Valorization of Beet Pulps Issued from Sugar Extraction in Cementitious Matrices. Effect of Original Pulp State

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Abstract. Beet sugar manufacturing generates considerable flows of co products among which pulps. At the end of the extraction of sugar, they are rich in water and hard to preserve. They generally undergo an over pressing bringing the proportion of dry matter about 30% and then can be thermally dehydrated and granulated. Over pressed pulps, still wet, keeps very well when sheltered from air. Granulated dried pulps occupy little volume and keep well away from moisture. However, the drying consumes significant amounts of energy. Currently, the main outlet of the pulps is animal feed. But, besides the decline in livestock production connected to the new sugar regulation and to energy problems make indispensable, to maintain the turnover of beet farmhouses, to find new applications to beet pulps. Different ways have been explored. The advantage of a valorization in the form of aggregates in cementitious matrix materials is the use of the co product in its entirety and the improving of the bio based character of construction. However, because energy problems, it was useful to determine the best way to introduce the beet pulp in the process. A comparative study was therefore conducted from over pressed pulps and pellets of the same origin.
It appears, at the optimum water content, that mechanical and thermal behavior are little influenced by the original pulp state whatever cement/pulp proportion used. This allows envisaging a valorization of these pulps without going through the stage of thermal dehydration. The results were also compared to those obtained with already marketed ligno cellulosic aggregates. It appears that beet pulps lead to competitive materials.

1 Introduction

A reduction in structures weight leads inevitably to general savings in construction. This explains the interest in lightweight aggregate concretes. However, if they can be used as structural materials, they are more suited to the development of insulating or bearing and insulating materials. Among the lightweight aggregate a special place should be reserved for ligno cellulosic aggregates because of their renewability, and worldwide, studies are made to enhance plant co-products in cementitious composites. Resources as different than the hemp, flax shives, bamboo, bagasse from sugar, sisal fiber, wood of eucalyptus, coproducts of the exploitation of bananas and other plants, were the subject of recent studies. Include without being exhaustive [1 à18].

France is the world's leading producer of sugar beet. Beet sugar manufacturing generates considerable flows of co products among which pulps. At the end of the extraction of sugar, they are rich in water and hard to preserve. They generally undergo an over pressing bringing the proportion of dry matter about 30% and then can be thermally dehydrated and granulated. Over pressed pulps, still wet, keeps very well when sheltered from air. Granulated dried pulps occupy little volume and keep well away from moisture. However, the drying consumes significant amounts of energy. Currently, the main outlet of the pulps is animal feed. But, besides the decline in livestock production connected to the new sugar regulation and to energy problems make indispensable, to maintain the turnover of beet farmhouses, to find new applications to beet pulps.

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2 Materials and experimental techniques

Cement is a Portland cement type CPA-CEMI 52,5 which come up to NF EN197-1 standard.

Water is the local area network one

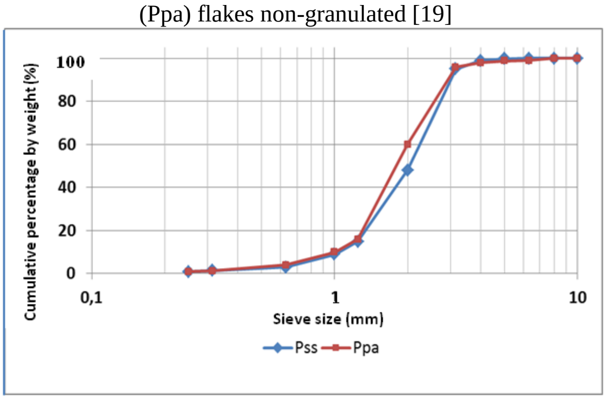
Beet pulps are collected after sugar extraction then suppressed for a partial dehydration. After that, it is thermally dehydrated, dried on and agglomerated in pellets to facilitate stocking and transport. To be used in materials, pellets have to be transformed in flakes by immersion during about 2 hours and dried at 100 °C till constant weight to avoid pellets swelling and breaking up during mixing on contact with water. Fig. 1 gives the appearance at the naked eye for the different stages and Fig. 2 shows granular distribution.

Fig.1. Appearance at naked eye for the different stages: (a) before granulation, (b) pellets, (c) flakes after breaking up [19]

For flakes obtained after immersion and drying, organic matter rate is evaluated to 92.33 % and the mineral fraction to 7.67%. In the case of not granulated pulp flakes, organic matter rate is evaluated to 93.16 % and is therefore closed to the one of flakes issued from pellets breaking up.

Flakes collected before granulation or after pellets breaking up show an uneven and rough surface that allows envisaging a good adhesion to cement matrix. Figure 3 shows SEM view of flakes obtained, after drying, from pellets breaking up (a) and not granulated (b).

Fig. 2. Granular distribution: (Pss) flakes after breaking up, (Ppa) flakes non-granulated [19]



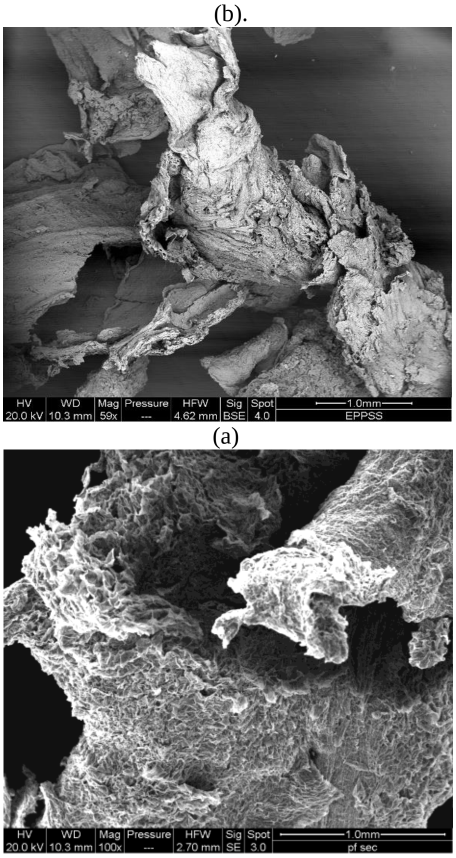
Pulps characteristics are given in Table 1. Saturation rate is defined in equation 1.

$$w\ \% = (Ms - M_0)/M_0 \quad (1)$$

where Ms is weight at saturation and M_0 dry matter weight.

After 1mn immersion, water absorption reaches 60 to 70% of maximal absorption. Saturation is reached after about 60mn.

Fig. 3. Scanning electronmicrographs of flakes obtained, after drying, from pellets breaking up (a) and not granulated. (b).



(a)

(b).

Table 1 Physical and hydrous characteristics of beet pulps (after immersion and drying in the case of pellets) before and after treatment

		Flakes from pellets breaking up	non granulated flakes
Bulk density (kg/m^3)	Apparent	163	199
	Real	285	333
	Absolute	529	609
Hydrous characteristics	Saturation rate (%)	300	250
	Saturation time (mn)	60	60
	Swelling (%)	310	230

It can be noted that increasing in apparent volume of saturated pulps squares with absorbed water volume that agrees with Rowel and Youngs works [20] who pointed out that as water diffuse towards internal part of cell wall, the volume increases almost proportionally to water volume absorbed till saturation point of the cell. With regard to absorption rate, it was noted that there is no difference between flakes submitted to granulation or not. However, not granulated flakes have saturation rate and swelling less considerable than flakes issued from pellets.

Saturated pulps are drained and then spun at slow speed to eliminate water adsorbed on the surface. They are mixed with cement, at slow speed, in a standard mixing machine for mortar. The mixing water is then gradually added during the mixing according to the procedure laid down by the standard.

3 Experimental results and analysis

3.1 Optimization of water added to the mixing content

It is based on the optimization of the density of the hardened material. The amount of water is expressed in relation to the amount of saturated pulp + cement. The table 2 summarizes the results.

Table. 2. Optimal percentage of water added to the tempering with saturated pulp and corresponding densities

	Beet/cement	H_2O opt (%)	Density opt (kg/m^3)
not granulated flakes	1	17,5	1400
	1,5	13	1100
	2	11	950
	3	9	625
Flakes from pellets breaking up	1	14	140
	1,5	12	1100
	2	9	925
	3	7,5	725

As expected, the optimal moisture content added during the mixing stage decreases as the proportion of saturated pulp increase. The curves representing the variation of density on the basis of water added during the mixing stage show a maximum relatively wide that is important for a subsequent manufacture. Indeed, an uncertainty about the water content will not have effect if it remains within this maximum. If the water content to achieve optimum density differ slightly depending on the type of pulp used, this difference is even less significant that the proportion of pulp increases. In addition, the values of the corresponding densities are little affected by the nature of pulp and seem only to depend on the pulp/cement proportions. It may be noted that the density at optimum water content ranges from 1400 kg/m^3, for a pulp/cement ratio equal to 1 to about 700 kg/m^3 for a pulp-to-cement ratio equal to 3 it is to say a ratio of densities near 1/2 when the proportion of pulp is multiplied by 3.

3.2 Influence of the nature of the pulp on the beginning of setting time

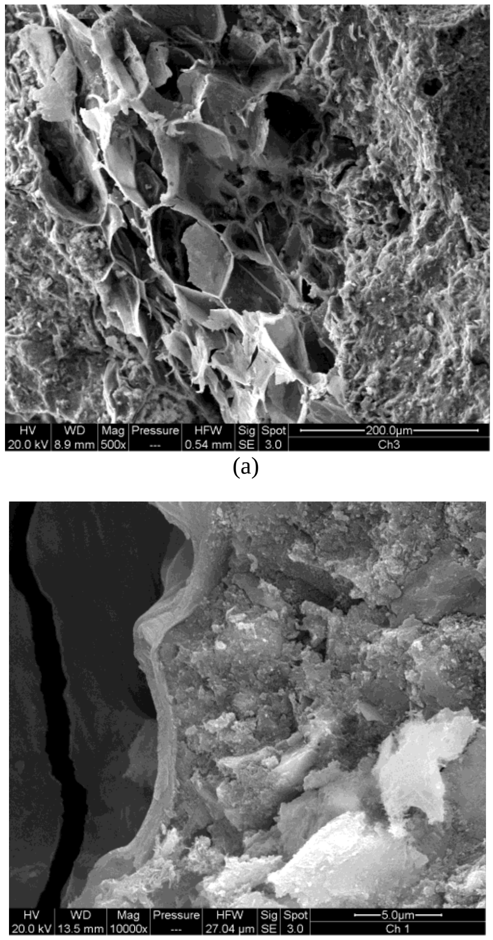
Setting time was determined for different mixtures to the optimum water content. The results in table 3 show that, for a same weight content in beet pulp, the state of pulp before saturation has no influence on the setting time.

Table 3 Setting time according to beet pulps ratio

	Not granulated flakes			Flakes from pellets breaking up			Normal mortar
Flakes/ cement (in weight)	1	1,5	3	1	1,5	3	
Setting time	30 mn	40 mn	36 h	40 mn	40 mn	36 h	2h 15mn

3.3 Influence of the nature of the pulp on the mechanical characteristics

Fig 2. Aspect of pulp in the matrix**:** (a) magnification = 500, (b) magnification = 10000



(a)

(b)

Table. 4. Mechanical characteristics for different mixtures to the optimum water content

	B/C	Rc(MPa)	Rf (MPa)
not granulated flakes	1	13	3
	1,5	8	2,8
	3	1,8	0,7
Flakes from pellets breaking up	1	17	3,5
	1,5	8,5	2,9
	3	2,8	0,9

Table 4 brings together the values of mechanical characteristics for different mixtures studied at optimum water content.

It can be seen that the mechanical resistance values remain the same order of magnitude whatever the original state of the pulp, the values obtained with the disaggregated pellets being however slightly higher. The values obtained are, despite the absence of treatment of the matrix or of the plant fraction, competitive with those obtained with aggregates already marketed as the Agreslith C that is to say Rc ranging from 2.5 to 7.8 MPa for densities between 600 and 1400 kg/m^3. It can then be highlighted the adhesion matrix/pulp as shown in the figure 2. Indeed, even at high magnification there was no gap between the wall of the pulp and the interfacial transition zone.

3.4 Influence of the nature of the pulp on the dimensional variations

The values obtained for drying shrinkage are important as for ligno cellulosic concretes in general [21, 22]. Table 5 shows that they increase when the B/C ratio increases and are slightly higher when the pulps are derived from the breaking up of pellets.

Table. 5. Dimensional variations for different levels of pulp

	Beet/cement (in weight)	Drying shrinkage	Extremal dimensional variations
Not granulated flakes	1	3,8	4,1
	1,5	6,2	3,1
	3	8,2	2,0
Flakes from pellets breaking up	1	4,8	3,6
	1,5	7,5	3,9
	3	9,8	2,9

Lignocellulosic concretes generally have sensitivity to climatic variations which results in reversible dimensional changes. This is why it is usually determined dimensional changes between extreme states, i.e. between extreme climate conditions (dry atmosphere and liquid water contact). In the case of beet-pulp, it appears relatively small dimensional changes compared to the values usually obtained for lignocellulosic concretes. They remain much lower than those of the drying shrinkage for high rates of pulp and decreases significantly when the B/C ratio increases.

3.5 Influence of the nature of the pulp on the thermal conductivity

Thermal conductivities do not appear to depend on the nature of the pulp. As expected, table 6 shows that they decrease with the increase of the plant fraction in the cementitious composites. They remain in the range of the values obtained for cellular concretes ($0.16 < \lambda < 0,33$W/m.K to $400 < \rho < 800$ kg/m^3) while being slightly lower.

Good thermal conductivities are explained by the maintenance of the cellular nature of pulp in the composite (figure 2) which could be observed whatever the proportion of pulp in the cementitious matrix.

Table. 6. Thermal conductivity for different levels of beet pulp

	Beet/cement (in weight)	Thermal conductivity (W/m/K)
non granulated flakes	1	0,37
	1,5	0,32
	3	0,16
Flakes from pellets breaking up	1	0,37
	1,5	0,33
	3	0,17

4 Conclusion

The cementitious composites incorporating beet pulp can be an interesting opportunity for the sugar extraction co-products. Indeed comparisons with other types of lightweight concretes showed that despite a lack of treatment of the plant fraction or matrix, the results obtained for the mechanical and thermal characteristics were competitive. The environmental problem was to know if a costly step from the energy point of view, i.e. the pelletizing, may be avoided. The results obtained by incorporation of pulps, granulated or not, into the cementitious paste show little difference in the characteristics of composites. This suggests that the valorisation of these pulps can be done without going through the stage of thermal dehydration and granulation.

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