
1.20	10	200	6000

### Binders

Two binders were used: hydraulic lime and Ordinary Portland Cement (CPA CEM I 32.5). The physical properties of these binders are presented in the Table-2.

**Table-2.** Physical properties of studied binders.

	Density (g/cm <sup>3</sup> )	Specific area (cm <sup>2</sup> /g)
Lime	2.20	4200
Cement	2.98	3214

### Mortar mixtures

Two types of mortar with a basis of coir, noted Mortar 1 and Mortar 2, were studied. For the manufacturing of Mortar 1, the binder used is the lime. The cement was used as the binder for the manufacturing of Mortar 2. The mortar formulation results from some modifications brought to the composition proposed by Asasutjarit *et al.* [14] on the basis of physical and mechanical properties. The quantity of mixing water is adapted in order to obtain the same workability for the two mortars. The compositions of the mortar are presented in Table-3.

**Table-3.** Mixing ratio by weight.

Designation	Constituent	Ratio in the mix
Mortar 1	Lime	2.50
	Coir	1.00
	Water	2.90
Mortar 2	OPC	2.50
	Coir	1.00
	Water	3.00

### Specimens casting and curing

For each composition, six prismatic specimens 40 mm x 40 mm x 160 mm were cast for the measurements of

physical and mechanical properties and six prismatic specimens 270 mm x 270 mm x 80 mm were cast for the determination of the thermal conductivity of samples. mortars are manufactured according to the procedure described below:

Binder (lime or cement) was added to the dried coir and thoroughly mixed. Water was then added and mixing was continued until uniformity was obtained. Water proportioning was adjusted to obtain fresh mortar with a slum test value of 10 cm. the mix was then placed in the molds and casing pressure was applied for 24 h at ambient temperature. Four level of pressure were adopted: 1; 2.5; 5 and 10 bars. This process allows obtaining mortar with various densities. The specimens were removed from the molds after 24 h and then kept in a saturated room for 28 days. For each property, three samples were used at the day of the test.

### Testing

#### Physical tests

##### Water absorption test

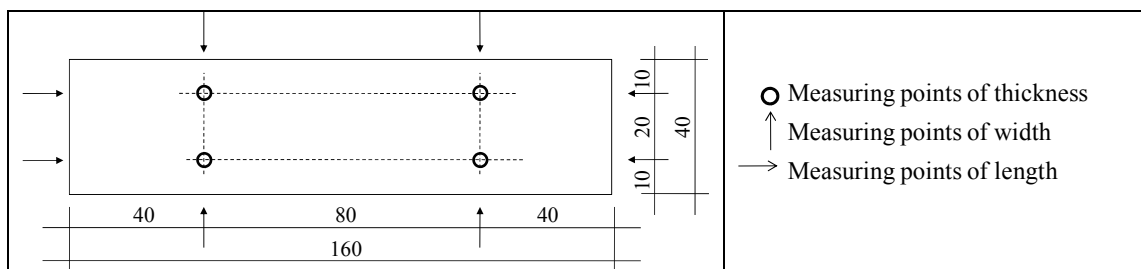
Water absorption was measured by total saturated water method according to RILEM CPC 11-1 [24] procedure. The specimens were immersed in tanks containing water. The specimens were kept immersed until they reached a constant mass ( $M_w$ ). After that, they were dried to an oven at 105°C until they reached a constant mass ( $M_d$ ). The water absorption is calculated using the following equation:

$$w(\%) = 100 \cdot \frac{M_d - M_s}{M_s}$$

##### Dry density test

This property was determined according to the French standard EN 772-13 [25]. The lengths, widths and thickness of dried specimens ( $M_d$ ) are measured in four points as shown in Figure-2. So, their respective means values are obtained with which the specimen volume ( $V$ ) is calculated. The dry density is calculated by the formula below:

$$\rho \left( \frac{kg}{m^3} \right) = \frac{M_d}{V}$$

**Figure-2.** Points to be measured of length, width and thickness.



### Mechanical tests

The mechanical properties (compression strength and flexural strength) were determined according to the French standard on prismatic specimens 40 mm x 40 mm x 160 mm.

- Flexural strength [26]

The flexural test based on the three-point loading principle was carried out on each of the specimens. The load is applied at approximately 10 mm/min from the surface of the sample and the maximum load (P) is measured. The flexural strength is calculated using the formula:

$$f_t(\text{MPa}) = \frac{3 \cdot P \cdot L}{2 \cdot b \cdot t^2}$$

Where P, maximum load (N); L, span (mm); b, width of sample (mm); t, thickness of sample (mm).

- Compression strength [27]

It was determined by using a PERRIER compression apparatus with a loading capacity of 300 kN. Tests were carried out on half of the specimens used in bending tensile strength test.

### Thermal conductivity test

The thermal conductivity of samples was determined by using TAURUS TLP machine via an acquisition software and data processing. This apparatus is based on the hot plate method [28] for the determination of thermal conductivity of specimen. This method consists to establish through two flat and parallel test pieces (so identical as possible), of sizes 270 mm x 270 mm x 50 mm (obtained after the sawing and the polishing of prismatic specimen 270 mm x 270 mm x 80 mm), a constant and uniform flow. Before these thermal tests, specimens were dried in an oven during 7 days (for Mortar 2) and 10 days (for Mortar 1). Figure-3 presents a schematic of hot plate method.

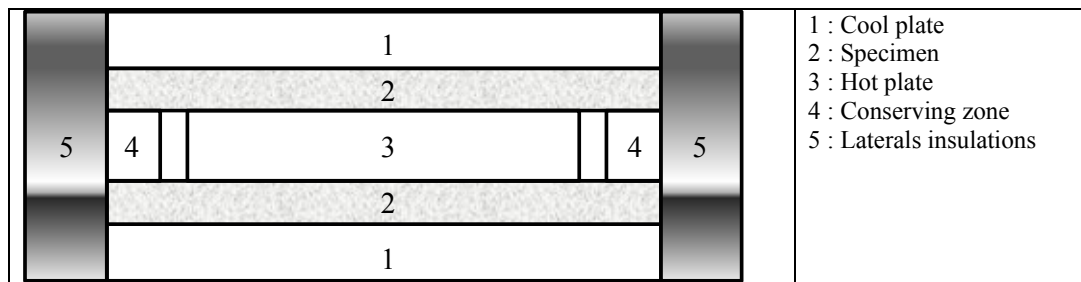


Figure-3. Setting position of hot plate and cool plate in respect to test samples.

## RESULTS AND DISCUSSIONS

### Physical properties

#### Dry density (DD)

The average measured values of mortars dry density (DD) are plotted against compaction level of samples in Figure-4. It can be observed that as far as the compaction increased, higher dry density was obtained for both mortars. Furthermore, DD of Mortar 1 is significantly lower than that of Mortar 2. The gap is upper than 5%. This fact suggests that the denser is the binder, the higher is specimen DD (Table-1). It can be concluded from Figure-4 that the type of binder plays a more important role on DD value than the compaction level of samples. However, it was observed that the gap between the DD of these mortar decreased (from 8% to 5%) for an increase in compaction level (from 1 to 10 bars). This may be due to the fact that with an increase in compaction level, the composites obtained became more compact.

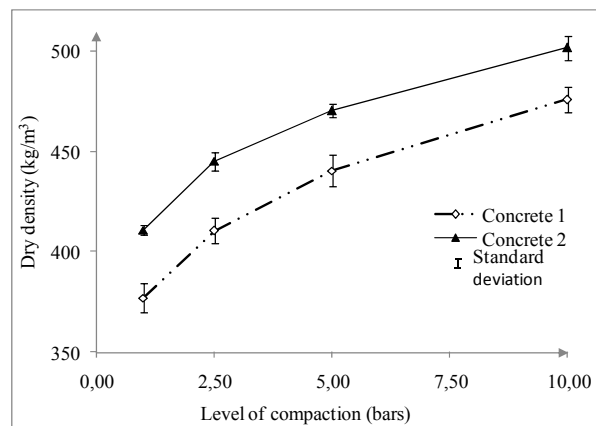


Figure-4. Dry density vs. compaction level for studied mortar.

#### Water absorption (WA)

Figure-5 presents water absorption (WA) versus dry density (DD) for both mortars. It can be seen that WA is inversely proportional to the increase of mortars DD, which is obvious. In fact, low density specimens have more void spaces than dense ones so that more water can be absorbed. Increasing specimen density decreases the



void and improves water absorption characteristics. Thus, the gap of WA is in the same order for these two mortars for a given increase of DD. However, it was observed in Figure-5 that for a same DD, Mortar 2 has lower WA than that of Mortar 1. This fact suggests that the physico-chemical interaction between natural fibers and binder does not modify (or moderately) the microstructure of these mortars. These results match with the previous works [20] which show mortar with a basis of lime is more porous than those with a basis of cement.

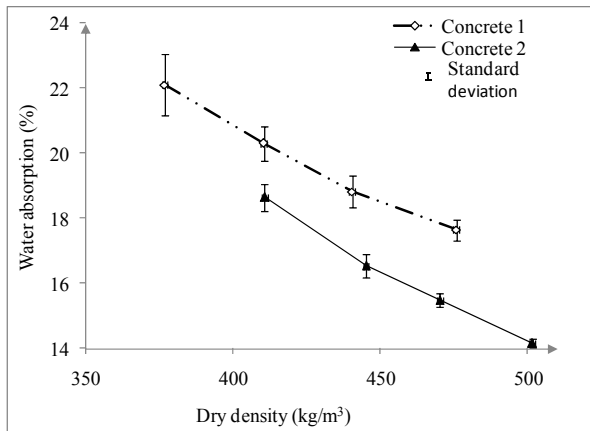


Figure-5. Water absorption vs. dry density for studied specimens.

**Mechanical properties**

Figures 6 and 7 present the compressive and flexural strength versus mortars dry density. These figures show that Mortar 2 has better mechanical properties than those of Mortar 1. The gain of resistance is about 8% to 17% in compression and 18% to 36% in bending. It can be noted that the use of natural fibers in cement composite improved significantly their flexural strength. However, for a same density, the gap between mechanical properties of both mortars is less than 5%. This fact shows that mortar density plays more important role on their mechanical properties than the type of binder. These results match with previous works [29] which indicate the existence of a relationship between compressive strength and density of concrete with a basis of hemp. The relationship obtained was independent to the type of binder. In Figures 8 and 9, it was observed that relationships can also be established between mechanical properties and dry density for both mortars with a basis of coir. These relationships are also independent to the type of binder.

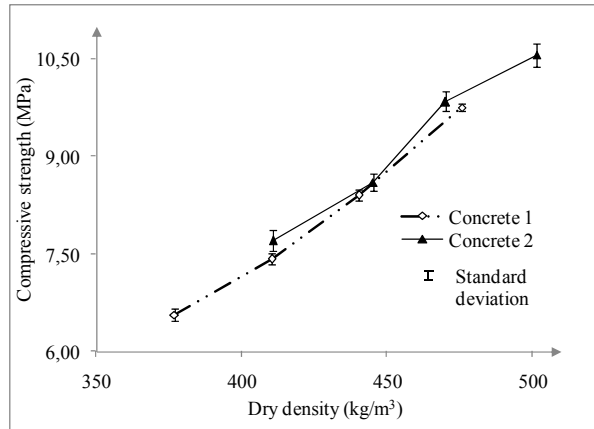


Figure-6. Compressive strength vs. dry density for studied specimens.

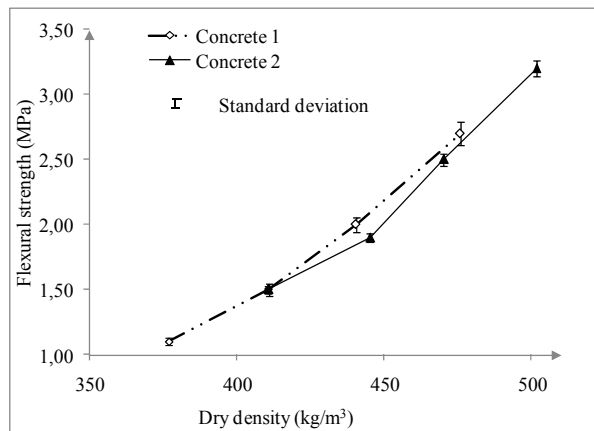


Figure-7. Flexural strength vs. dry density for studied specimens.

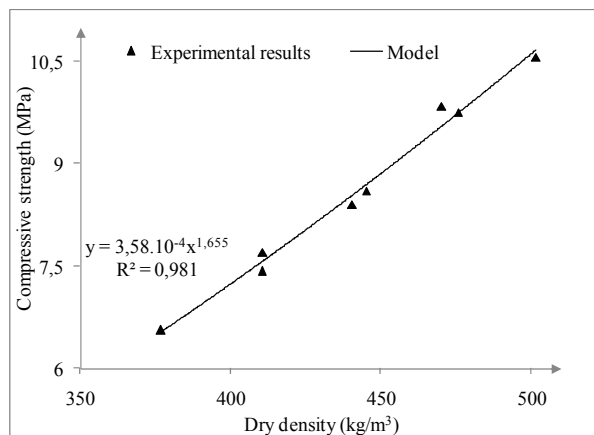
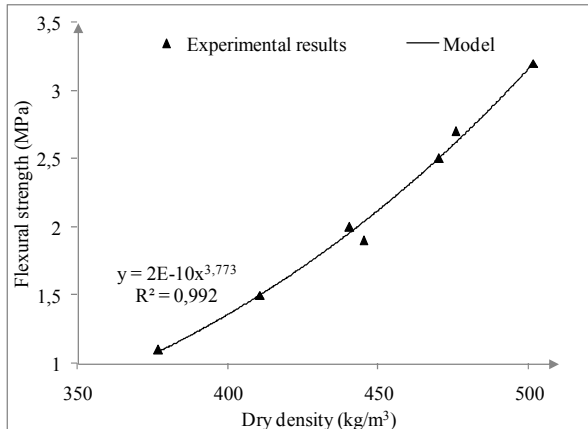


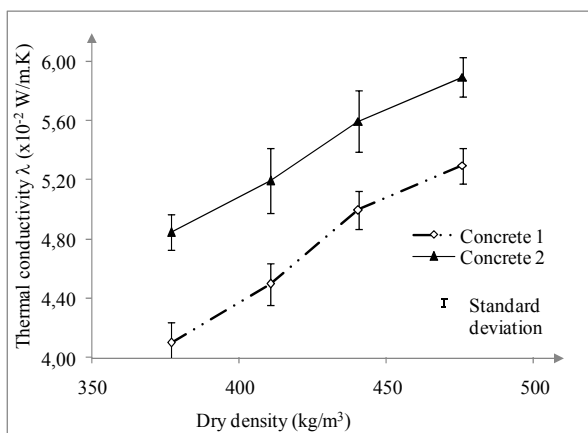
Figure-8. Relationships between compressive strength and dry density for studied specimens.



**Figure-9.** Relationships between flexural strength and dry density for studied specimens.

### Thermal conductivity

The average thermal conductivity of mortars as a function of dry density is plotted in Figure-10. It can be observed a consistent dependence of thermal conductivity on dry density and binder type. Mortar 2 possesses high thermal conductivity compared to Mortar 1 as these are denser as explained in the previous sections. This report shows the effect of material porosity on thermal conductivity. Higher is the water absorption (so the porosity), higher is the thermal conductivity. These results match with those of Gourlay and Arnaud [30] who indicated that the profile of thermal conductivity of concrete made with hemp is strongly dependent to the type of binder. So, for a given thermal conductivity, Mortar 2 has to have a lower density than that of Mortar 1 as shown in Figure-10. However, the values obtained for these two mortars remain lower than that imposed by Ivorian Standard on materials used for thermal insulation ( $\leq 0.065$  W/m.K).



**Figure-10.** Thermal conductivity of mortars vs. dry density for studied specimens.

### CONCLUSIONS

In this study, the physical, mechanical and thermal properties of mortars with coir were analyzed. It was concluded that:

- The type of binder has more important role on thermal conductivity and physical properties of composites with coir;
- Specimens dry density play a main role on mechanical properties of these composites as compared to the type of binder;
- More porous is the material (low density), lower is its thermal conductivity; and
- Relationships are established between mechanical properties and dry density of studied specimens. An equilibrium can be found between physic-mechanical properties of these composites and thermal conductivity according to their destination in the construction.

This work has confirmed the excellent suitability and performance of composites made with coir. That allows a large use of these natural fibers into cementitious materials.

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