VALORISATION OF CLAYEY SEDIMENTS IN THE FORM OF CELLULAR CONCRETES. INFLUENCE OF THE ADDITION OF FIBRES ON DIMENSIONAL AND WEIGHT VARIATIONS

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ABSTRACT

Previous studies conducted in the laboratory have shown the potential value of hemoglobin in the production of construction materials and added as air entraining agent to create a regular cellular structure without consumption of energy other than that of mixing.

In addition, sand deposits exploited in France are more and more clayey and tailings represent volumes becoming increasingly important. They are currently poorly valued and most often are rejected in the settling ponds. The proposal was to transform them into cellular concretes with a foaming agent, hemoglobin, which combines a very good foaming capacity with the possibility of giving, by mixing, a very stable foam in adequate conditions.

However, the presence of clay particles leads to important weight and dimensional changes which may affect the durability of the material. The power of mechanical consolidation of fibres and especially their action on dimensional change is known. This work is therefore interested in the impact of the addition of fibres of polypropylene in the material. It turns out that their presence is beneficial with regard to dimensional variations in the material, which suggests a better durability.

Keywords: Clayey Sediments, Proteinic Foaming, Polypropylene Fibres, Drying Shrinkage, Extreme Dimensional and Weight Variations

INTRODUCTION

Sand deposits exploited in France are more and more clayey and tailings represent larger volumes therefore representing an increasing shortfall. They are currently poorly valued and most often are rejected in the settling ponds. The objective here is to transform them in the form of cellular concretes by addition of haemoglobin, which combines a very good foaming capacity with the possibility of giving, by mixing, a very stable foam in adequate conditions [1].

Previous works have shown that the presence of protein in a clayey matrix can favorably impact its properties and behaviour [2]. Reference [3] reported that hemoglobin was at the origin of strong bonds between the clayey particles. Reference [4] showed that the affinity of a surface of clay for a protein can be very important. Reference [5] has optimised the foaming of clay-cement pastes using hemoglobin, based on rheological criteria and preserving the mechanical characteristics needed for use as insulating and insulating and bearing material. However, the presence of clay particles leads to important weight and dimensional changes which may affect the durability of the material. The power of mechanical consolidation of fibres and especially their action on dimensional change is known. This work is therefore interested in the impact of the addition of polypropylene fibres on dimensional and weight variations.

RAW MATERIALS AND EXPERIMENTAL TECHNIQUES

Raw Materials

Clayey sludge comes from the quarry of Landelles to about 50 km west of Rennes (Brittany, France). After dehydration, we obtain a clayey material consisting almost entirely of kaolinite with a density of 2650 kg/m^3 and little plastic. After drying, crushing and sifting, it gets a granular material which the grading curve obtained by laser granulometry is given in figure 1.

Cement is a CPA - CEM I 52.5 (NF EN 197-1) its grading curve is given in Fig.1.

Hemoglobin is produced by the company Vapran from bovine blood, and is marketed under the name of Vepro 95 BHF. Obtained by fractionation and thermally stabilized, it comes in the form of powder.

Fibres used are length 12 mm polypropylene fibres

The mixing water is drinking water, pH 7.75 at a temperature of 20 ± 2 °C. In accordance with the recommendations of previous study [5], it is added with soda 0.0385 mole/l to optimize foaming.

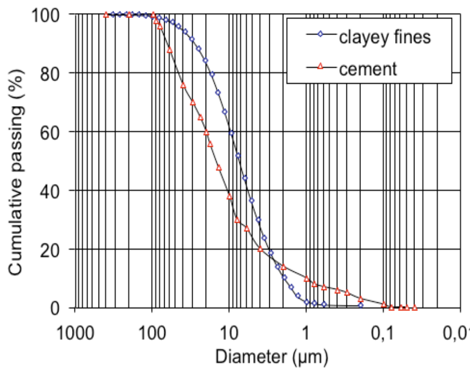


Fig.1 Size distribution of clay filler and cement

Development Of Materials

Reference [5] optimised the proportions of the various components: E/A = 0. 7; C/W = 0. 35; H/A= 0.021 with E = water mixing with soda, A =clayey sediments, C = cement, H = hemoglobin. Mixing is done first in dry state, for 1 minute at speeds of 60 revolutions per minute. The amount of water is then added while mixing at the same speed for 1 minute. After having scraped the walls of the mixing bowl, hemoglobin powder is added carefully so as to not waste material and mixing is extended to fast speed of 120 rounds per minute for 2 minutes. The fibres are added at the end of mixing.

After pouring the material fresh in the moulds, the whole is placed in a conservation room with humidity of 98% and a temperature of 20°C, for a duration of 24 hours. After demoulding, conservation is carried out either in a conservation room at HR=98%, or controlled atmosphere following test.

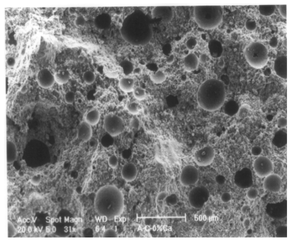
Figure 2 shows the appearance of the hardened material with addition of protein during the mixing, with or without addition of polypropylene fibres. Reference [5] has shown that the introduction of fibres of polypropylene in the proportions of the study has little impact on compressive strength and workability of the fresh material and this behavior has been confirmed by the authors of this work.

Furthermore, analysis of the species present in the material showed that hemoglobin does not interfere with the hydration of cement. Hydrated calcium silicates also indeed grow in both cases [6].

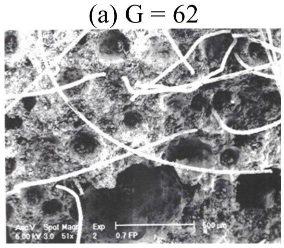
Characterization Techniques

The dimensional changes are determined on 40x40x160 mm^3 testing sample equipped at their ends with metal studs through an electronic retractometre to appreciate variations in 10^{-3} mm. At the same time, the weight changes were determined using a scale with a precision of 0. 01 g.

The microstructure study was conducted through a scanning electronic microscope PHILIPS FEG XL 30. Samples were coated with a thin layer of gold to make them conductor (Fig.2).



(a) G = 62



(b) G = 51

Fig. 2 Matrix clay-cement with foaming (a) SEM and without fibres, (b) with foaming and fibres (0.7% polypropylene)

EXPERIMENTAL RESULTS AND ANALYSIS

The dimensional variations were determined during the drying stage and hygrothermal conditions simulating climatic conditions.

Dimensional Variations During The Drying Stage

After demoulding, samples are placed in a 65% relative humidity and 20 °C atmosphere to study the dimensional and weight variations in the normal conditions of use.

Reference [7] has shown that protein lightening reduced dimensional and weight variations through the role of consolidation by the protein film highlighted by previous works in the study of the mechanical properties [5]. However, they remain important due to the presence of clay. So, it was interesting to evaluate the impact of the presence of polypropylene fibres on the dimensional and weight variations of the lightweight material. The results are compiled in tables 1 and 2 .

It is noted that shrinkage varies from 5.9 mm/m for lightened material (without addition) to 5.02

mm/m for 0.7% fibres added. The action of these additions was felt as well in the kinetics of variations as on the maximum observed at 28 days. Changes due to shrinkage continue during the first fortnight of conservation, and then tend to stabilize.

Table 1 Evolution of the dimensional variations of the lightened material versus the time for different percentages of polypropylene.

	Polypropylene fibres (%)			
Time (days)	0	0.2	0.5	0.7
0	0	0	0	0
1	0.71	0.46	0.37	0.29
7	2.71	2.24	2.07	1.89
14	4.87	4.12	3.99	3.79
21	5.64	5.32	5.14	4.95
28	5.9	5.42	5.18	5.02

The variation of the masses shows a growing tendency during the first half shrinkag with a tendency to stabilize up to 28 days. It corresponds to the loss of water by the clay matrix during drying. For the addition of polypropylene fibres, a slight increase of weight variations is found.

After 28 days, weight variation varies from 22.5% (without addition of polypropylene fibres) to 24.94% for adding 0.7% fibres. The kinetics of drying is also faster with the additions of polypropylene.

Table 2 Evolution of weight variations versus time for different percentages of polypropylene after lightening

	Polypropylene fibres (%)			
Time (days)	0	0.2	0.5	0.7
0	0	0	0	0
1	2.54	4.87	5.34	6.05
7	15.35	16.75	17.74	18.46
14	21.09	22.85	23.54	24.08
21	22.47	23.74	24.58	24.81
28	22.50	23.78	24.62	24.94

It would be noted that the impact of polypropylene fibres on dimensional changes complies with commonly observed phenomena. .

Dimensional And Weight Variations In Variable Climatic Environment.

In service, materials can undergo extreme situations due to climatic variations, is why dimensional and weight variations corresponding to variations between dry and saturated states are generally determined (EDV - EWV). The dry state corresponds to an exposure to a hot and dry climate and the saturated state to a prolonged contact with liquid water. However, if, in a normal situation, the material is subjected to more or less moist environments, it is not generally in contact for a long time with liquid water, except in the event of flooding or infiltration. Three types of cycles are therefore be examined (Table 3).

Table 3 Stages of the various cycles

Cycle	Nature of the cycle
1	Passage of a very hot dry state (60°C) to a prolonged contact with liquid water (20°C)
2	Passage of a very hot dry state (60°C) to a 'normal' atmosphere (HR= 60%, 20°C) and then maintained in a very humid atmosphere (HR= 98%, 20°C)
3	Passage of a very hot dry state (60°C) to a very humid atmosphere (HR=98%, 20°C)

A material subjected to variable climatic environments will undergo alternations of swelling and shrinkage that can affect durability. An example of cycle 1 is presented below (Fig.3) in the case of a not lightened material. It shall designate by Extreme dimensional variation the dimensional gap between the dry state dry and saturated state that corresponds to the transition from the dry state to a contact with liquid water.

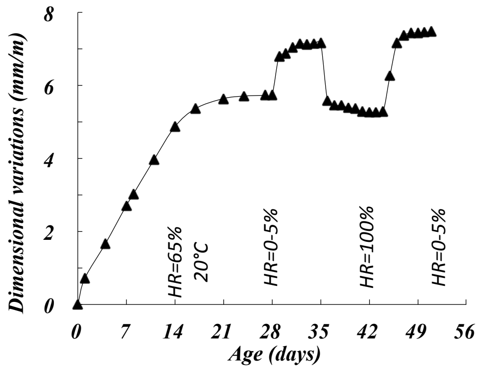


Figure 3 Example of evolution of dimensional changes versus time for different states of conservation in the cycle 1-case of a not lightened material

A comparison between the Extreme Dimensional Variations (EDV) and Extreme Weight Variations (EWV) of lightened and not lightened material is shown on table 4.

The influence of the addition of polypropylene fibres has been illustrated for cycles 2 and 3.

Table 4 Extreme dimensional and weight changes for the material with and without lightenin

Cycle 1	not lightened	lightened
EDV (mm/m)	2.33	1.88
EWV (%)	6.82	5.75

The percentage of fibres is one that fits the best mechanical resistance. The EDV and EWV values are reported in the table 5.

Table 5 Extreme dimensional and weight changes for the studied cycles

	Lightweight and without fibres	Lightened 0% fibres	Lightened 0.7 % fibres
Cycle 2			
EDV	1.92	1.88	1.24
EWV	2.32	3.58	3.7
Cycle 3			
EDV	1.92	1.88	0.93
EWV	2.32	3.58	3.87

It is thus seen that the lightening as well as the addition of polypropylene fibres significantly reduces the dimensional variations. This decrease of dimensional changes is probably due to the phenomenon of stiffening of the material by the presence of the protein film on pore surface and fibers [6] [8]. These dimensional changes are accompanied by an increase in the loss of mass when the proportion of polypropylene fibres increases. The impact of the fibres of polypropylene on the dimensional and weight variations is notable whatever the studied cycle. The results obtained are reinforced by those concerning adsorption which showed that the presence of polypropylene fibres reduces capillary adsorption. However, the brutal transition from dry to very wet state reduces these variations due most likely shorter exposure to moisture in the air. It should be noted in this regard that the authors have shown that the presence of polypropylene fibres does not reduce the water diffusivity of the material but instead seems to increase the sensitivity of the material to the resumption of water. This phenomenon could be linked to the reduction of the presence of pores in the matrix (14.5% entrained air in the matrix instead 17%) thus reducing the tortuosity and facilitating the progression of the front of imbibition [6]. Porosity created by air entrainment is not affected by water transfers. Only are concerned the capillary pores of the gel matrix and the spaces between the sheets of clay.

CONCLUSION

The presence of moisture and its transfer can significantly influence the durability and performances of the materials. In addition, the presence of clay, even stabilized with cement, can fear a sensitivity to water resulting in particularly by dimensional changes.

In order to enjoy the interactions of the material with water and the impact of the addition of polypropylene fibres, studies have been conducted in varying environments and in contact with liquid water. They show that the addition of polypropylene fibres is beneficial in regards to extreme dimensional and weight changes as to the drying shrinkage of clay-cement composite lightened by protein foaming. This suggests a better durability.

This new type of material can therefore represent an attractive solution to enhance both agri-food industry and aggregates industry waste.

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