Characterization and mechanical proprieties of soil-vegetal fibre material

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Abstract:
The construction in cob is an ancestral technique that consists to mix soil, vegetable fibres and water. This construction technique exists in the northwest of France and the south of the United Kingdom. This technique enables an optimal using of natural resources with low environmental impact. The aim of this study is to understand the influence of soil and vegetal fibre characteristics on the mechanical strength of different cob formulations. Cob specimens of size 150×150×150 mm, were prepared. Two kinds of soils were used: sandy-silt soil (F2), and a silty soil of medium plasticity (UK6); also, two kinds of vegetal fibres: flax straw and reed. These fibres have different physical and water absorption characteristics. Then, the mechanical strength of cob materials under simple compression was determined.
The results reveal that the F2 soil-flax straw mix (2%) provides a higher mechanical strength than the other mix (1.95 MPa). The lowest behavior is obtained for the F2 soil-flax straw mix (1.45 MPa). The water content and the density are the parameters influencing the mechanical strength of the cob materials.

Key words: Soil, Vegetal fibre, Cob, Water absorption, Mechanical strength.

1. Introduction

European Buildings consume most of the energy, responsible for 40% of final energy consumption (DIXIT *et al.*, 2010). The use of local materials, as well as the absence of hydraulic cement, reduces the consumption of grey energy due to the construction. For a long time, people have built their houses and cities using earth material, it is one of the most used materials in construction. We have different construction methods using earth: daub, rammed earth, compressed earth blocks (CEB), and cob. The cob method is very common in northwestern of France and southern of the United Kingdom, the cob construction consists to mix soil, vegetal fibre, and water. It allows a use of natural resources with low environmental impact (MOREL *et al.*, 2001). The cob material has been less studied than other earthen construction methods (WEISMANN & BRYCE, 2010; LEBAS *et al.*, 2007) and often confused with these methods. Recent studies

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(RÖHLEN & ZIEGERT, 2013; MICCOLI *et al.*, 2014) have presented answers to some problems about the cob technique, by comparison with other methods of earth construction. The objective of this study is to investigate the influence of soil and vegetal fibre characteristics on the compressive strength of the cob material composed of different mixes.

2. Materials and methods

2.1 Methods of material characterization

For the characterization of the materials, two different soils were selected for this study: F2 from Normandy (France), and UK6 from England, see Figure 1. The properties of the soils were determined by particle size analysis (XP P94-041, 1995), the Atterberg limit test (NF EN ISO 17892-12, 2018), the methylene blue test (NF P94-068, 1998), and the Proctor test (NF P94-093, 2014). The vegetal fibre used in this study is natural flax straw and reed as shown in Figure.1. Regarding the characterization of vegetal fibres, the parameters determined are the absolute density and the water absorption coefficient.

Figure 1. UK6 and F2 soils (left) - vegetal fibres (right).

2.2 Cob formulation and mechanical behavior

Specimens of size 150×150×150 mm were prepared with different formulations, mixing F2 soils with 2% and 4% flax straw and reed, the formulations are presented in Table 1. In a tank, the mix of the soils and fibres was done manually, by adding the necessary water until a homogeneous mix was obtained. The cubic molds were filled layer by layer, with manual compaction rod.

Table 1. Formulations of cob mixes

Mixes	*Samples number*	*Fibre type*	*Fibre (%)*	*Water content (%)*
F2 A2	6	Flax straw	2	20
F2 R2	6	Reed	2	20
F2 A4	6	Flax straw	4	20
F2 R4	6	Reed	4	20

After two weeks of drying in ambient air and humidity (T°C= 20°C± 2 and RH= 50% ±5), the specimens were removed from the molds and the uniaxial compression test was carried out on the F2 A2% and F2 R2% specimen mixes, using an IGM press with a capacity of 250 kN. The press is force-controlled, with an imposed loading rate of 0.01 kN/s. The stress-strain curve was obtained using a 20 mm displacement sensor.

3. Results

3.1 Material characterization

The soil F2 has a high fine fraction (≈ 81 %), but Soil UK6 present higher clay activity than soil F2 (Figure 2 and Tables 2 and 3). The soils used were classified according to the LCPC-USCS classification, soil F2 is sandy-silt soil, and UK6 is silt soil.

Table 2. Granulometric properties of soils.

Soil	D_{max} (mm)	Passing to 2 mm (%)	Ø < 80µm (%)
F2	31.5	89.13	7.84
UK6	20.0	92.78	81.79

According to proctor test, the maximum dry densities of soils F2 and UK6 range: 1700 to 1800 kg/m^3, see Figure 3 and Table 3.

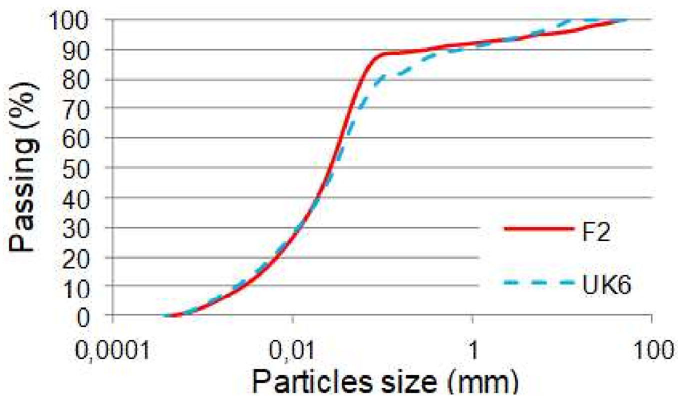

Figure 2. Soil particle size distribution, (PHUNG, 2018).

Table 3. Properties of soils.

Soils	Nature of soil (USCS classification)	VBs (g/100g)	W_L (%)	W_P (%)	I_P (%)	W_{OPN} (%)	Dry density (kg/m^3)
F2	Sandy-silt soil	0,55	31	20,5	10,5	14	1827
UK6	Silt soil	2,62	30,2	23	7,2	18	1708

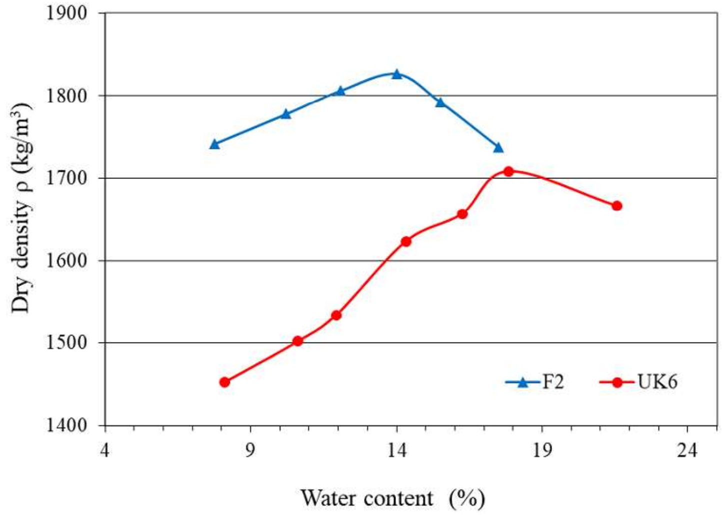

Figure 3. Proctor curves, (PHUNG, 2018).

The natural flax straw and reed fibres were used in the mixes (see Figure 1). The raw fibres were cut, within 5 to 10 cm for flax straw and 4 to 6 cm for reed. The water absorption capacity was performed according to RILEM protocol (AMZIANE *et al.,* 2017). After 24 hours, Flax straw shows water absorption of 431 % and reed 203 %, see Figure 4. The water absorption capacity of fibres influences the mix properties at fresh state (absorption of available water), and at long term (hygrometric balance). The maximum tensile strength is 112 MPa (PHUNG, 2018). The average absolute density of flaw straw is 1360 kg/m^3 and 1300 kg/m^3 for reed.

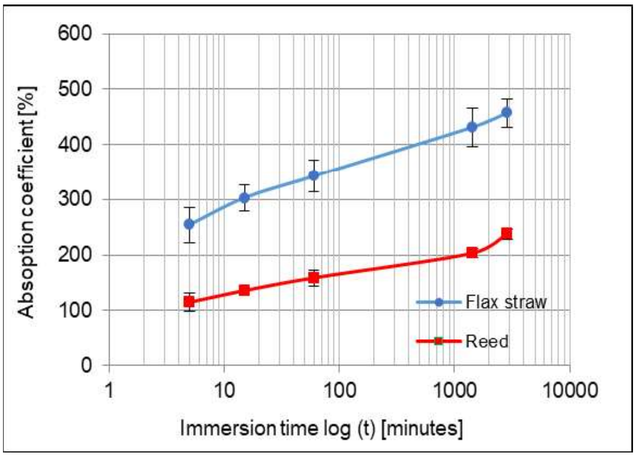

Figure 4. Absorption coefficient curve of fibres.

3.2 Compressive strength

The results of the compressive strength show that the F2-flax straw soil mixture (2%), with a yield stress of 1.95 MPa (see Figure 5a), provides a higher mechanical strength than the F2-Reed mixture (2%), which presents an elastic and then plastic behavior, see Figure 5b.

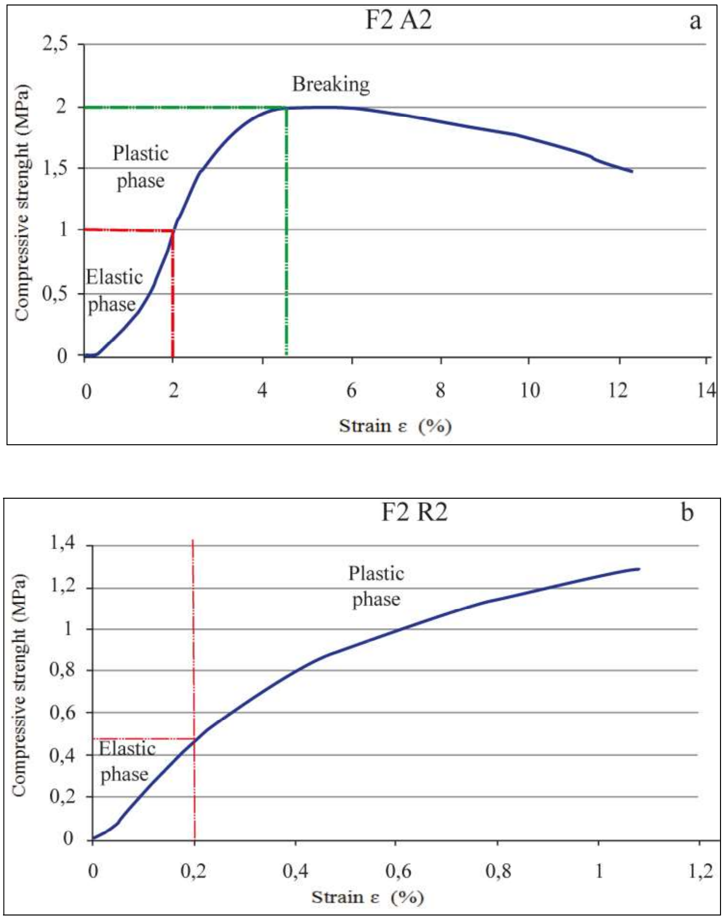

Figure 5. Stress-strain curve of mixes F2 A2 (a) and F2 R2 (b).

4. Conclusions and perspective

In this paper, the main factor that impacts the mechanical strength of the cob mixes is the initial water content (20 %). The physical characteristics of the vegetal fibres are water absorption, and density. The soil type has a role in the connection between the components of the soil-fibre mixes. The soil mixed with water allows better covering of the fibre area, creating a great soil-fibre connection. Based on the analysis of the results obtained from the characterization of the different soils, vegetal fibres, and the compression strength tests of the F2-flax straw (2%) and F2-reed (2%) mixes, this work contributed to observe that:

- When the initial water content decreases, the mechanical strength increases.
- The cohesion of the soil-vegetal fibre mixes is related to the clay activity of the soil.
- The flax straw in the soil makes good compressive strength and the reed increases the ductility of the material.

Other mixes will be made and tested with compressive strength, with the UK6 soil and the same 2% and 4% vegetal fibres.

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