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ELABORATION AND CHARACTERIZATION OF CEMENTITIOUS COMPOSITES WITH DISS FIBRES AS MASONRY UNITS

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Abstract

The Diss (*Ampelodesmos mauritanicus*, family of Poaceae) is a very luxuriant plant growing in wild state around the Mediterranean North Africa and dry areas of Greece and Spain. It grows in France, mainly, in the departments of the Alpes-Maritimes, the Var, the South of Corsica and Herault. In the past, it was used as building material because of its mechanical and hydrous qualities.The purpose of this research is to determine the effects of treated and untreated of the vegetables fibres.The use of such a fibrous plant in a cementitious matrix leads to lightweight materials with very attractive tensile behavior that can be used as advantageous infill in structures subjected to seismic effects. The basic vegetable material, very fibrous and siliceous, presents indeed an absorption of about 90% that would be corrected by using optimum water/cement ratio. Moreover, we noted a considerable retardation of setting and very low resistances during the composite tests with natural crushed diss, despite the fact that the fibres have considerable tensile strength about 100 MPa. To improve the fibres contribution in cementitious composites, we have carried out a treatment by boiling the fibres of diss to extract the substances responsible for the bad connection between fibres and the cement paste. The Diss fibres were also prewetted before introduction into the mixer. This treatment will eliminate a loss in workability due rapid absorption, and improve mechanical properties. Thus diss fibres reinforcements in cimentitious composites having encouraging mechanical properties, which may expand the applicability of these composites as masonry units in constructions.

Keywords: Diss; ampelodesma mauritanica; lignocellulosic; fibres; composites; prewetted; infill; masonry

1. Introduction

Since ancient times, fibres have been used to reinforce brittle materials; straw was used to reinforce sun-baked bricks. In modern times, a wide range of engineering materials

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incorporate fibres to enhance composites properties. In a previous study of Diss in cimentitious composites, Merzoud and Habita [1] reported that boiling water treatments improves the performance of the composite thanks to the elimination of the water-soluble compounds. The optimum composite composition in term of volume of diss fibres: cement: water ratio is therefore 4:1:0.7.

Shrive [1] shows that fibre reinforced polymers (FRPs) constitute a class of advanced composite materials which have the potential to change significantly masonry rehabilitation and strengthening. Their light weight means that they do not alter the mass of a structure and thus the inertial forces from seismic excitation and open an exciting new line of possibilities as infill in structures submitted to seismic actions.

Lo et al. [3] studied the microstructure of the Interfacial Transition Zone (ITZ) between lightweight aggregate and the cement paste. They suggested that the improvements in the ITZ microstructure were probably due to the absorption of water by the lightweight aggregate from the past. They confirmed that when the pre-wetting time of the aggregate increased, the strength and workability of the concrete increase too.

Asasutjarit et al. [4] used residues of coconut coir as aggregate in lightweight cements boards (CCB). It was concluded about this research, that for the production of coconut coir cement boards, it’s required to boil and wash the coir, and this pretreatment enhanced some of the physical and mechanical properties of coir fibres.

Demirbas and Aslan [5] showed that the addition of lignocellulosic elements like the ground hazelnut shell, wood and waste of tea is negative on the mechanical properties of cement. They showed that the compressive strengths and to the inflection decrease with the increase in the proportions of these mixtures. The experimental results showed that the lignocellulosic material specimen cannot be used like composite in the industry of the concrete. The hazelnut shells and the back wood can be used like partial or additive replacement with Portland cement. On the other hand the use of waste of tea like addition or aggregate is never allowed. Savastano et al. [6] used residues of sisal, banana tree and eucalyptus as reinforcement in cementing composites. The composites thus obtained present acceptable mechanical performance. Aamar Daya [7] used dust from the stripping of flax fibres as aggregate in a composite with cementing matrix. His works showed that the treatment of flax dust with boiled water improves considerably the mechanical resistance of the composites.

Elsharief [8] studied the effect of dry and prewetted lightweight aggregates on the microstructure and durability of mortar. And it appears to be only a small difference in the microstructure of the interfacial transition zone (ITZ) between dry and prewetted lightweight aggregate mortars. Peschard [9] confirmed that cement hydration retard increases with high polysaccharides to cement weight ratio (P/C).

However, the presence of a plant within a cementitious matrix gives rise to a concern increased sensitivity to water, in addition to other mechanical disorders, and thermal disperformance (Piementa et al. [10]). The strongly alkaline environment developed by the hydration of cement causes hydrolysis reactions and solubilises some compounds, as sugars, hemicelluloses and pectins (Simatupang [11]). Garci Juenger et al. [12] and Bilba et al. [13] have studied the influence of sugars on the setting of the cementitious composites and showed that sugar retards cement hydration.

The existing literature concerning diss fibres seems to indicate that there is a lack of technological valorisation of this plant, in particular in the field of cementitious composites. This plant species exists in wild state and in large quantity around the Mediterranean countries, and its fibrous nature seems to offer as much qualities to the cementitious composites as the traditional fibres. However many studies [13] reported a great oil accumulation in the vegetable matter, which is likely to interact with the cementing paste. This is why further treatments must be carried out.

In order to reduce the retardation of setting observed during the mechanical tests on composites containing crushed natural Diss [1], we have carried a thermal treatment of fibres by boiling (extraction of the soluble substances). And to improve the bonding at the fibres-cement, the diss fibres are prewetted to minimise the effect aggregate absorption on the hydration water content at the aggregate/cement interface zone during the hydration process.

2. Materials and Experimental Methods

2.1 Materials

The diss material as aggregate in our composites, has been crushed with a 10 mm mesh Retsch type cutting mill. The different stages of study of crushed diss fibres are as follows:

- Tr1: fibres of natural diss, dried in the oven at 50°C
- Tr2: fibres boiled in water and washed, then dried in the oven at 50°C
- Tr3: fibres prewetted before mixing

During the treatment with boiling water, we have preserved the boiled water residue to study its influence on the setting of cement.

The cement used was a CPA type CEMI 52.5 (standard EN 196-1).

2.2 Experimental methods

The morphology of various fibres was studied by scanning electron micrographs (SEM).
The images have been taken with the following devices:

- video microscope (Controlab®) VH-Z25 provided with a zoom 25x to 175x,
- an annular light with cold lighting appliance, nondiffuse lighting, semi-shaving, positioned on the video microscope, allowing the description of the relief of the samples,
- a system of vision VIDEOMET (Controlab®) allowing digitalisation and visualisation of images.

The test specimens made with various fibres, treated or not, are preserved during 28 days in a storage room (R.H = 95%, t= 20°C), and then dried at 50°C until a constant mass before testing.

Mechanical tests were carried out, according to the European standard EN 196-1, on prismatic specimens 4×4×16 cm. The tensile strengths were measured using a three points flexural test bench, equipped with a system of acquisition. The compression tests were carried out on the half retained from flexural testing, with a standard machine Perrier 68.7.

The dynamic elastic modulus was determined by sonic method, standard E0641 Ultrasonic Tester, on prismatic specimens 4x4x16 cm. The principle is based on the determination of the propagation velocity of the ultrasonic waves (celerity) in the composite. The dynamic elastic modulus is given by the relation:

$$Ed = \rho C_L^2 \quad (1)$$

With Ed = dynamic elastic modulus (MPa), ρ = Bulk density of the specimen (kg/m^3), C_L= celerity of wave (m/s)

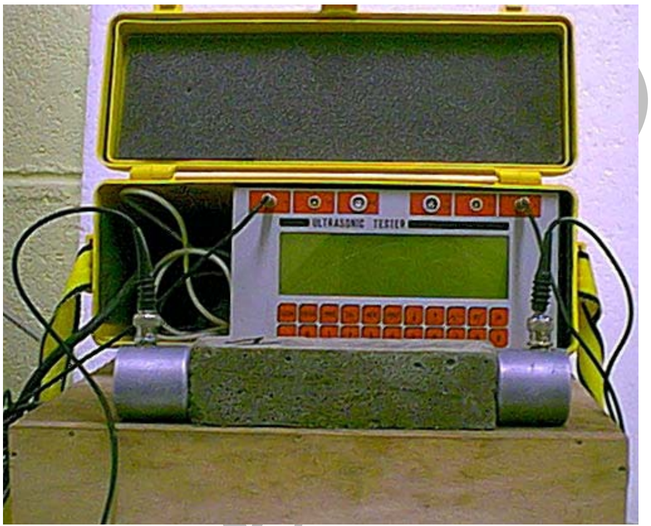

Figure 1. Standard E0641 Ultrasonic test setup

2.3 Formulations

The Water/Cement ratio (W/C) was fixed at 0.7 for all formulations [1]. The Diss fibres/cement ratio was set to 4:1 (by volume). For prewetted fibres, including saturation water was adjusted to obtain a water/cement ratio of 0.7. Table 1 summarises the obtained experimental results of water absorption percentage for various treatments applied to fibres.

Table 1. Water absorption percentage for various treatments applied to diss fibres

Vegetable fibres	% of Water absorption
Tr1	92. 38
Tr2	90. 00
Tr3	0.00

3. Results and Discussions

3.1 Dynamic elastic modulus

The average values obtained during this work for the dynamic elastic modulus and bulk density are represented in Figure 2 for various formulations.

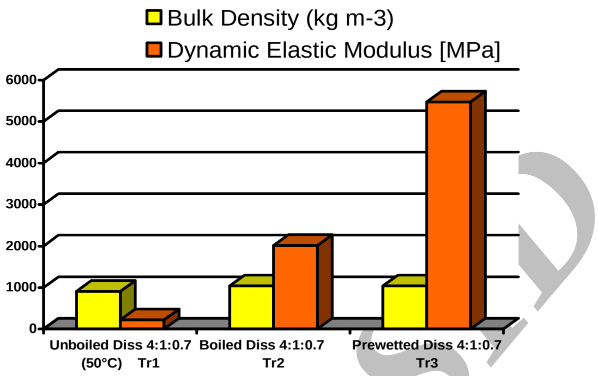

Figure 2. Dynamic elastic modulus and bulk densities for various treatments

It can be observed that for the same bulk, the dynamic elastic modulus values are very low for the untreated diss fibre composites. This can be attributed to the absence of diss fibres adherence to the cement paste because of the bad cement hydration. Medium values were obtained for the boiled and washed diss coated, because of the fibres strong adhesion to the cementing matrix. It was found that 2 h of boiling in water was sufficient to reduce water soluble chemicals such as sugar, starch, resin, and phenols. Then diss fibers must be washed with abundant tap water until the color of water became clear. The most values were obtained for the prewetted diss fibres, because the saturation treatment influences clearly the dynamic elastic modulus.

3.2 Mechanical strengths

The average mechanical strength in compression and flexion, and bulk densities of various composites are represented in Figure 3 for various formulations.

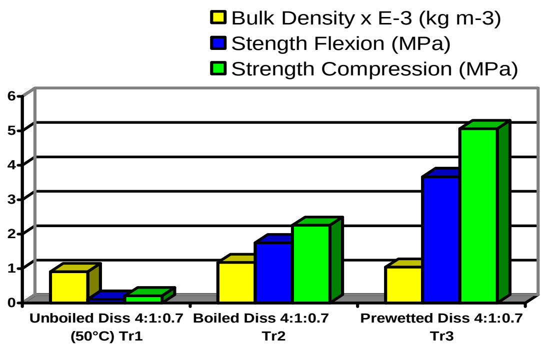

Figure 3. Mechanical strength and bulk densities for various treatments

3.3 Untreated vegetable fibres

The mechanical strength results of composites containing unboiled diss dried in the oven at 50 remain very low. This phenomenon is certainly due to exchanges occurring at the matrix-fibres interface and the hydrolysis and solubilisation reactions of some compounds such as sugars, hemicelluloses and pectins caused by the highly alkaline environment developed by cement hydration. It can be noted that water-soluble fractions evaluated at 16.83 % are the cause of weak adhesion of materials.

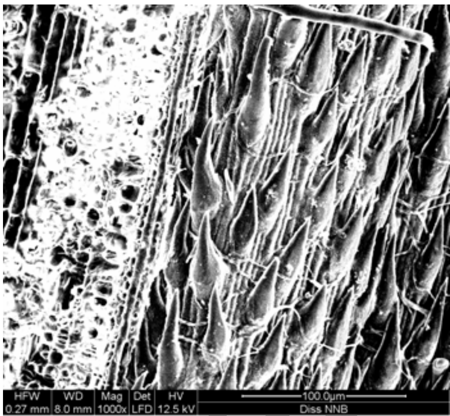

Figure 4. Scanning electron micrographs of unboiled diss fibres, magnification × 1000

a) After flexural test b) After compression test

Figure 5. Unboiled diss composite specimen

4. Influence of Hydrothermal Treatment: Boiling Treatment

In accordance with the results obtained by Demirbas [1] et al. and Ledhem et al. [4] and Aamar Daya [5], the boiling treatment of diss fibres in the treatment water allows to eliminate soluble matters, which are the cause of retardation of setting and lack of cohesion between aggregate and matrix. Indeed the use of water treatment in the cement paste has showed an important initial retardation of setting. The results are summarized in Table 2.

Figure 6. Video microscope image on the crack of unboiled diss composites, magnification x 25

Table 2. Tests of initial setting time with various mixing waters

SAMPLE	Initial setting time (Hours)	Final setting time (Hours
Cement + Water of the network	4.50	6.00
Cement + Water residue of the boiled diss	8.00	16.00

Strong strengths are of course due to the elimination of the detrimental substances, but it is also necessary to point out to the influence of the diss fibres skin. Indeed the skin of diss fibres is composed of tiny spines which will allow a better adhesion to the cement paste as shown on Figure 13. This type of fibres/matrix cohesion offers better tensile strength in flexural tests and better lateral tension in compressive tests.

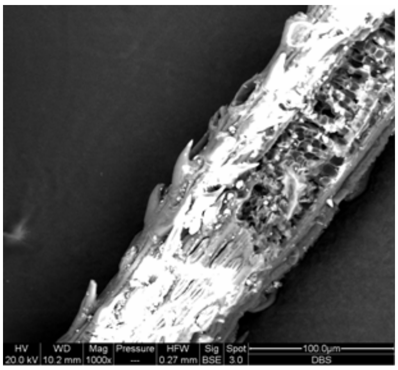

Figure 7. Scanning electron micrographs of boiled diss fibres, magnification × 1000

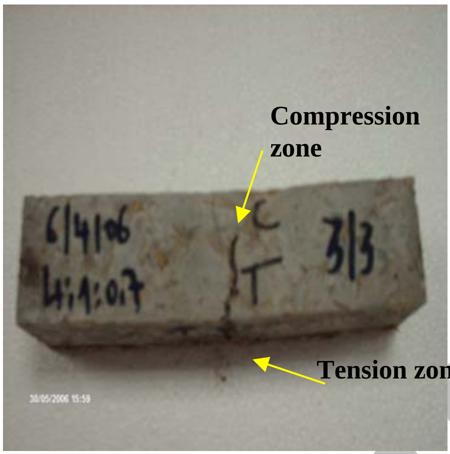

Figure 8. Boiled diss composite, W/C=0.7 ratio, after flexural test

The high strength of these composites is also due to the fact that the fibres are placed longitudinally, which enables them to adhere well to the cement paste, and behave as reinforcement (Figure 8). Moreover, at the flexural crack level at the tensional section, we noted that the diss fibres are well coated in packages by the cement paste, which enables them to resist well to the tensile stress. (Figures 9 and 10).

Figure 9. Video microscope image on the crack, magnification × 50

Figure 10. Detail of fibre of Figure 15 surrounded in red, magnification × 175

5. Influence of Saturation Treatment: Prewetting Treatment

Vegetable fibres are generally materials with the capability of absorbing significant amounts of water, about 90% for Boiled Diss fibres. The diss fibres are prewetted to minimise the effect fibres absorption on the hydration water content at the fibre/cement interface zone during the hydration process.

The absorptive properties of vegetables aggregates require consideration during mixing.

The rate of absorption as well as the maximum total absorption have to be properly integrated into the mixing cycle ton control consistency properly.

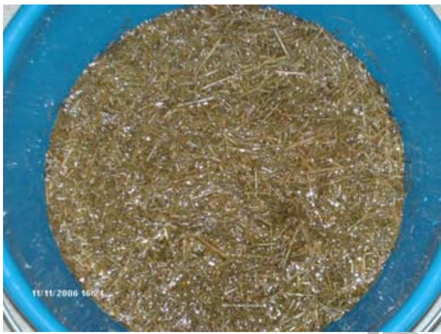

Figure 11. Saturation of Diss fibres during 1 hour

Figure 12. Prewetted diss fibres composite, W/C=0.7 ratio, after flexural test

Figure 13. Video microscope image on the crack, magnification×50

The compressive strength to flexural strength ratio of fibres composites equal to 1.38 is very low. On the contrary this ratio is very high for normal aggregates composites. The fibres strength, stiffness, and the ability of the fibres ton bond with cement paste of the composite are important fiber reinforcement properties (Figure 18). Bond is dependent of the aspect ratio of the fibres.

6. Conclusion

This work related to the optimization of a cementing composite containing treated and untreated Diss fibres. It clearly appears that boiling water treatment improves the performance of the composite thanks to the elimpination of the water-soluble compounds evaluated for unboiled diss at 16.83 %, and for boiled and washed diss at 4.95 %. Results of this study indicated that the best treatment of diss fibres was to prewet them as it can enhance the mechanical properties of diss composites, as shown on Figures 2 and 3.

The treatment of diss fibers of diss by boiling improves the mechanical properties of the composites, but the prewetting of the fibers gives the best properties.

The prewetted and boiled diss composites have considerably resisted at the tensile stress in flexural tests without appearance of cracks at the firsts loadings stage. In compression, these boiled diss composites have not shown any crack and the specimen remained undamaged. While the unboiled diss composites did not appear any resistance in flexion and in compression.

The treatments in boiled water have improved the mechanical characteristics of the composites, while the structure of fibres did not change. The fibres are placed longitudinally in the composites, which offer them the ability as reinforcement, without increasing the bulk densities which vary from 800 to 1200 kg/m^3. Because of their lightness and their ductility behaviour, these composites can be used as infill in the structures subjected to the seismic efforts. The improvements caused by the presence of boiled diss fibres in the composites are due to:

- the adherent capacity of the fibres to the cement paste, caused by their thorny structures;
- the better tensile strength, caused by the formation of package by the cement paste;
- their fine structure favourable to the longitudinal fibres disposition in the composites and offer them the ability to improve the mechanical strength.

The optimum composite composition in term of volume of diss fibres: cement: water ratio is therefore 4:1:0.7.

Moreover, the fibres are placed longitudinally and in parallel, which tends to increase their role of reinforcement.

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