Research Journal of Applied Sciences, Engineering and Technology 4(10): 1244-1249, 2012
ISSN: 2040-7467

Submitted: November 21, 2011 Accepted: December 27, 2011 Published: May 15, 2012

Effect of Binder's Type on Physico-Mechanical and Thermal Properties of Mortars with a Basis of Coir

Athanas Konin
Institut National Polytechnique Félix Houphouët-Boigny (INP-HB),
Yamoussoukro, Côte d'Ivoire

Abstract: This study 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 nº1 (Mortar 1) and cement is used for mortar nº2 (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.

Key words: Binder, coir, dry density, mechanical properties, thermal conductivity, 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 (Ledhem *et al*., 2000; Toledo Filho *et al*., 2000; Ghavami, 2002; Bilba *et al*., 2003; Pehanich *et al*., 2004; Khedari *et al*., 2004; Silva *et al*., 2006; Ramakrishna *et al*., 2010). In any case, the results show that the use of natural fibers in cement composite increases flexural strength and offer significant cost reduction as compared to synthetic fibers. Savastano *et al.* (2000) showed that the use of sisal waste as reinforcement in concrete improve the mechanical properties of these concrete. The works of Asasutjarit *et al.* (2007) 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 (2008) 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 (Deschenaux, 2001; Yates, 2002; Bütschi, 2004; Bütschi *et al*., 2004; Collet, 2004; Cerezo, 2005; Evrard, 2005; Elfordy *et al*., 2008) 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 (Ministry of Agriculture and animals resources, internal report 2008). The literature concerning these fibers seems to indicate an insufficient technological valorization, in particular 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

This study was started to carry out at Polytechnical National Institute (INP-HB) of Côte d'Ivoire on July 26th 2010.

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

Fig. 1: Coir crushed and dried used in this study

Table 1: Physical and mechanical characteristics of coir

Density (g/cm^3)	Water absorption (%)	Tensile strenght (Mpa)	Modulus of elasticity (Mpa)
1.20	10	200	6000

Table 2: Physical properties of studied binders

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

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

were afterward crushed and dried in the steam room at a temperature of 50ºC. This operation allows to obtain 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 (Fig. 1). Table 1 indicates the physical and mechanical properties of these fibers.

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.

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.* (2007) 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.

Specimens casting and curing: For each composition, six prismatic specimens 40 mm × 40 mm × 160 mm were cast for the measurements of physical and mechanical properties and six prismatic specimens 270 mm × 270 mm × 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 to obtain mortar with various density. 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 (1994) 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 105ºC until they reached a constant mass (M_d). The water absorption is calculated using the following equation:

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

Dry density test: This property was determined according to the French standard (AFNOR, 2000). The lengths, widths and thickness of dried specimens (M_d) are measured in four points as shown in Fig. 2. So, their respective means values are obtained with which the specimen volume (V) is calculated. The dry density is calculated by the formula:

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

Mechanical tests: The mechanical properties (compression strength and flexural strength) were determined according to French standard (AFNOR, 2001a; AFNOR, 2003) on prismatic specimens 40 mm × 40 mm × 160 mm.

Flexural strength (AFNOR, 2001a): The flexural test based on the three-point loading principle was carried out on each of the specimens. The load is applied at

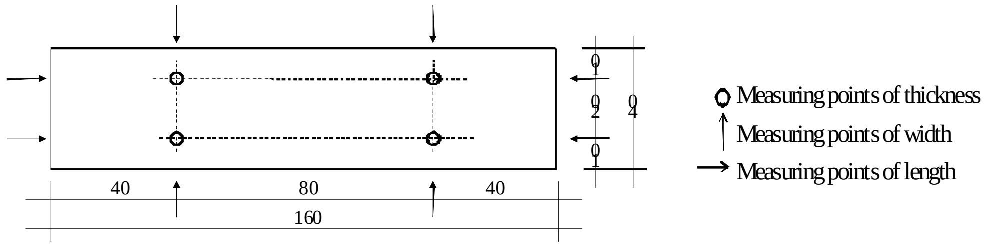

Fig. 2: Points to be measured of length, width and thickness

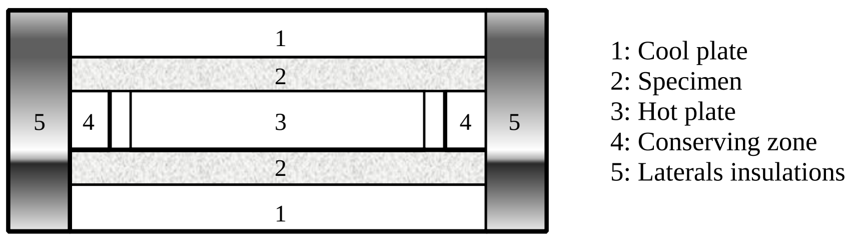

Fig. 3: Setting position of hot plate and cool plate in respect to test samples

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:

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

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

Compression strength (AFNOR, 2003): 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 plat method (AFNOR, 2001b) 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 × 270 mm × 50 mm (obtained after the sawing and the polishing of prismatic specimen 270 mm × 270 mm × 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 plat method.

RESULTS AND DISCUSSION

Physical properties:

Dry density (DD): The average measured values of mortars Dry Density (DD) are plotted against compaction level of sample in Fig. 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 Fig. 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.

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

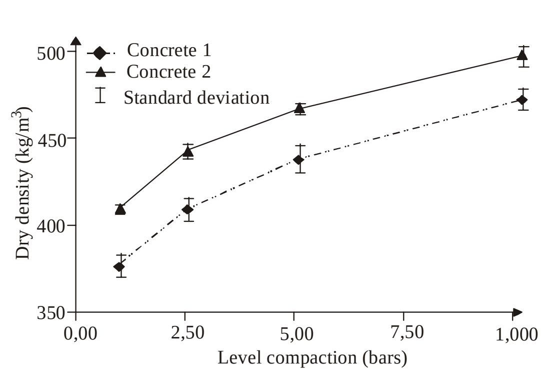

Fig. 4: Dry density vs. compaction level for studied mortar

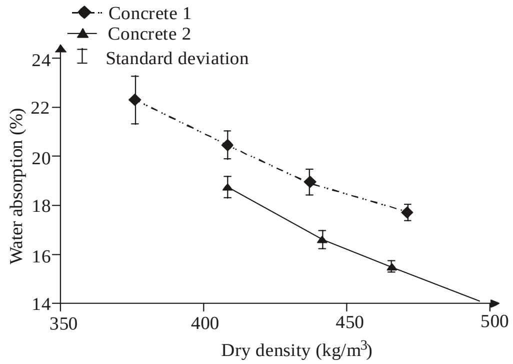

Fig. 5: Water absorption vs. dry density for studied specimens

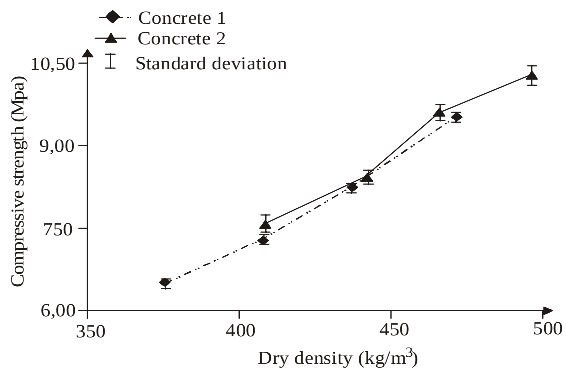

Fig. 6: Compressive strength vs. dry density for studied specimens

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 Fig. 5 that for a same DD, mortar 2 has lower WA than that of mortar 1. This fact suggests that the physic-chemical interaction between natural fibers and binder does not modify (or moderately) the microstructure of these mortars. These results match with the previous works (Evrard, 2005) which show mortar with a basis of lime is more porous than those with a basis of cement.

Mechanical properties: Figure 6 and 7 present the compressive and flexural strength versus mortars dry density. These Figures shows 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 (Mounanga *et al*., 2009) which indicate the existence of

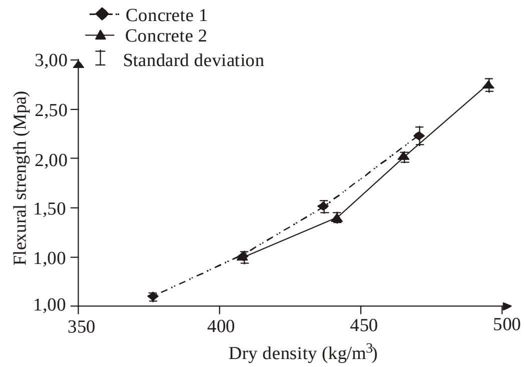

Fig. 7: Flexural strength vs. dry density for studied specimens

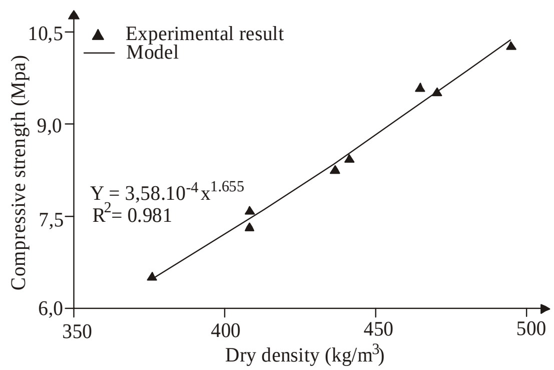

Fig. 8: Relationships between compressive strength and dry density for studied specimen

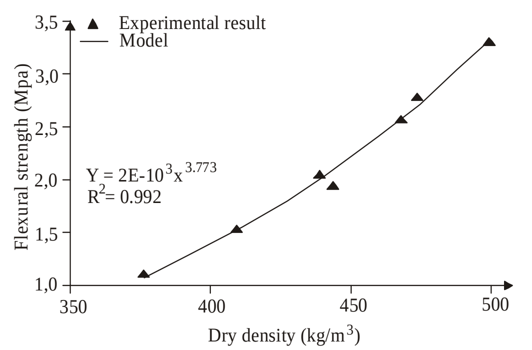

Fig. 9: Relationships between flexural strength and dry density for studied specimens

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 Fig. 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.

Thermal conductivity: The average thermal conductivity of mortars as a function of dry density is plotted in Fig. 10. It can be observed a consistent dependence of

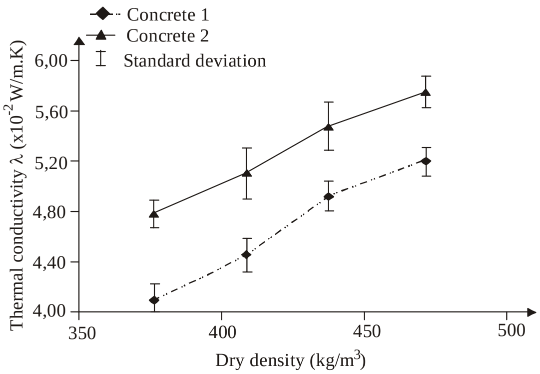

Fig. 10: Thermal conductivity of mortars vs. dry density for studied specimens

thermal conductivity on dry density and binder type. Mortar 2 possess high thermal conductivity compared to mortar 1 as there are more dense 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 (2010) 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 Fig. 10. However, the values obtained for these two mortars remain lower than that imposed by Ivorian Standard on materials used for thermal insulation (≤0.065 W/m.K).

CONCLUSION

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

REFERENCES

AFNOR, 2000. NF EN 772-13, France.

AFNOR, 2001a. NF EN 12390-5, Testing hardened concrete-Part 5: Flexural strength of test specimens, France

AFNOR, 2001b. NF EN 12667, Thermal performance of materials and building products - Determination of thermal resistance by the method of guarded hot plate and heat flow meter methodsproducts of high and medium thermal resistance, France.

AFNOR, 2003. NF EN 12390-5, Testing hardened concrete - Part 3: Compressive strength of test specimens, France.

Asasutjarit, C., J. Hirunlabh, J. Khedari, S. Charoenvai, B. Zeghmati and U. Cheul Shin, 2007. Development of coconut coir-based lightweight cement board. Construction Building Materials, 21: 277-288.

Bilba, K., M.A. Arsene and A. Ouensanga, 2003. Sugar cane bagasse fibre reinforced cement composites. Part I. Influence of the botanical components of bagasse on the setting of bagasse/cement composite, Cement Concrete Composites, 25: 91-96.

Bütschi, P.Y., 2004. Bütschi, P.Y., 2004. Use of hemp for the prefabrication of building elements. Ph.D. Thesis, University of Moncton, Canada.

Bütschi, P.Y., C. Deschenaux, B. Miao and N.K. Srivastava, 2004. Characterization of a masonry composed of elements chipboard hemp Canadian J. Civil Engineering, 31: 526-529.

Cerezo, V., 2005. Mechanical, thermal and acoustic-based material of vegetable particles: Experimental approach and theoretical modeling. Ph.D. Thèsis, Ecole Nationale des Travaux Publics de l'Etat, France.

Collet, F., 2004. Water and thermal characterization of civil engineering materials with low environmental impacts. Ph.D. Thèsis, INSA de Rennes, France.

Deschenaux, C., 2001. Product artisan to industrial prefabrication, the second conference on construction Hemp, Fribourg, Switzerland.

Elfordy, S., F. Lucas, F. Tancret, Y. Scudeller and L. Goudet, 2008. Mechanical and thermal properties of lime and hemp concrete (''hempcrete'') manufactured by a projection process, Construction and Building Materials, 22: 2116-2123.

Evrard, A., 2005. Concrete of lime and hemp: Phenomenaof heat transfer and mass behavior under dynamic loading, Report Master. Catholic University of Leuven, Belgium

Ghavami, K., 2002. Composites with bamboo and vegetable fibres: A contribution to a sustainable development, Proceedings of 3rd International Conference on Non-Conventional Materials Technologies, NOCMAT/3; Construction Publishing House, Vietnam, pp: 54-70.

Gourlay, E. and L. Arnaud, 2010. Hygrothermal behavior of concrete hemp. French Society of Thermal, Conference Proceedings 2010,

Khedari, J., N. Nankongnab, J. Hirunlabh and S. Teekasap, 2004. New low-cost insulation particle boards from mixture of durian peel and coconut coir. Build. Environ., 39: 59-65.

Ledhem, A., R.M. Dheilly, M.L. Benmalek and M. Quéneudec, 2000. Properties of wood based composites formulated with aggregate industry waste. Construct. Build. Mater., 14: 341-350.

Ministry of Agriculture and Animal Resources, 2008. Internal Report at MINAGRA annual Meeting, Abidjan Côte d'Ivoire.

Merzoud, M. and M.F. Habita, 2008. Development of cementbased composite diss *Ampelodesma mauritanica*. Afrique Sci., 4: 231-245.

Mounanga, P., P. Poullain, G. Bastian and P. Glouannec, 2009. Effects of formulation and manufacturing process on the mechanical behavior of different hemp concretes. Proceedings of the 19th French Congress of Mechanics, Marseille, France.

Pehanich, J.L., P.R. Blankenhorn and M.R. Silsbee, 2004. Wood fiber surface treatment level effects on selected mechanical properties of wood fiber-cement composites. Cement Concrete Res., 34: 59-65.

Ramakrishna, G., T. Sundararajan and S. Kothandaraman, 2010. Evaluation of durability of natural fibre reinforced cement mortar composite-A new approach. ARPN J. Eng. Appl. Sci., 5: 44-51.

RILEM, T.C., 1994. RILEM recommendations for the testing and use of construction materials. CPC 11.1: Absorption of water by concrete by immersion, E & FN SPON, pp: 33.

Savastano, J.H., P.G. Warden and R.S.P. Coutts, 2000. Brazilian waste fibres as reinforcement for cement-based composites. Cement Concrete Comp., 22: 379-384.

Silva, F.A., J.A. Melo Filho, R.D. Toledo Filho and E.M.R. Fairbairn, 2006. Mechanical behavior and durability of compression moulded sisal fiber cement mortar laminates (SFCML). Proceeding of 1st International RILEM conference on textile reinforced concrete (ICTRC), Aachen, Allemagne, pp: 171-180.

Toledo Filho, R.D., K. Scrivener, G.L. England and K. Ghavami, 2000. Durability of alkali-sensitive sisal and coconut fibres in cement based composites. Cement Concrete Comp., 6: 127-143.

Yates, T., 2002. Final Report on the Construction of the Hemp House at Haverhill, Report 209-717, Revue 1, Building Research Establishment, United Kingdom.