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Physical and transfer properties of mortar containing coal bottom ash aggregates from Tefereyre (Niger)

Edem Baite [a,b], Adamah Messan [a,*], Kinda Hannawi [b], François Tsobnang [a], William Prince [a,b]

[a] Institut International d'Ingénierie de l'Eau et de l'Environnement (2iE), Laboratoire Eco Matériaux de Construction (LEMC), Rue de la science, Ouagadougou, Burkina Faso
[b] Institut National des Sciences Appliquées (INSA), Laboratoire de Génie Civil et Génie Mécanique (LGCGM), 20 Avenue des Buttes de Coësmes, Rennes Cedex 7, France

HIGHLIGHTS

- Use of Tefereyre coal bottom ash (CBA) as fine aggregate in mortar.
- CBA aggregates significantly affect the porosity and the gas permeability.
- CBA aggregates reduces the specific weight and thermal conductivity.
- Mortar containing CBA offer an opportunity to recycle high amount of Tefereyre CBA.

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ABSTRACT

This study is focused on the use of coal bottom ash from Tefereyre (Niger) power plant coal-fuelled, as a fine aggregate in cementitious mortar. Various volume fractions of natural sand (0%, 10%, 20%, 30%, 40%, 50%, 75%, and 100%) were replaced by the same volume of fine aggregates of coal bottom ash. In order to determine the effect of coal bottom ash incorporation on the composites obtained, fresh and dry density water absorption, porosity, thermal conductivity, ultrasonic pulse velocity, gas permeability and microstructure analyses were investigated.

The results show that incorporating coal bottom ash in mortar causes an increase in the apparent porosity and that leads to an increase of the water absorption and the apparent permeability of the samples at 28 days curing age. The densification of bottom ash mortar during the curing age contributed to significantly reduce the increase in the porosity and the apparent permeability. This densification was confirmed by SEM analysis and ultrasonic velocity measurement. However, the use of coal bottom ash reduces the specific weight and the thermal conductivity of cementitious materials. Overall, the mortars containing coal bottom ash offer an opportunity to recycle (by-product) wastes.

1. Introduction

In recent years, many researches have been conducted on the utilization of recycled waste like fly ash, silica fume, and blast furnace slag, marine sediment, Municipal Solid Waste Incinerator (MSWI), bottom ash in civil engineering materials [1–3].

Most recently, because of the high increase of coal combustion residues (CCRs) in the world [4–8], the use of shredded CCRs has known a growing interest as recycled materials in civil engineering. The incorporation of waste (by-product) in mortar and concrete provides additional advantages in terms of environmental and potential economic considerations. Coal bottom ash (CBA) is a by-product material generated from thermal power plant. However, his particle distribution is similar to natural sand (fine aggregate) and natural gravel (coarse aggregate), it could also be used as aggregate replacement in concrete and masonry block production.

Indeed, several studies were carried out to investigate physical and mechanical properties of cement and concrete containing coal bottom ash as mixes. The research work carried out by Singh and Siddique [3], Kim and Lee [9] indicates that flexural strength and elasticity modulus of concrete mixes made with coal bottom ash as a substitute for fine aggregates decrease with the increase in the content of coal bottom ash. However the compressive behaviour was not strongly affected. Sani et al. [10] found that the compressive strength at 3 days for 20% and 30% sand replacement level is higher compared to other washed bottom ash concrete. They concluded that the optimum amount in order to get favourable strength, environment saving and lowering cost is 30% of washed

* Corresponding author.
E-mail address: adamah.messan@2ie-edu.org (A. Messan).

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bottom ash (WBA) as sand replacement. Chi-Sun [11] also reported that mixing concrete containing bottom ash with fixed slump showed a higher compressive strength at all ages compared to control concrete. However, the compressive strength of bottom ash concrete mixes with a fixed water cement ratio decreased with the increase in bottom ash content. Kim and Lee [12] investigated the effects of fine bottom ash (FBA) aggregates on the density, compressive strength, dynamic elasticity modulus and flow characteristics of the mortar. They also measured the porosity and water capillary absorption of the mortar in order to evaluate the properties of moisture transport, which may affect the durability of the mortar. They found from the study that the mortar flow characteristics were increased by 10–20% with the replacement by FBA aggregates.

In other previous works it was observed that, to achieve the same slump of concrete, water demand increases on use of coal bottom ash as aggregate replacement in concrete. The workability values increase with the increase in bottom ash content in concrete [11–13]. However, there are some contrary observations reported in the literature. Aggarwal et al. [14], Chun et al. [15] indicate a decrease in workability of concrete on use of bottom ash. In the work by Kim and Lee [9], effect of fine and coarse bottom ash on physical properties of concrete are studied. They observed that densities of hardened concrete decreased linearly as the replacement ratio of fine and coarse aggregates of bottom ash increased.

However, only few limited research works are reported on the transfer properties of concrete containing coal bottom ash, as an aggregate. Siddique [16] presented physical properties of self Compacting concrete (SCC) containing coal bottom ash as fine aggregate. The study concluded that water absorption and sorptivity of SCC mixes increase with the increase in bottom ash content at a particular age. Still these properties decrease with the increase in age. Also Boel et al. [17] evaluated gas and water transport in self Compacting concrete with limestone filler or flay ash, was found to have low transport properties.

In this study, we discussed the utilization of coal bottom ash from Société Nigérienne de Charbon (SONICHAR) a coal mining and energy provider company in Niger. The power station coal-fuelled is equipped with two 18.8 MW generators to burn about 300,000 tons of coal mineral to generate power and produce about 150,000 tons of coal bottom ash yearly. This study is focused on investigating the physical and transfer properties of mortar incorporating fine aggregate of coal bottom ash from Tefereyre (Niger) as aggregates. An experimental test program on mortars containing different percentages of coal bottom ash fine aggregates, was conducted in two steps. Firstly, various physical and transfer properties including fresh and dry density, water absorption, porosity, ultrasonic velocity, gas permeability apparent and thermal conductivity were measured. Secondly, pore size distribution and Scanning electron microscope (SEM) was used to investigate the microstructure.

2. Experimental study

2.1. Characterization of the materials

The materials used in this work were:

- Portland cement CEM I 42.5 with 3.15 specific density and 2.96 m^2/g specific surface area obtained by BET surface analysis.
- Coal bottom ash (CBA) obtained from coal-fuelled power plant (the coal is locally mined at the site of Tefereyre, 75 km north-west to Agadez in Niger). The coal bottom ash was screened to remove the oversized particles and the material passing 5 mm used to prepare the mortar. The chemical composition of coal bottom ash is given in Table 1. Chemical analysis show that coal bottom ash of Tefereyre is mainly composed of silica and alumina. Physical properties of coal bottom ash used in this study are shown in Table 2.

The particle size distribution of coal bottom ash is presented in Fig. 1. Coal bottom ash contains 50% particles passing through a 125 μm sieve compare to 63 μm in the case of natural sand. Fig. 2 represents photographs of coal bottom ash aggregates. Pore-size distribution of bottom ash was determined by nitrogen adsorption. As shown in Fig. 3, pore diameter between 20 Å and 250 Å present less small pores below 50 Å than large pores (between 50 Å and 250 Å).

From the SEM image shown in Fig. 4, it was observed that the coal bottom ash had angular shape and many micropores on the surface. Fig. 5 shows the absorption kinetics of coal bottom ash aggregates. In this figure, we can notice that the kinetic curve is in two parts. The first, substantially linear, characterized by a steep slope, expresses the high water absorption of the aggregates within five (5) minutes. The second curvilinear portion stabilizes after 60 min; it characterizes saturation particles. This high absorption can be explained by the porous structure of the coal bottom ash grains as observed in Fig. 4.

Table 1
Chemical composition of coal bottom ash [18].

Oxides content [%]	Coal bottom ash
SiO_2	62.32
Al_2O_3	27.21
FeO	3.57
K_2O	2.58
TiO2	2.15
MgO	0.95
Na_2O	0.7
CaO	0.5
MnO	0.01

Table 2
Physical properties of natural sand and coal bottom ash.

Types of aggregates	Sand	Coal bottom ash
Apparent density [kg/m^3]	1617	770
Specific gravity	2.71	2.22
Water absorption by mass after 24 h [%]	-	20.15
Fineness modulus	2.51	2.71

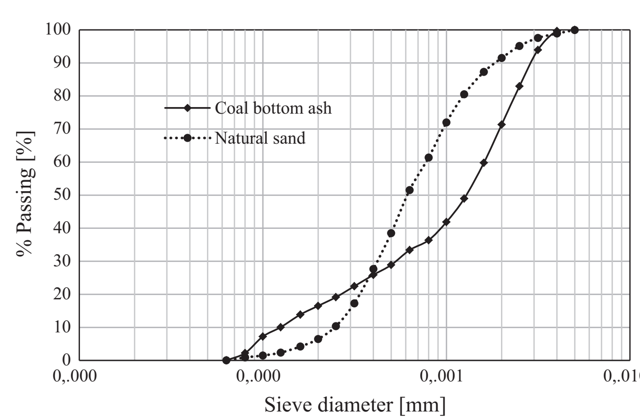

Fig. 1. Grading curve for bottom ash aggregates/natural sand.