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Effect of sorption capacity on thermo-mechanical properties of unfired clay bricks

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ABSTRACT

The present work aims at studying the effect of sorption capacity on mechanical and thermal properties of three types of unfired clay bricks. They were industrially produced by the Briqueteries du Nord, a factory located in the north of France. This study has demonstrated that these green materials have a high sorption capacity, compared to other building materials such as concrete block or fired clay bricks. In fact, the moisture content of unfired clay bricks reached 3.5% at 95% of relative humidity. This quality of earthen materials enabled to balance the indoor building climate by adsorbing or releasing moisture according to changes in the relative humidity of the ambient air. This advantage however causes a decrease on compressive strength and thermal resistance of unfired clay bricks. An identification of physico-chemical properties of soils was done in this work to study the sorption capacity and its impact on brick properties.

1. Introduction

In recent years, the interest in earth-based materials within the development of sustainable construction materials has shown a marked increase, in light of their advantages in providing solutions to economic and ecological concerns. Indeed, raw earth is an abundant natural and recyclable resource. It is one of the oldest building materials, used in many different ways around the world for centuries. Approximately 50% of the population of developing countries, the majority of rural populations, and at least 20% of urban populations live in earth homes [14]. Despite its qualities, it has long suffered from lack of recognition, loss of orally-transmitted know-how, and lack of international standardisation [8]. Nevertheless, raw earth has many features that can provide solutions for current energy performance and environmental concerns and is in perfect harmony with the environmentally-friendly construction approach. In fact, earthen construction has become a forward-looking building technology offering multiple advantages. Several studies have been carried out about benefits of earthen construction. It reduces the energy required to manufacture these products, the energy required for construction as well as transportation needs [23,31,33,37,41,6].

Furthermore, the thermal inertia and hygroscopic properties of this material enable promising opportunities for its use in new construction and renovation projects alike. Indeed, earthen construction balances the indoor climate by adsorbing and releasing moisture according to changes in the relative humidity of the air. A level of moisture that is too high or too low affects the thermal performance of buildings, as well as the comfort and the occupants' health. In general, the range of humidity levels recommended for human comfort is between 40 and 60%, as noted by most authors [2,38,39].

Morton et al. [24] showed that the relative humidity inside houses built of unfired earth masonry remains relatively constant at around 60% throughout the year. This is primarily due to the hygroscopic properties of earthen materials, as demonstrated by research conducted by [21,22]. He found that clay coatings adsorb 3 times more water vapour than lime coatings and 10 times more than plaster coatings, passing the air humidity from 50% to 80% at a temperature of 21 °C.

In addition, Padfield [32] tested the effectiveness of different construction materials in lowering the indoor relative humidity, using an experimental environmental chamber. The most efficient materials in terms of hygroscopic behaviour were wood and a mixture of bentonite (a type of montmorillonite clay) and perlite. Furthermore, Lindberg and Akander [19] conducted an experiment in a full room with earthen walls. They concluded that the thermal capacity and water regulation properties reduced the need for ventilation, and consequently lowered energy consumption. Cagnon et al. [5] confirmed the capacity of five earth bricks studied to

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regulate the relative humidity of indoor air. Another study conducted by McGregor et al. [20], indicated that unfired clay masonry has a much higher potential to regulate the indoor humidity than conventional construction materials, through a study conducted on 114 unfired clay masonry samples. Similarly, the hygroscopic qualities of earthen structures were mentioned in several other previous studies [1,11,15,18]. Nevertheless, the effect of this advantage on sustainability of these materials has not been processed before. This work was developed to answer these issues, and to study the impact of soils properties on sorption capacity and its impact on brick performances.

2. Materials and methods

The Briqueteries du Nord company produces three types of unfired clay bricks (A, B and C). The differences between these three types of bricks derived mainly from the fabrication method and the raw material.

2.1. Identification of soils properties

Three different soils were selected in this work. They were used in the manufacture of bricks and were sampled from three quarries of the Briqueteries du Nord company, located in the region of Nord/Pas-de-Calais in France. In fact, the company possesses three production sites. Each production site has its own quarry, which is adjacent to factory production.

The sampling, preparation and treatment method were identical for all three samples in order to enable their comparison. The samples characterisation was intended to identify and determine their main properties.

Identification tests were used to classify samples and understand the impact of their characteristics on development and production of unfired clay bricks, as well as the behaviour of these products in their utilisation in construction.

They were designated by A, B and C. The main physicochemical and geotechnical characterisation tests were performed on three samples according to recommendations and international standards.

2.1.1. Particle size distribution

Particle size distribution was determined using a wet sieving and a sedimentation test, according to standard [40]. It presents one of the main criteria in the selection of the suitable technique for earth construction. Delgado and Guerrero [8] showed a normative review about recommendations for maximum particle size, contents of the different fractions of the soil and nomograms for granularity. The examined techniques were adobe, rammed earth and compressed earth blocks. Fig. 1 showed the grain size distribution for the three selected soils used for brick manufacturing in this study.

The grading curves show that the three samples are primarily fine soils. Indeed, they contain more than 10% fines (particles that pass through a 0.063 mm sieve). Soils A and B contained a significant amount of fine particles accounting for almost 95% of total mass.

According to the distribution of granular fractions defined by standard [29], the results indicated that the sample A consisted primarily of a fraction of 6% clay, 8% fine silt, 20% medium silt, 61% coarse silt and 5% sand. The soil B was a slight variation of the soil A, while the sample C contained a larger quantity of sand (15%).

2.1.2. Plasticity

Atterberg limits were determined using a standard method for measuring liquid and plastic limits described in NF P94-051 [25].

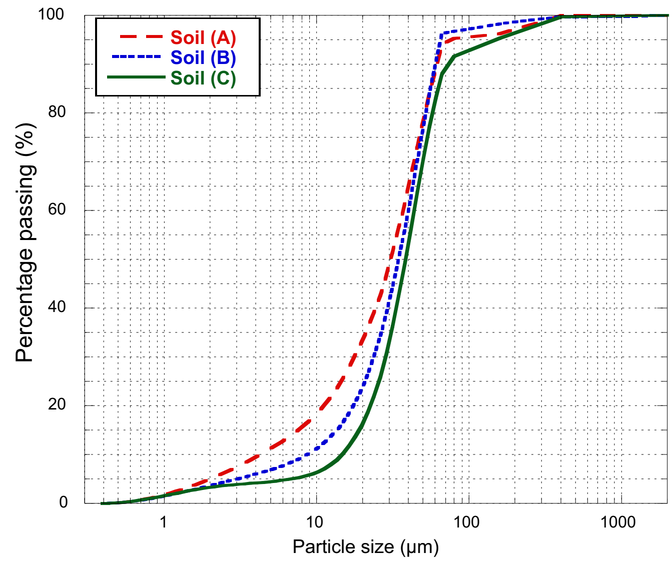

Fig. 1. Particle size distribution of soil samples.

Table 1
Atterberg limits of soil samples.

	Water content w (%)	Liquid limit LL (%)	Plastic limit PL (%)	Plasticity Index (PI=LL−PL) (%)
Soil (A)	24	100	28	72
Soil (B)	32	60	29	31
Soil (C)	21	24	21	3

Table 1 illustrated Atterberg limits obtained for the three different soils (A, B, C). Plasticity index was also reported on this table.

According to results, the three soils had a different behaviour depending on the moisture content. It can be observed that soils (A) and (B) had a high plasticity index value, which classifies them in the category of plastic soils. However, the low plasticity value of the soil (C) (PI=3) indicates that the sample has weak plasticity. The main factors accounting for the behaviour of these soil are their low clay content and the abundance of quartz.

2.1.3. Chemical and mineralogical composition

The mineralogy of different soils was determined using X-Ray Diffraction (XRD) analysis (Fig. 2). The diffractogram of the soil (A) showed that it basically consisted of quartz, kaolinite, aluminosilicates and traces of illite and pyrite. The presence of kaolinite in the sample contributes to good shaping and drying properties of products [17]. In contrast, the mineralogical composition of the soil (B) includes montmorillonite, which causes difficulties during drying due to significant shrinkage and capillary retention.

The soil (C) consisted of a high proportion of quartz resulting in a relatively low plasticity as has been demonstrated, and the occurrence of a texture-layering phenomenon.

The chemical composition of samples was determined by X-Ray Fluorescence (XRF) technique. Mass percentages of oxides and the loss on ignition (LOI) data are presented in Table 2.

The soil (A) contained a significant amount of silica, primarily from the aluminosilicates and the quartz. It also showed a high concentration of Al_2O_3, generally related to clayey silicates, which contributes to good plasticity results [17]. Other trace oxides (Mg, Na, Ti, etc.) have been detected in the chemical analysis of the sample. However, the soil (B) contained a smaller amount of silica and a larger amount of iron oxides, whereas silica and alumina were predominant in the soil (C).