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Mechanical characterisation of filler sandcretes with rice husk ash additions
Study applied to Senegal

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Abstract

To capitalise on the local materials of Senegal (agricultural and industrial wastes, residual fines from crushing process, sands from dunes, etc.), rise husk ash and residues of industrial and agricultural wastes have been used as additions in sandcretes. The mechanical resistance of sandcrete blocks obtained when unground ash (and notably the ground ash) is added reveals that there is an increase in performance over the classic mortar blocks. In addition, the use of unground rice husk ash enables production of a lightweight sandcrete with insulating properties, at a reduced cost .The ash pozzolanic reactivity explains the high strengths obtained.

Keywords: Sandcrete; Rice husk ash; Agricultural wastes; Ground ash; Blockworks; Pozzolanicity

1. Introduction

The exploitation of local resources, the development of innovative techniques, and the use of sandcrete have been studied previously [1–3]. Production in Senegal has also been studied [4,5]. However, the additions used were exclusively residual-filled sands that resulted from crushing limestone, sandstone, chert, and basalt. The accumulation of agricultural wastes such as rice husk has posed environmental problems; thus it is judicious to recycle these products.

The employment, promotion, and exploitation of agricultural and industrial by-products, with the aim of minimising production costs or producing new products, would therefore represent an interesting proposition and would save raw materials.

The objective of the study of filler sandcretes using rice husk ash additions is viewed from three points of view: (1) preservation of the environment, (2) generation of a value-added increase in the construction of buildings, and (3) ascribing physical and mechanical properties to the material.

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2. Origin of the material

2.1. Sand

Red dune sand exists in "inexhaustible" quantities, covering approximately 70% of the national territory. The exploitation of these sands was carried out close to suburbs of Dakar (North Foire).

2.2. Ashes

The ashes were supplied by SO.NA.COS. (Marketing National Society of Oleaginous, Senegal), who use the rice husk as a supplement to combustion. The average annual production of rice husk ash is approximately of 2,300 tonnes.

2.3. Cement

The cement was produced by the SO.CO.CIM. (Cement Marketing Society, Senegal) and is type CEM II/A32.5, conforming to the current standard NS-02 in Senegal.

3. Description of materials

3.1. Dune sand

Observation of the sand grains using a binocular optical microscope revealed that the grains were essentially quartz

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Table 1
Synthetic table of geotechnical characteristics of materials used

Materials	% of fillers	γ_s	U_r	F_m	S_s (cm^2/g)
Portland cement	84	3.14	–	–	2,935
Unground ash	7	2.35	4	1.7	–
Ground ash	85	2.35	–	–	6,960
Dune sand	2.1	2.94	2.5	1.3	4,390

F_m = fineness modulus, U_r, = uniformity ratio = hazen ratio, S_s = specific surface, γ_s = specific density, % of fillers = percent of particles smaller than 80 microns.

(99%) with a red staining. The staining was due to a thin film of iron shale that covered the grains [6].

The characteristics of the sand are shown in Table 1. It can be noticed that the sand is very fine and well-graded according to the Atterburg classification.

Examination using a scanning electron microscope (SEM) at a ×50 magnification shows grains of regular form, well-rounded, which is attributed to the aeolian transportation mechanism in dunes. A magnification of ×2,000 reveals that the land particles are covered with a coating of iron shale, which is responsible for the red colour (see Figs. 1 and 2). The efficiency of the sands as a substitute for beach sand, the exploitation of which is forbidden, has been previously proven [6].

3.2. Portland cement

The principal characteristics of the cement are shown in Table 1. The values found are in reasonable agreement with those supplied by the producer, a compressive resistance at 28 days of 42.5 MPa ($\sigma_c 28$ = 42.5 MPa). The results of the chemical analysis of the cement are shown in Table 2.

3.3. Rice husk ash

Two types of ashes have been used, ground and unground. The use of unground rice husk ash has enabled both

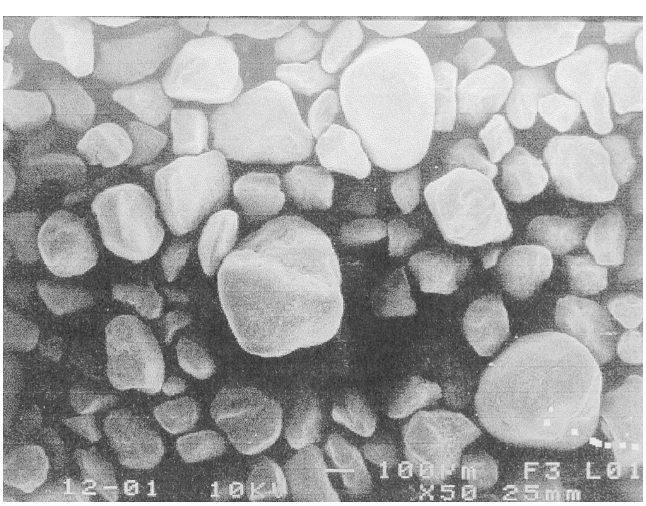

Fig. 1. Form of the dune sands examined by SEM.

Fig. 2. Land particles of dune sand.

the production of a lightweight insulating concrete and cost reduction (saving energy by eliminating the grinding process).

Chemical analysis (see Table 2) reveals the highly siliceous nature of the ash, which gives the ash a pozzolanic quality as described by Diop and Thioune (1994) [4]. The pozzolanic quality is also linked with amorphous structure of silica.

A grading analysis of the ground rice husk ash, of which 85% of the particles are smaller than 80 microns, was carried out by laser. Results indicate that 34.46% of the particles are smaller than 7 microns (Fig. 3); these particles appear to be responsible for the pozzolanic reactivity of the amorphous silica [8]. The grading analysis, by sieving, of the unground ash shows the presence of 7% fines with a low-fineness modulus, and a well-graded size distribution (Fig. 4). The characteristics of the material are shown in Table 1 and confirm the low density of the ash (γ_d = 0.30 g/cm^3 and 0.72 g/cm^3, respectively, for unground and ground ash) and the extreme fineness of the ground ash (Blaine specific surface, S_s = 6,960 cm^2/g).

The analysis using SEM shows:

- Unground ash: particles in a tubular form split longitudinally with the presence of small bristles distributed over an undulated surface (see Fig. 5). Fig. 6 confirms the presence of hydroscopic pores.
- Ground ash: Fig. 7 shows the cellular structure.

Table 2
Chemical anlaysis results of cement and ash

	Fe_2O_3	CaO	Na_2O	K_2O	Al_2O_3	SiO_2	Loss on ignition
Cement	8.9	60.1	0.3	0.3	4.0	19.8	6.3
Ash	2.6	6.0	6.3	5.5	1.6	79.2	0.5

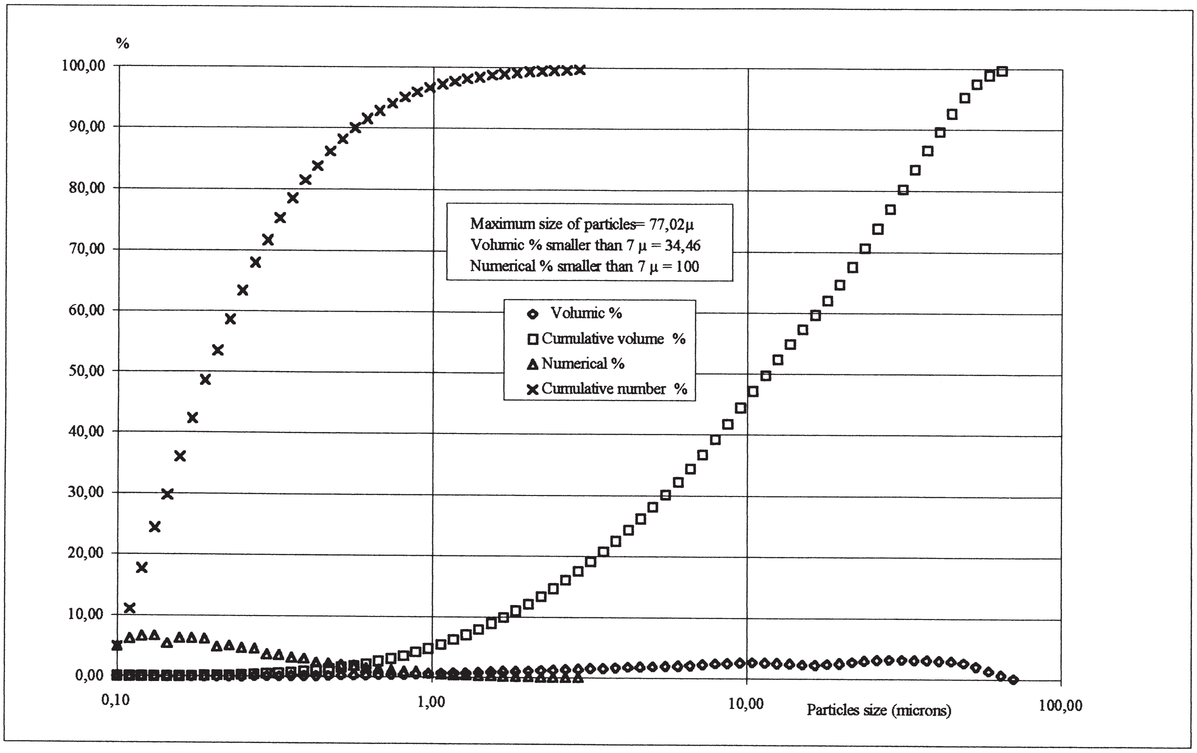

Fig. 3. Grading curve by laser of rice husk ash fillers.

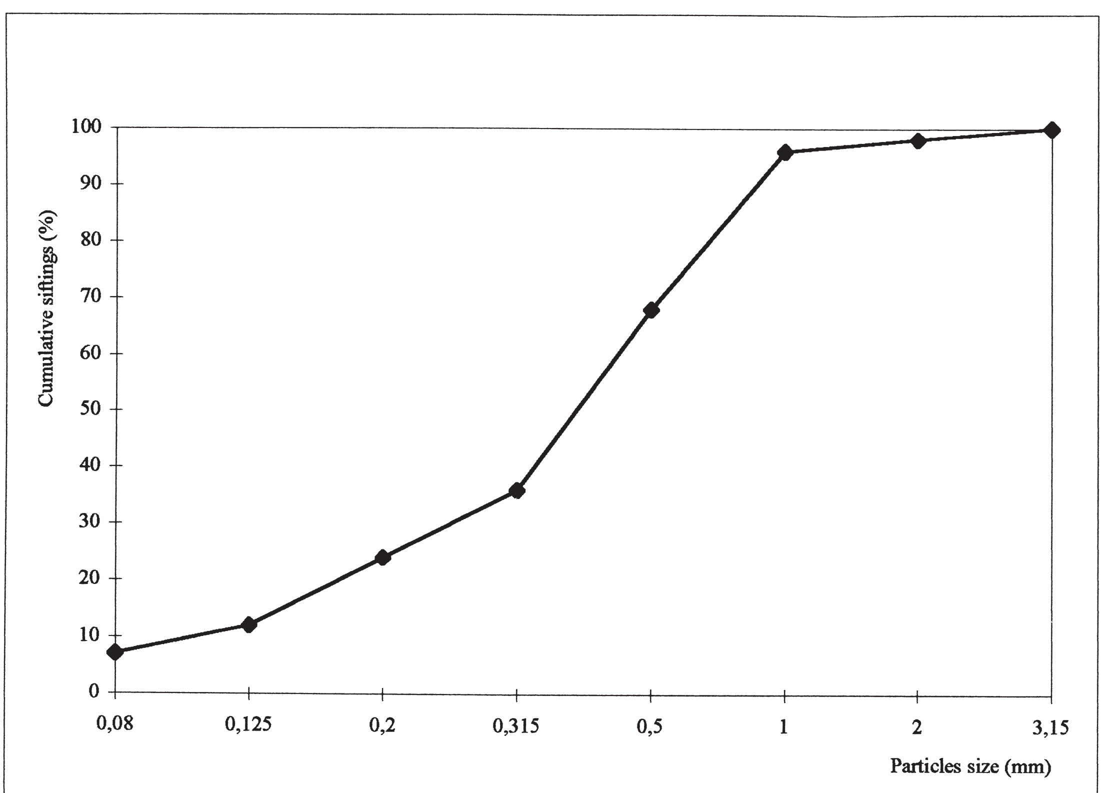

Fig. 4. Grading curve by sieving of the unground rice husk ash.

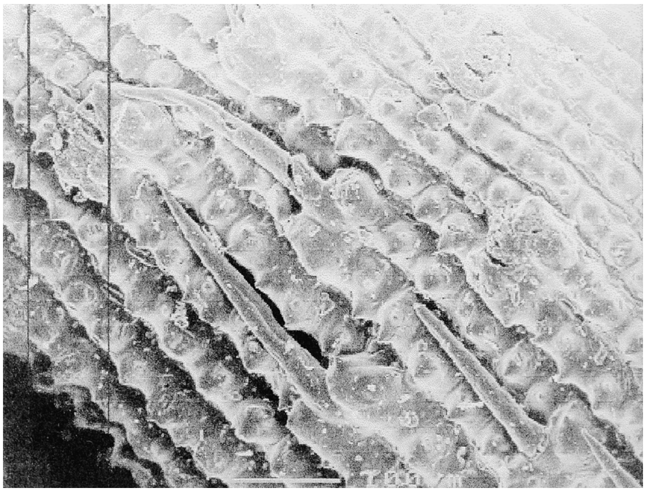

Fig. 5. Texture of unground rice husk ash particles.

The pozzolanicity test following norm NF P 15-462 shows that the rice husk is very reactive in comparison with other products that are reputed to be pozzolanic such as basalt, volcanic slags, and the ash of groundnut shells [9].

4. Characteristics of the sandcretes

Samples of filler sandcretes (4 × 4 × 16 cm prisms) were produced in accordance with the method described by Laquerbe et al. (1996) [9].The details of the constituents of the mix are shown in Table 3; E' represents the actual quantity of water added to the mix to attain 10- to 12-cm spreading of the mix when subjected to 15 s on a vibrating table, and C' represents the total filler (cement plus fillers). E' takes into account the rate of water absorption by the ash and the dune sand.

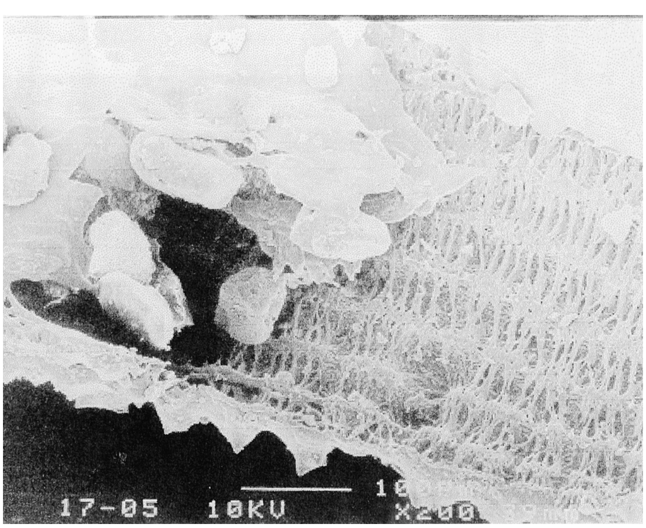

Fig. 6. Identifying the porous sight of the unground rice husk ash.

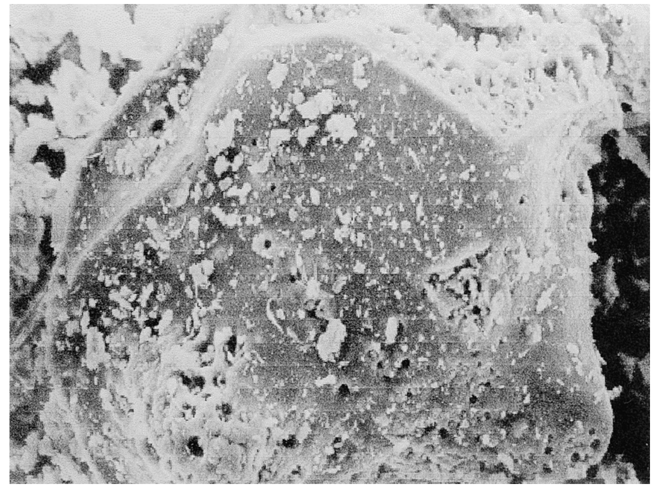

Fig. 7. Visualization of the cellular structure of the ground rice husk ash.

Table 4 makes a synthesis of the characteristics determined. An examination of the data leads to the following comments:

1. It is noted that there is weight loss for samples cured in air between 7 and 28 days; this loss is slightly more for the unground ash than the ground ash. On the contrary, the weight gains of samples cured in water by the absorption of water is almost double in the same period. In other words, the ash absorbs more water than what is liberated, which is illustrated by the morphology as demonstrated by SEM observation (Figs. 6 and 7).
2. The mechanical strength increases through the curing period, more rapidly for the samples cured in water. It is well known that humid conditions enhance the hydration process. The ratio of the age coefficients demonstrates the importance of water curing.
3. The mechanical strength of the sandcretes with ground ash is on average twice that of sandcretes with unground ash, regardless of the curing method and age. This is due to the pozzolanic nature of the ash, which will develop more rapidly in the case of the fine particles than the coarse particles that have the same mineralogical and chemical compositions [10].

Table 3
Batching of the filler sandcretes

Batching parameters	Unground rice husk ash sandcrete	Ground rice husk ash sandcrete
Cement (kg)	250	200
Dunes sand (kg)	913	1864
Rice husk ash (kg)	885	279
E' (kg)	330	196
E'/C	1.32	0.98
E'/C'	1.10	0.65

See text for explanation of symbols.

Table 4
Mechanical parameters of the different sandcretes

Parameters measured	Unground rice husk ash sandcrete		Ground rice husk ash sandcrete	
	7 days	28 days	7 days	28 days
$(\sigma_{c28})_{water}$ (MPa)	3.69	9.56	8.31	18.59
$(\sigma_{c28})_{air}$ (MPa)	3.31	4.98	6.50	10.37
Weight loss (%)	12.60	13.81	7.30	7.60
Weight gain (%)	0.84	1.61	0.85	1.59
Bulk density (t/m^3)	1.88		2.05	
$(\sigma_{c28}/\sigma_{c7})_{water}$	2.59		2.24	
$(\sigma_{c28}/\sigma_{c7})_{air}$	1.50		1.59	
$\frac{(\sigma_{c28}/\sigma_{c7})_{water}}{(\sigma_{c28}/\sigma_{c7})_{air}}$	1.72		1.40	

The percentage of particles smaller than 7 microns (higher for the ground ash) is a characteristic that accentuates the pozzolanicity as already demonstrated by Jarrige [8].

4. If the cumulative effect of density, grinding (which reduces the water cement ratio from 1.1 to 0.65), and the pozzolanicity explain the highly significant increase in strength of concrete made with ground ash, only an increased cement content (250 kg/m^3 in place of 200 kg/m^3) and the pozzolanicity would enable the use of unground ash. With unground ash, two factors contribute to the reduction in mechanical strength of the concrete: (1) the lower density of the ground ash and (2) at the time of mixing there is a reduction in the maximum aggregate size (D), which would increase a minimum content of fines (cement + addition) greater than that predicted by the empirical formulae (en $\sqrt[5]{D}$).This factor has not been taken into account because it would be necessary to know the dimension of D. In addition, one must consider that the water content of the unground ash is higher than the ground ash; this will similarly lead to a reduction in strength.

The fact that the grinding of rice husk ash demands a higher water content in the mix was found by Pateha in 1991 [11]. Also, the use of plasticizers that reduce water content would allow the increase in the efficiency of these fillers, which are hydraulically reactive. The influence of the characteristics of fillers on sandcretes was previously studied [12].

Finally, even it is true that the strength found from the $4 \times 4 \times 16$ cm samples is not significant, it was noted that the sandcretes made with rice ash husk demonstrated a superior mechanical strength when compared to sandcretes made with filled limestone or chert [9] and had the same or higher cement contents (Table 5).

One sees, therefore, that there is an interest in promoting filler sandcretes with rice husk ash addition, especially ground, since mechanical strengths are greater than those obtained using other additions. In effect, even volcanic materials (tuffs, scorias, basalt) that are reputed to be pozzolanic do not attain values as high as those produced by ground ash (Table 5).

Table 5
Comparison of sandcretes

Additions	Cement content (kg)	$\sigma_{28\ days}$ (MPa)
Other types of sandcretes		
Unground rice husk ash	250	9.56
Ground rice husk ash	200	18.59
Filled no sandy limestone 0/3	250	6.78
Filled sandy limestone 0/3	250	9.10
Filled cherts 0/3	265	7.47
Sandcretes using pozzolanic fillers		
Ground rice husk ash	200	18.59
Filled basalt 0/3	250	12.93
Ground black volcanic slags	200	16.68
Ground volcanic tuffs	200	10.25

Table 6
Cost comparison study of the different sandcretes

	Cost of cubic metres (f CFA)
Sandcrete with filled limestone addition	13,522
Sandcrete concrete with filled basalt addition	14,454
Sandcrete concrete with filled sandstone addition	12,808
Sandcrete concrete with filled cherts addition	13,404
Mortar of sand and cement	13,505
Sandcrete with unground rice husk ash addition	12,965
Sandcrete with ground rice husk ash addition	11,051

f CFA = Senegalese currency.

5. Conclusions

The introduction of rice husk ash as an addition to sandcretes has allowed improvement of the physicomechanical performance of this material. In fact, with the use of ground ash one can achieve unexpectedly high strengths, while the unground ash permits the production of a robust material. These results are explained respectively by the chemical nature and morphology of this material of organic origin. Equally, the financial competitiveness of the material should be pointed out, since sandcrete blockwork with rice husk addition has a lower cost compared with those using other types of additions (Table 6).

In summary, the use of these agricultural wastes is highly justified and confirms the conclusions of previous studies [7,11].

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