Analysis of the response of flax concrete submitted to intense hygrothermal solicitations

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ABSTRACT Flax concrete, an alternative material to hemp concrete, has been studied several times because of its interesting hygrothermal and acoustic performances. However, the durability of this material is questionable and there is a lack of knowledge about it. This paper aims to study the evolution of the compressive strength of flax concrete after accelerated ageing. Two different ageing protocols were carried out: immersion-drying (ageing 1) and immersion-freezing-drying (ageing 2). The results show that the compressive strength is initially affected by the length of the flax shiv. The reference concrete has a higher strength with larger flax shiv, while the impact of ageing is greater compared to concrete with medium flax shiv. After intensive hygrothermal solicitations, the compressive strengths decreased, the reduction is higher for ageing 2 compared to ageing 1, which is explained by the thermal solicitations in addition to the hygric one.

Keywords flax shiv, concrete, accelerated ageing, compressive strength

I. INTRODUCTION

Nowadays, bio-based materials are widely studied. The researches show a low environmental impact, thermal and acoustic insulating qualities (Bennai et al., 2018). In addition, they have excellent moisture buffering capacity (MBV) to maintain the quality of indoor air. Nevertheless, there is a lack of knowledge about their durability properties. The problem of swelling-shrinkage at the cement-aggregate plant interface and fungal growth are the most important criteria for assessing the degradation of these materials. These properties are directly related to the evolution of the hygrothermal properties. Recent researches use different aging protocols (Marceau et al., 2017; Page et al., 2017). The protocol that seems the most reliable to qualify durability can take several months. To address this problem, two accelerated aging protocols have been applied in this paper. Because of the abundance of flax shives, generated by an important annual production in France (Dupre, 2014), the durability of flax concrete was studied by monitoring mechanical strength after immersion-drying and immersion-freezing-drying protocols.

II. MATERIALS AND METHODS

A. Materials

The bio-aggregate used in this paper is flax shiv. Two samples were evaluated: large flax shiv (LF) and medium flax shiv (MF). The samples are presented in Fig.1.

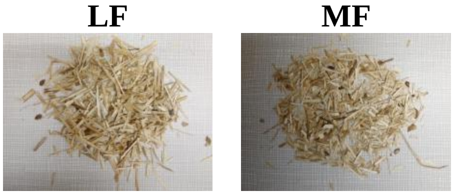

FIGURE 1. Large and Medium flax shives

Flax concrete are manufactured with Tradical PF70 lime, a mixture of air lime, hydraulic lime and pozzolan (Chamoin, 2013), according to the procedure defined in the construction rules (Association Construire en chanvre, 2012). The water/binder ratio is W/B=1.45, and the aggregate/binder ratio is A/B=0.42. The flax concretes from medium and large flax shives are noted MFC and LFC, respectively. MFC and LFC have initial bulk densities of 589 kg/m^3 and 643 kg/m^3, respectively.

B. Aggregate characterization

The physical characterization of plant particles (bulk density, dust content and particle size distribution) was realized according to RILEM Technical-Committee 236 – BBM (Bio Based Building Materials) recommendations (Amziane et al., 2017).

C. Experimental methods on flax concrete

After mixing, the flax concretes were cast in 100 x 100 x 400 mm^3 moulds. The samples were then cut in samples of 50 x 50 x 50 mm^3. The three ageing protocols are detailed in Table 1. Compressive strength tests were conducted after 58 days of ageing protocols on 3 samples each, with a loading speed of 5 mm/min.

TABLE 1. Description of Reference and Ageing protocols

Protocols	Descriptions
Reference	• Storage at 20±2°C - 50±10%RH for 58 days
Ageing 1: immersion/Drying	• Storage at 20±2°C - 50±10%RH for 28 days • Cycles of ageing for 30 days (5 cycles): ○ Immersion in demineralized water for 48h ; ○ Drying in oven at 50°C for 72h ;
Ageing 2: Immersion/Freeze /Drying	• Storage at 20±2°C - 50±10%RH for 28 days • Cycles of ageing for 30 days (6 cycles): ○ Immersion in demineralized water for 48h ; ○ Freeze at -18° C ; ○ Drying in oven at 50°C for 72h ;

III. RESULTS

A. Aggregate properties

The image analysis method allows plotting the cumulative area of particles as a function of three morphological parameters: the Equivalent Area Diameter (EAD), based on a particle of circular cross section, and major and minor axes, i.e. length and width as presented in (Nozahic and Amziane, 2012). These size distributions of the flax shives are plotted on Fig. 2. The two shives have similar minor axes, so the difference between the two is mainly relative to their length. Thus, the circularity is higher for medium flax shiv MF. The two flax shives have not so much particles with a very low circularity (0-0.1) compared in (Lagouin et al., 2019) and as in (Bourdot et al., 2019). Because of their size, large particles LF have lower bulk density (Table 2.). The LF bulk density is in accordance with other study (Rahim et al., 2015).

TABLE 2. Physical properties of flax shives

Flax shiv	Bulk density (kg/m³)	Dust content (%)
MF	121.9 ± 1.8	3.4
LF	95.3 ± 1.4	1.2

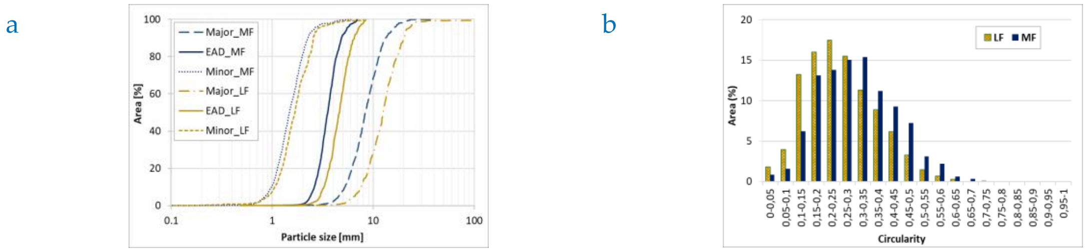

FIGURE 2. Particle size distribution (a) and circularity (b) of the two flax shives

B. Mechanical properties after accelerating ageing

Results of the compressive strength of flax concretes are shown in Fig. 3. Results show that compressive strength is affected by the length of flax shiv at reference state. Concrete reference has higher strength with larger flax shiv (LFC) compared to concrete with medium flax shiv (MFC). Thus, considering this reference state, LFC seems more interesting. After intensive hygrothermal solicitations, the compressive strengths decreased. After Ageing 1, the reductions are of 23% and 34% compared to reference values for MFC and LFC, respectively. The reduction is higher for ageing 2 compared to ageing 1. After Ageing 2, the reductions are of 42% and 63% compared to reference values for MFC and LFC, respectively. That can be explained by thermal solicitation in addition to hygric solicitation. Finally, after ageing 2, the mechanical properties are similar for the two flax concretes. Consequently, the environment is important to take into account as for standard building materials to characterize the durability of bio based materials.

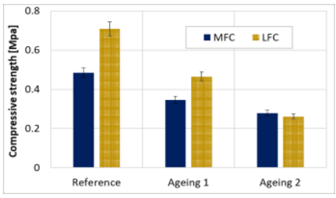

FIGURE 3. Compressive strength of flax concrete at a reference state and after ageing protocols at 58 days

IV. CONCLUSION

In this study, two flax shives were characterized before concrete confection. Flax concrete were studied through the monitoring of mechanical resistance after three ageing storage. The results showed that the physical properties of flax shives influence the compressive strength at reference state. The mechanical properties of concretes decrease proportionally to the increasing intensity of hygrothermal solicitations. The reduction is higher for ageing 2 compared to ageing 1. That can be explained by thermal solicitation in addition to hygric solicitation. Finally, after ageing 2, the mechanical properties are similar for the two flax concretes whereas LFC seems more interesting at reference state according to this parameter.

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