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Characterization of River-Dune Sand Concrete Lightened by Addition of Wood Shavings

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ABSTRACT

The undertaken work is an experimental study which aims at the development of a new lightweight concrete. The studied composite is a sand concrete lightened by adding wood shavings. The obtained results showed that, the mixture of fine sand with coarse sand gives a micro concrete where the dune sand acts as sand in ordinary concrete and the alluvial sand as gravel. The addition of fillers increases the compactness and consequently the mechanical strength of the sand concrete. Besides, the addition of wood reduces considerably its density and improves its thermal properties. For against, the wood addition decreases the mechanical strength, but it's always possible to obtain all categories of concrete. The structure appears relatively homogeneous and the adherence 'wood – matrix' is good. Finally, it should be noted that the treatment of wood shavings before their use, improves the mechanical properties without affecting too much lightness and thermal insulation.

INTRODUCTION

Indeed, the valorisation of local materials, as well as the reuse of industrial wastes became currently a necessary solution for the resolution of the economic and environmental problems of countries. It is within this framework that we undertook this study. The valorized materials are local dune and river sands which are available in large quantities in several areas of Algeria and the reused wastes are fillers and wood shavings coming respectively from aggregates crushing wastes and woodwork activities. The studied composite is a sand concrete lightened by addition of wood shavings. Let's note that by definition, a sand concrete either does not comprise any gravels at all or only contains a small enough proportion such that the mass ratio (Sand / Gravel) remains higher than 1. If it contains gravels, the material would be called 'a loaded sand concrete' [Presse de l'ENPC 1994; Chauvin and Grimaldi 1988]. This material, which was the subject of several researches currently, enters within the framework of the valorisation of local materials. This latter became a necessary solution to the economic problems of developing countries. In previous works, it was shown that the sand concretes are able to replace the conventional concretes in certain structures, along with the conclusion that the use of fillers is essential [Bederina et al. 2005].

Besides, the various industrial wastes constitute an environmental nuisance and generated particularly complicated problems. The reuse of these wastes has also been the focus of considerable research lately. Moreover, the lignocellulosic material addition within a cementing matrix provides the topic of numerous studies and applications [Campbell 1980; Nenitescu 1988] owing to the thermal and acoustic qualities as well as the renewable aspect of the employed resources. The idea pursued herein of introducing woodwork waste into sand concrete to improve its thermal performances, while preserving its mechanical qualities, was thus quite attractive.

Finally, it should be noted that the purpose of this study is the physico-mechanical and structural characterization of river-dune sand concrete sand based on wood shavings.

EXPERIMENTS

Sand

Two different sands were used in this study, a dune sand (DS) and a river sand (RS). The two sands are from the town of Laghouat. Results from the particle size distribution analysis of these sands, established according to standard NF P18-560, are presented in the Figure 1 and their densities have been listed in Table 1.

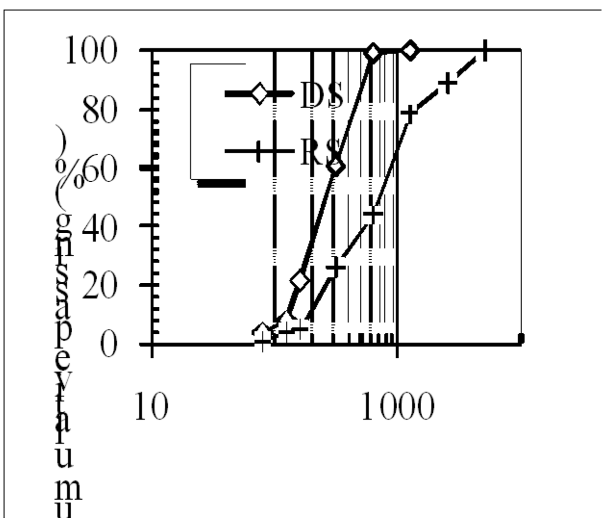

Fig. 1. Particle Size Distribution of Used Sands

Table 1. Densities of the Used Sands

Sand	Apparent density (kg/m^3)	Specific density (kg/m^3)
Dune Sand	1428	2596
River Sand	1482	2576

The X-ray analysis of both dune and river sand demonstrates their essentially siliceous nature. Let's note that the sand used in this study is a mixture of these two sands which displays a ratio RS/DS equal to 1.7 (by mass) [Bederina et al. 2005].

Cement

The used cement is a Portland cement (type II) of class 45 whose denomination is ''CPJ-CEM II/A''. The physical characteristics are the following: specific density 3078 kg/m^3 and specific surface area 289 m^2/kg and the chemical analysis are shown in table 2.

Table 2. Chemical Analysis of the Cement Used

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	PF
20.66	4.77	2.88	63.31	1.17	2.32	1.06

Fillers

The fillers used in this work have been obtained by sifting (with a sieve opening of 0.08 mm) crushing waste from a quarry located in the region north of Laghouat. The chemical analysis conducted shows that these fillers are mainly composed of limestone. The specific density is of 2900 kg/m^3. The specific surface (as measured according to the standard **EN** 196-6) is of 312 m^2/kg.

Wood shavings

The shavings are obtained from woodwork activities waste; they display an irregular shape, with particle size distribution ranging from 0.1 mm to 8 mm (Figure 2). These characteristics however are only given as an indication, since their significance has not been determined rigorously due to a lack of rigidity and the geometry of shavings. Real density of the shavings was taken as the apparent density of a solid of wood block. The measured value amounted to approximately 512 kg/m^3. The apparent density of shavings is on the order of 160 kg/m^3. Water absorption, as measured after total immersion of wood block until weight stabilization and expressed by the ''water/shaving'' mass ratio, stands at approximate 36%.

Fig. 2. General Aspect of Used Shavings

Admixture

The admixture used is an Algerian superplasticiser of MEDAPLAST (SP40).

Mixing and Conservation

The sand, the cement and filler, dried beforehand, were introduced into a mixer and mixed for 3 min at slow speed. Once the mixture has become perfectly homogeneous, wet wood aggregates were added. Mixing then continued at slow speed for another 3 min. The mixing water was added gradually. Material homogenisation was guaranteed by mixing at slow speed for 3 min, then at high speed for one more minute. Following setting of the (90% HR and 20°C), after 24 h, they were demoulded and kept in a dry environment (50% HR and 20°C) to remain close to local climatic conditions.

Wood Treatment

Concerning the treatment of the shavings, different treatments have been used in former works and it was shown that the treatment by coating with cement gives good results, in particular in mechanical strength and shrinkage [Ledhem 1997, Bederina et al. 2009]. For this study, a milk prepared by mixing cement (CPJ-CEM II/A) with water according to a mass report/ratio “cement/wood” about 2.5, was used for coating the shavings.

Measurement Tests

The compressive strengths are measured on cubic samples of 10x10x10 cm^3, the analysis of structure by SEM observation and optical microscope and the thermal conductivities are measured on dry half-cubic samples of 10x10x5 cm^3 using TPS method [Bederina 2007]. Let’s note that the theoretical bases of TPS-technique have been discussed by SE Gustaffson [Gustafsson S.E. 1991] as well as by various other authors [Saxena et al. 1992, 1999; Bouguerra et al. 1997]. The experimental device used is composed of Transient Plane Source (TPS) element (Figure 3), a power supply stabilized in tension, a Wheatstone bridge, an acquisition power station and a microcomputer for the data control and processing.

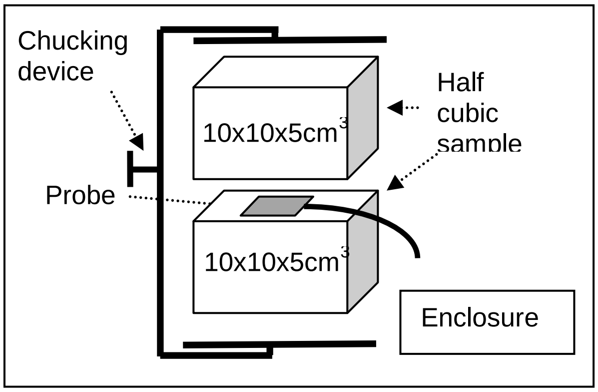

Fig.3. Introduction of TPS-Element between Two Half Cubic Sample

The surfaces of the two half-samples were polished beforehand in order to minimize the influence of contact resistance. A chucking device was employed to ensure a good contact between the various elements. The whole assembly was then introduced into an enclosure to allow controlling the experimental temperature. Two thermocouples were welded onto the metal plates to check thermal stability at the samples level. The probe was standardized on several materials of known thermal characteristics in order to validate both the test conditions and parameters.

RESULTS AND DISCUSSION

Optimization of the Matrix

The matrix of the studied composite is only constituted with sand concrete. An experimental study of formulation based on compactness – workability was undertaken in order to determinate the optimum proportion of every component [Bederina et al. 2005]. Several dosages of fillers going from 0 to 300 kg/m^3 have been envisaged. The obtained optimum composition is showed in Table 3.

Table 3. Composition of the Sand Concrete (without Shavings)

Cement (kg/m^3)	Sand (kg/m^3)	Fillers (kg/m^3)	Water (l/m^3)	Superplasticiser * (%)
350	1473	140	207	1,5

* The percentage of admixture is calculated in mass, compared to the cement mass

Lightening of the Composite

The sand concrete, thanks to its small granularity is lighter than conventional concrete. The introduction of wood shavings reduces it more. The greater the amount of wood is, the higher the concrete is light (Figure 4). This lightness is essentially due to the porous structure of wood.

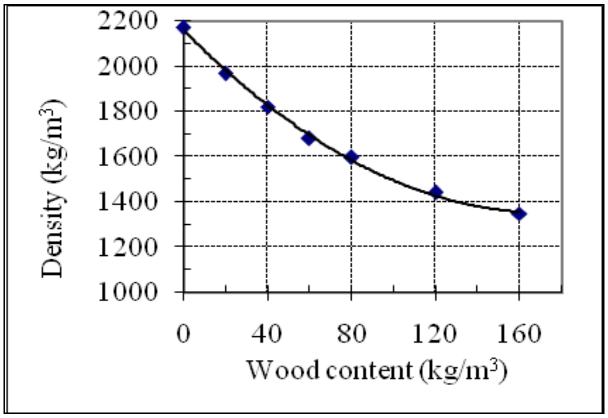

Fig. 4. Evolution of the Density According Wood Content

For this study, wood shavings are incorporated in river-dune sand concrete according to optimal composition found in the preceding study (Fillers content = 140 kg/m^3). The wood contents considered were pushed up to 160 kg/m^3. The figure 4 shows that the addition of wood increases the porosity of the material and therefore makes it lighter. Going to 16O kg/m^3 of wood, the weight of the material is reduced by about 38%.

Compressive Strength

According to the fillers content and without wood shavings, the analysis of experimental results reveals the existence of an optimal fillers concentration. At the beginning, the fillers addition increases the compactness of material, and consequently its strength. But starting from a certain optimum, the vacuums are saturated, and the filler addition makes only a decrease in the compactness of material, which consequently decreases its strength [Bederina et al. 2005].

What is necessary to note from this part of study, is that with an optimal filler concentration of approximately 140kg/m^3, we could increase the compressive strength of River-dune sand concrete more than 50% [Bederina et al. 2005].

However, and according to wood content, the figure 5 shows that the compressive strength decreases by increasing the content of wood shavings, but, it is possible to obtain interesting strengths with small contents of wood which allow the use of this material in certain carrying structures.

It should be noted that the loss in strength in the lightweight concretes is replaced surely by a profit of other interesting properties such as the heat and acoustic insulations (Jennifer L. et al., 2004). Other authors announced this result and even showed that with certain treatments applied to the shavings, we can improve the mechanical performances of the material [Jennifer et al. 2004; Eustafievici et al. 2002].

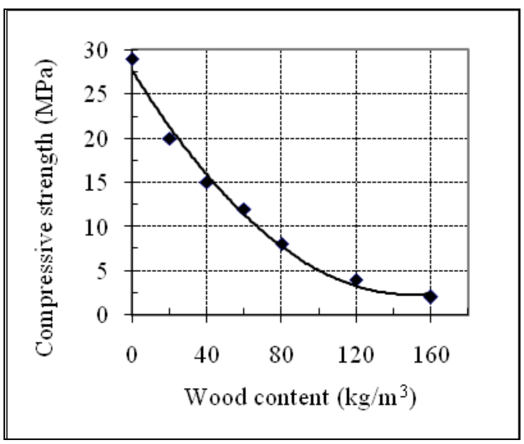

Fig. 5. Evolution of Compressive Strength According Wood Content

Thermal Conductivity

The thermal conductivity of wood indeed, is definitely very lower than that of the concrete. Thanks to its low thermal conductivity, the incorporation of wood shavings in concrete decreases its thermal conductivity [Bederina et al. 2007] which is shown in figure 6. Thus it is clear that the thermal conductivity of river-dune sand concrete decreases with the increase in wood proportion. By pushing wood content up to 160 kg/m^3, we could reduce the thermal conductivity of this concrete more than 75%.

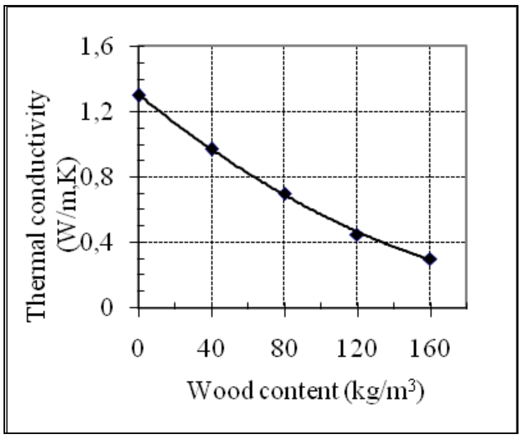

Fig. 6. Evolution of Thermal Conductivity According Wood Content

Compromise Mechanical Strength - Thermal Conductivity

According to Kass and Compbel (1972), a construction-insulation concrete must have a strength ranging between 15 and 3.5 MPa and a thermal conductivity lower than λ=0.75 W/m.K. According to this basis, therefore, we notice that with a proportion of wood of approximately 80 - 120 kg/m^3, we can obtain a lightweight sand concrete (density lower than 1600 kg/m^3) which can be used in both construction and insulation.

Let us note that, even with shaving contents lower than 80 kg/m^3 (40 kg/m^3 for example), we can obtain a construction concrete having a thermal conductivity definitely lower than that of a concrete without wood.

Structure of the Studied Concrete

The figure 7 reveals that wood grains adhere well to the cementing matrix, however, small defects around the wood shavings can be also observed at time, most likely due to the different dimensional variations between the matrix and the wood [Ledhem 1997**].** This type of defect was already noted by Aouadja [Aouadja et al. 1995]. Similarly additional porosity is observed at the level of the matrix.

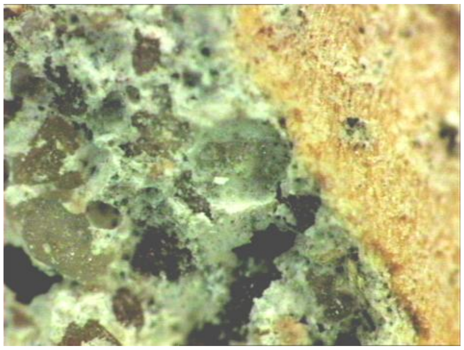

Fig. 7. Optical Micrograph of the Studied Wood Sand Concrete (G=150)

Treatment of Wood Shavings

Finally, and in order to search improvements on certain characteristics of the studied concrete, the treatment of the shavings before their use was necessary. The used treatment was chosen starting from the literature. It is a cement surface coating [Bederina et al. 2009].

For this study, a paste prepared by mixing cement (CPJ-CEM II/A) with water according to a ‘‘cement/wood” mass ratio of 2.5, was used for the coating of the shavings. The dry shavings were then sprayed with paste until total surface coating. The duration of drying was fixed at 28 days. Figure 8 shows the general aspect of the treated wood shavings.

Fig. 8. General Aspect of Treated Wood Shaving

The shaving treatment considerably improves the compressive strength of sand concrete. As the content of wood increases, the compressive strength increases in comparison to untreated shavings sand concrete: a strength gain of about 20% has been recorded with a content of wood of 80 kg/m^3 and of about 230% with a content of 160 kg/m^3. The improved compressive strength, due to the wood surface treatment, can be related to the increase in wood shaving rigidity and the improvement of wood–matrix adherence. It should be noted that the gain in strength is attractive, since thermal conductivity is little affected by the treatment.

Finally, it is interesting to note that other problems arising from the sand concrete containing untreated shavings were solved such as the shrinkage and the water absorption [Bederina et al.2009].

Benefits and Applications of the Material

The results show that it's possible to develop a new lightweight sand concrete mainly formulated from River-dune sand and lightened by adding wood shavings. This material is able to bear loads of structure while providing good thermal insulation. Certainly, its mechanical strength is inversely proportional to the proportion of wood used, but it should be noted that the decrease in strength caused by the addition of wood shavings is replaced by other interesting properties such as:

- A considerable lightness which will reduce the energy of the implementation of concrete in construction sites;
- A very important insulation which is very useful for the region of Laghouat, where it is very hot in summer and very cold in winters. This property will decrease the energy of heating and cooling in constructions.

Note that the mechanical strength has been improved by the treatment of the wood shavings before their use. Moreover, the qualities of the sand concrete itself which is characterized by a small granularity offering the following advantages:

- Absence of segregation;
- Ease of pumping for large distances;
- Ease of injection and projection
- Possibility of making very attractive aspect of surface.

CONCLUSIONS

The purpose of this work was the study of the influence of the addition of wood shavings on the properties of river-dune sand concrete. This new composite, and thanks to its lightness and its porous structure, could find multiple applications, in particular as a filling material and as heat and acoustic insulation. For small contents of wood, we can reach interesting mechanical strengths which allow the use of this concrete in carrying elements.
In general, the following points are noted:

1. The optimum composition of the matrix is obtained by a proportion of fillers of approximately 140 kg/m^3.
2. The increase in the proportion of the shavings considerably reduces the weight of river-dune sand concretes.
3. The increase in the wood content appreciably decreases the compressive strength. On the other hand, thermal conductivity is definitely better, whenever the proportion of wood is higher.
4. However, it is possible to ensure a compromise between the compressive strength and the thermal conductivity for obtaining structural dune-river sand concrete.
5. The observation by means of optical microscopy shows that the matrix of the studied composites is relatively homogeneous and the adherence wood-matrix is good.
6. The treatment of the shavings considerably improved the compressive strength, the shrinkage is considerably improved, the water absorption is reduced, the insulation capacity is slightly influenced, the structure of the composite is more homogeneous and compact, and the wood–matrix adherence is better

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