Study of mechanical properties and microstructure of mortars based on oyster shell powder

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RESUME This paper aims at valorise oyster shell co-products in mortars. Oyster shell are calcareous porous materials. Consequently, their use could improve the thermal insulation properties of the concrete. In order to qualify the impact of oyster shell on mortar properties, the influence of the incorporation of oyster shell powder (OS) as a substitution of sand was studied. Mortars made by replacing a part of the sand (0 – 30 – 60 %wt) by shell powder were characterized in terms of mechanical properties and microstructure. The study revealed that the substitution of sand with OS induce a decrease of their mechanical properties. This effect can be explain by higher porosity of 56% increase with 60% OS substitution compared to the reference. Open porosity measurements are confirmed by the reduction of the wave velocity by ultrasonic measurement and microscopic observations revealing smaller pores for shell based materials.

Mots-clefs Oyster shell powder, mortar, mechanical properties, porosity

I. INTRODUCTION

Fishing and shellfish farming activities produce an annual production of about 200,000 tonnes of shells in France generating thousands of tons of seashell by-products (Nguyen et al., 2017). Consequently, these activities generate large quantities of wastes. The valorisation of different shells has already been studied (Nguyen et al., 2017). The use of sea-shell co-products can provide two clear advantages; the first one is the consumption of wastes that that would otherwise be dispersed in the environment, and the second one, even more relevant, is the reduction of the depletion of natural resources needed for building materials production. In this context, oyster shells was studied in previous papers for application as insulating load-bearing concrete (Bourdot et al., 2019; Schifano et al., 2019). These previous studies have highlighted the increased porosity of mortars and concretes. The aim of this study is therefore to increase this effect by reducing the particle size of the shell co-products in order to improve insulating properties. Thus, mortars based on oyster shell powder were made to be characterized in mechanical terms and more particularly in terms of microstructure.

II. MATERIALS AND METHODS

A. Materials

For the production of tested mortars, the following materials were used :

- CEM 1 Portland cement 52.5 N
- 0/2 mm sand (Fig. 1), which is a natural siliceous sand
- Oyster shell powder noted OS, obtained by crushing oyster shells into a powder of 0/0.4 mm (Fig. 1). It has a bulk density of 803 kg.m^{-3} and an absolute density of 2575 kg.m^{-3}. It presents an intraparticular porosity inducing an absorption coefficient of 30.2% according to (AFNOR NF EN 1097-6, 2014).

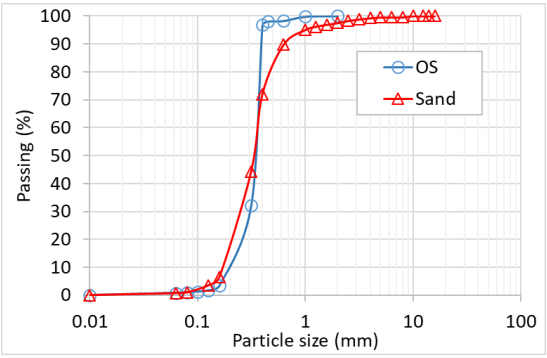

FIGURE 1. Particle size distribution

B. Mortar mixes

Mortar specimens have been prepared according to the procedure described in (AFNOR NF EN 196-1, 2006) with $W_{efficient}/C = 0.45$. Three amounts of oyster shell powder 0% – 30% - 60 % by weight have been substituted to sand (because of similar absolute densities), the mortars are noted PSMI_0, PSMI_30 and PSMI_60, respectively. The total water content has been increased to take into account the absorption of the oyster shell powder.

C. Methods

The mortar specimens were tested at 7 and 28 days of endogenous curing. Flexural and compressive strength test was performed according to (AFNOR NF EN 196-1, 2006). Open porosity was obtained according to (AFNOR NF P18-459, 2010) with 24h under vacuum before immersion and 48h under vacuum for immersion step. Microscopic observations were carried visually and with a KEYENCE VH-Z100R optical microscope. The wave velocity was calculated using ultrasonic apparatus. The different apparatus are presented in Fig. 2.

FIGURE 2. Porosity system, Microscope and Ultrasonic apparatus

III. RESULTS

Flexural and compressive strengths of the hardened mortars at 7 and 28 days are shown in Fig. 3. Flexural and compressive strength declined compared to the PMI_0 from 9% and 21% for PSMI_30 and, 23% and 48%PSMI_60, respectively. At high percentage of substitution, the amount of water required for the mortar mix might lead to an increase of porosity that makes the mortar specimens less resistant. Nevertheless, flexural and compressive strength at 28 days are always interesting for mortar applications with hygrothermal properties.

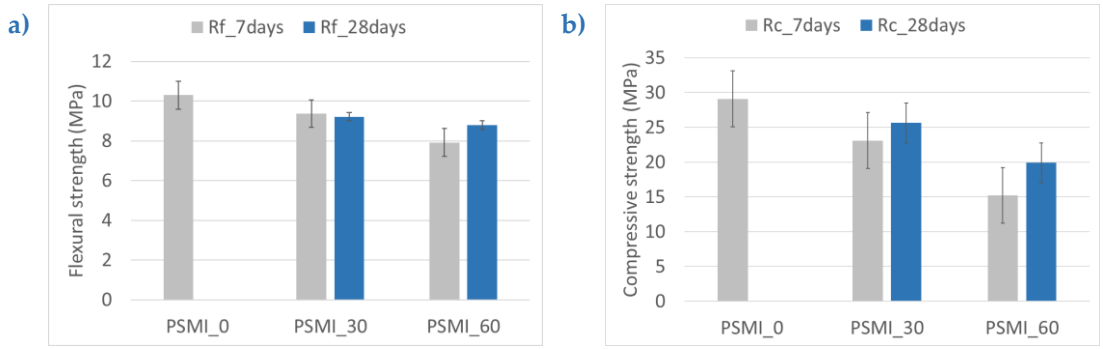

FIGURE 3. Flexural (a) and compressive (b) strength of the tested mortars at 7 and 28 days

As expected, the open porosity of mortars increase by the increasing rate of oyster shell powder. The results are presented in Fig. 4a. The increase is of 13% for PSMI_30 and, 56% for PSMI_60 compared to PSMI_0. These measurements are in adequacy with ultrasonic wave velocity even if the velocity decrease at 28 days is more proportional to the increasing rate of OS than the reduction at 7 days (Fig. 4b).

Qualitative microscopic observations are given in Fig. 5. The figures show a clear modification of the mortar's poral space. According to open porosity measurement, it increases with the OS substitution proportion. However, at the eye, the mortar PSMI_60 seems denser. This is explain by a smaller size of pores as measured under microscope. This property could induce modification in diffusion process and mass transfer in the materials. It could be so interesting to study this part and the stabilisation of probable chemical elements introduced by the presence of oyster shell in future research.

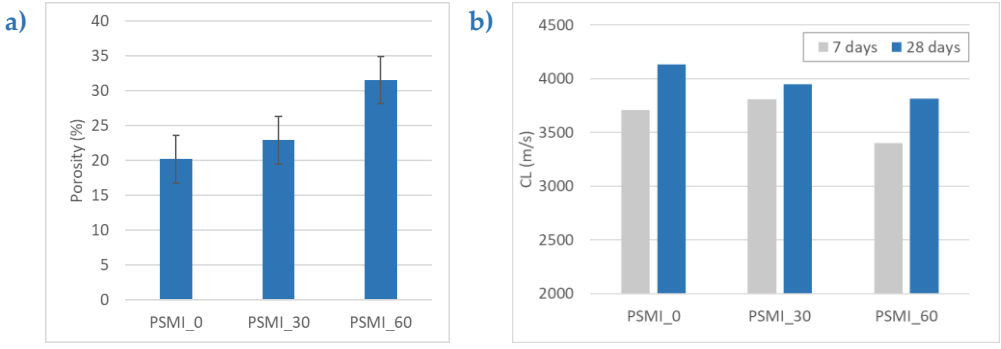

FIGURE 4. Porosity at 28 days (a) Ultrasonic wave velocity of mortars (b)

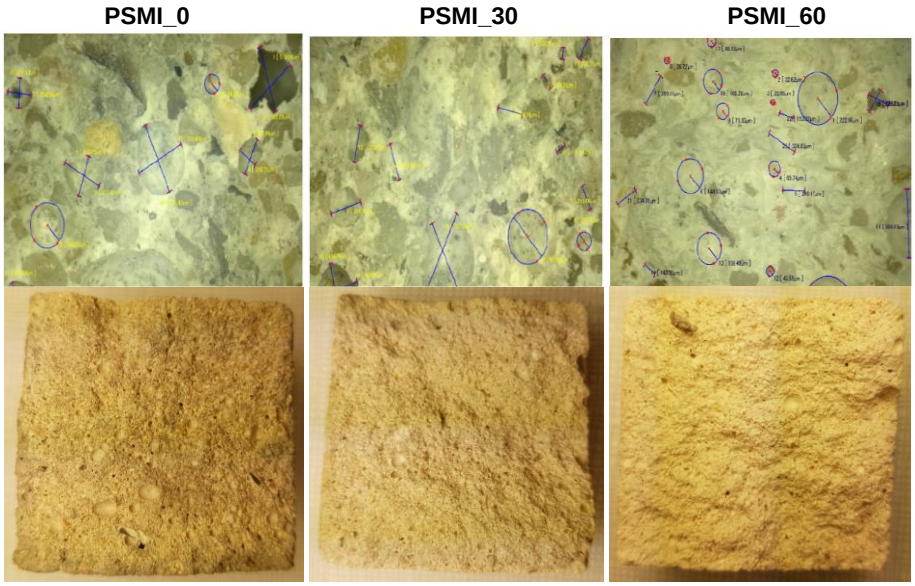

FIGURE 5. Microscopic observations of mortars at 0%, 30% and 60% of oyster shell powder.

IV. CONCLUSION

In this study, mortars based on powders of oyster shell co-products were studied through the monitoring of mechanical resistance and characterization of the microstructure. The results showed that the mechanical properties of the mortars decrease proportionally to the increasing rate of sea-shell co-products in the presence of CEM I. The study of the microstructure helped to explain the decrease in mechanical resistances with 56% increase in open porosity. The increase in pore content was confirmed by ultrasonic method. Microscopic observations showed that the porosity certainly increases in the presence of shells but with smaller pores. This porosity could be of interest with regard to thermal insulation and moisture vapour capacity, and consequently hygrothermal regulation.

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