Available Online at http://www.journalajst.com

ASIAN JOURNAL OF
SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 16, Issue, 01, pp. 13398-13402, January, 2025

RESEARCH ARTICLE

SUSTAINABLE USE OF PLASTER AND COAL BOTTOM ASH FOR THE DEVELOPMENT OF INNOVATIVE CONSTRUCTION MATERIAL

Saley Mahamadou[1*], Abass Saley Abdoulatif[1] and Kailou Djibo Abdou[2]

[1]Ecole des Mines, de l'Industrie et de la Géologie (EMIG), BP 732, Niamey, Niger
[2]Ecole Africaine des Métiers de l'Architecture et de l'Urbanisme, BP 2067, Lomé, Togo

ARTICLE INFO

Article History:
Received 19th November, 2024
Received in revised form
19th December, 2024
Accepted 30th December, 2024
Published online 22nd January, 2025

Keywords:
Coal bottom ash, plaster,
Recycling, Niger.

ABSTRACT

Mineral coal bottom ash, a residue from power plants, is an under-exploited industrial waste in Niger despite its interesting properties, notably its low density. This study aims to add value to this material by developing an economical, high-performance composite combining bottom ash powder (≤80 microns) and construction plaster, intended for interior applications such as false ceilings, wall coverings and decorations. Mortars with different proportions of clinker (0-70%) were formulated to assess their mechanical strength and thermal conductivity. The results show that replacing plaster with 20-35% clinker optimizes technical performance, with a 1.32-fold increase in compressive strength for 20% clinker. Thermal properties are also unaffected. This composite material offers an economically advantageous solution, by reducing the cost of construction materials and valorizing the large stocks of bottom ash accumulated, notably at the SONICHAR company in Niger. This approach contributes to the sustainable management of industrial waste while meeting the needs of the construction sector.

Citation: Saley Mahamadou, Abass Saley Abdoulatif and Kailou Djibo Abdou. 2025. "Sustainable use of Plaster and coal bottom ash for the Development of Innovative Construction Material", *Asian Journal of Science and Technology*, 16, (01), 13398-13402.

INTRODUCTION

Coal Bottom Ash (CBA) is one of the residues left over from the combustion of coal-fired power plants. Its low density makes it a potentially interesting material for interior use in buildings, notably for false ceilings, insulating walls and decorations. With this in mind, we are interested in studying a composite material made from coal bottom ash powder and plaster. If justified, this combination would contribute to the management of the several thousand tonnes (Omar 2022) of coal bottom ash stockpiled by the Anou Araren coal company of Niger (SONICHAR) in the north-east of the Republic of Niger. The aim of this study is therefore to formulate a building material composed of 80-micron sieved mineral coal bottom ash and construction plaster, to make a composite material that can be used for false ceilings, wall cladding and various decorative applications. If this combination does not alter the essential properties of plaster, it will make this construction material more affordable in terms of cost and availability.

MATERIALS AND METHODS

Coal Bottom Ash: Coal bottom ash is a fairly heterogeneous and highly porous material, with a porosity of around 70% (Mahamadou *et al*. 2024). This material is characterized by interesting pozzolanic properties (Mahamadou *et al*. 2021), making it a promising raw material for the elaboration and/or improvement of hydraulic binders. At the boiler outlet, mineral coal bottom ash comes in the form of aggregates of varying dimensions, with characteristics depending on the base coal and the technology used. According to (Mahamadou *et al*, 2024), the oxides encountered in most cases are: silica SiO_2, alumina Al_2O_3, iron oxide Fe_2O_3, lime CaO, magnesia MgO, sodium oxide Na_2O, potassium oxide K_2O, titanium oxide TiO_2, phosphorus oxide P_2O_5, sulfuric anhydride SO_3. Table 1 lists some of the chemical compositions found in the literature. In this study, the fractions used are those passing through an 80 µm sieve (Figure 1) and whose particle size curve is shown in Figure 2.

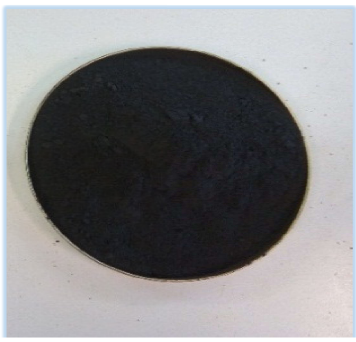

Figure 1. Coal Bottom Ash powder

Corresponding author: Saley Mahamadou,
Ecole des Mines, de l'Industrie et de la Géologie (EMIG), BP 732, Niamey, Niger

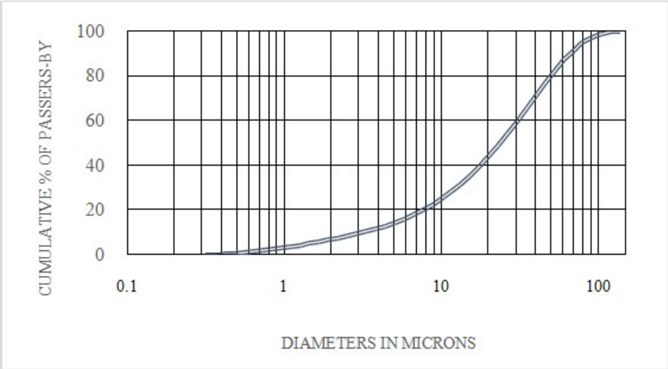

Figure 2. Particle size distribution of CBA 0/80 µm

Plaster: The plaster used in our study comes from the Egyptian company PLATERIE EL DJABAS with the following characteristics provided by the manufacturer:

- H_20 crystallization: 4.30;
- Compressive strength: 13.26 MPa;
- Flexural strength: 03 MPa;
- Recommended water/plaster ratio: 0.70 to 0.80 ;
- Setting time: 4 min to 6 min ;
- Setting time: 8 min to 15 min.

METHODOLOGY

To assess the performance of the CBA-plaster (M-P) material, we produced 4x4x16 (cm) prismatic specimens using mortars containing clinker and construction plaster in varying proportions. For this purpose, 07 types of mixes were produced in accordance with the proportions shown in Table 2. These mortars will be used to assess the impact of the addition of clinker powder on the mechanical strength of the plaster.

Table 1. Chemical composition of CBA

Auteurs	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2	P_2O_5	SO_3
(Men, Argiz 2021)	52,2	27,5	6	5,9	1,7		0,57	1,53	0,74	0,13
(Singh, Bhardwaj 2020)	65.02	19.18	6.86	1.76	2.00	0.85	-	0.93	0.04	-
(Hashemi et al. 2019)	50.49	27.56	10.93	4.19	1.24	0.57	0.82	2.23	0.24	0.10
(Sigvardsen, Ottosen 2018)	47.1	23.1	5.7	7.8	1.5	0.7	5.3	1.2		1.5
(Oruji et al. 2017)	58.7	20.1	6.2	9.5	1.6	0.1	1.0	-	1.0	0.4
(Shahbaz et al. 2017)	44.10	9.21	24.30	13.00	1.88	–	1.25	–	–	–
(Baite et al. 2016)	62.32	27.21	3.57	0.50	0.95	0.70	2.58	2.15	-	-
(Singh, Siddique 2016)	56.44	29.24	8.44	0.75	0.4	0.09	1.24	-	-	-
(Arenas et al. 2015)	64.45	15.89	7.77	3.92	2.45	0.89	1.6	-	<0.01	<0.01
(Menéndez et al. 2014)	49,97	26,95	8,34	8,28	1,12		0,78	2,25	0,95	0,11
(Siddique 2013)	57.76	21.58	8.56	1.58	1.19	0.14	1.08	-	-	0.02
(Lee, Kim, Hwang 2010)	44,2	31,5	8,87	2	2,6		4,04	2,38	0,3	1,34

Table 2. CBA - plaster proportions

Mixes	Proportions (%)	
	CBA	Plaster
M-P0	0	100
M-P1	20	80
M-P2	30	70
M-P3	40	60
M-P4	50	50
M-P5	60	40
M-P6	70	30

M-P specimens are made from mortars with a water/binder ratio (E/L) as defined in Table 3.

Table 3. Water/binder ratio (W/B) of mortars

Mortars	Ratio (E/L)
M-P0	0.5
M-P1	0.5
M-P2	0.5
M-P3	0.55
M-P4	0.55
M-P5	0.6
M-P6	0.6

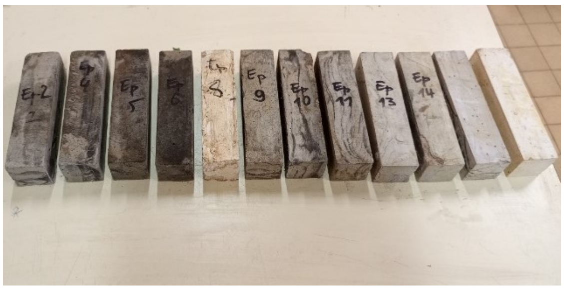

Figure 3. Tests and measurements on M-P specimens

Compression test on M-P specimens: Uniaxial compression tests will be carried out on the various specimens after 07 days, using a universal press fitted with a test body as shown in Figure 4.

Figure 4. M-P Uniaxial compression test

Thermal conductivity measurements on M-P specimens: Measurements will be carried out using the Sciencéthic thermal resistance meter Ref. 005 027 (Figure 5). The measurement principle is based on exploiting the phenomenon of steady-state heat conduction. Under steady-state conditions, when temperatures no longer change over time, each plane has a homogeneous temperature over its entire surface, and the thermal resistance of the material can be determined using the relationship:

$$\mathbf{R_{th}} = \frac{(\mathbf{T1 - T2})}{\mathbf{\Phi}}$$

Rth: wall thermal resistance in K.W-1
T1; T2: temperatures of the two surfaces in degrees Kelvin (K).
Φ: thermal flux or thermal power in watts (W)
A material's thermal resistance depends on its thickness d, surface area S and thermal conductivity λ. It is given by the relationship:

$$\mathbf{Rth} = \frac{d}{\lambda . S}$$

Measurements of Rth and the material's dimensions d and S are used to determine its thermal conductivity λ (W $m^{-1}K^{-1}$).

RESULTS

Compressive strength: The average 7-day fracture stress values obtained for the different M-P series are shown in the histogram in Figure 6, which compares compressive strengths as a function of clinker content.

Thermal conductivity: The results of thermal conductivity measurements on M-P specimens are listed in Table 4 below.

Figure 5. Thermal resistance meter (Manufacturer: Sciencéthic, Ref.005-027)

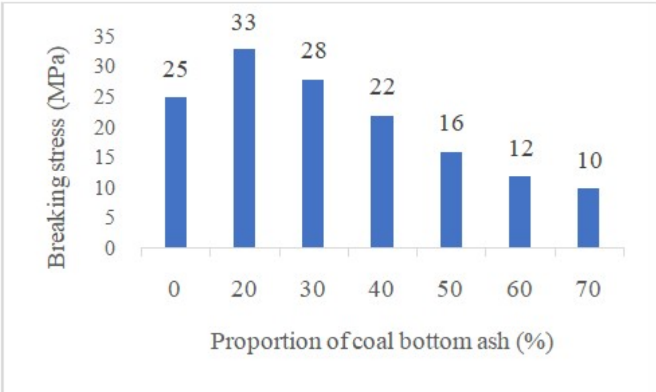

Figure 6. Compressive strength of M-P mortars

Table 4. Thermal conductivity of M-P specimens

Mortars	λ (W/mK)
M-P0	0,375
M-P1	0,384
M-P2	0,39
M-P3	0,392
M-P4	0,401
M-P5	0,401
M-P6	0,402

ANALYSIS AND DISCUSSION

Analysis of the curve showing the evolution of the average break stress of M-P specimens as a function of the rate of substitution of plaster by CBA (Figure 7) shows an increase in compressive strength for clinker proportions not exceeding 35%. In other words, the addition of CBA to this mix can save up to 35% plaster, with compressive strengths much higher than those obtained with plaster mortar alone (25 MPa). From the graph in Figure 8, it can be seen that the thermal conductivity of the specimens increases with the rate of CBA substitution. Although this increase is slight, it can be concluded that Coal Bottom Ash is thermally less resistant than plaster.We then note that, as in the case of (Amina 2015) who worked on “the study of the durability and thermo-phonic behavior of gypsum concretes reinforced with date palm plant fibers", the addition of the secondary constituent did not significantly alter the thermal properties of the plaster.

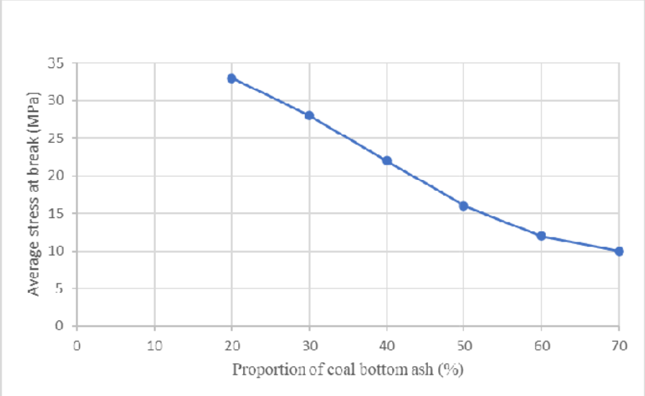

Figure 7. Evolution of break stress as a function of the proportion of CBA

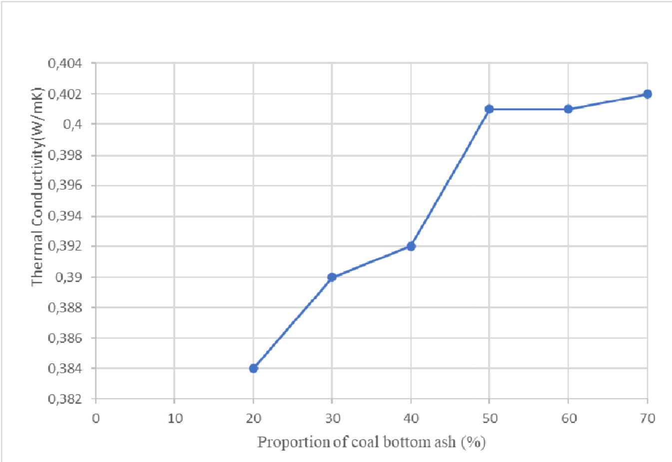

Figure 8. Thermal conductivity as a function of % CBA

M-P panels can be used in various parts of buildings, including infill walls, insulation systems and decorative elements, as shown in the illustration in Figure 9.

Figure 9. Building with M-P walls

CONCLUSION

The study of different M-P mixes reveals the possibility of improving the technical performance of plaster. Indeed, adding clinker powder to plaster in a substitution proportion not exceeding 35% considerably increases compressive strength (up to 1.32 times for 20% clinker). The thermal conductivity values obtained on all the specimens suggest good insulating properties. However, the higher the clinker content in the mortar, the lower the thermal resistance of the mix.

Acknowledgements: The authors expressed their gratitude to all those who helped make this work a success.

REFERENCES

Amina, D. 2015. *Etude de la durabilité et du comportement thermo-phonique des bétons de plâtre renforcés par des fibres végétales du palmier dattier*. Ecole Nationale Polytechnique - Alger.

Arenas, C., Leiva, C., Vilches, L. F., Cifuentes, H., & Rodríguez-Galán, M. 2015. Technical specifications for highway noise barriers made of coal bottom ash-based sound absorbing concrete. *Construction and Building Materials*, *95*, 585–591. https://doi.org/10.1016/j.conbuildmat.2015.07.107

Baite, E., Messan, A., Hannawi, K., Tsobnang, F., & Prince, W. 2016. Physical and transfer properties of mortar containing coal bottom ash aggregates from Tefereyre (Niger). *Construction and Building Materials*, *125*, 919–926. https://doi.org/10.1016/j.conbuildmat.2016.08.117

Hashemi, S. S. G., Mahmud, H. Bin, Ghuan, T. C., Chin, A. B., Kuenzel, C., & Ranjbar, N. 2019. Safe disposal of coal bottom ash by solidification and stabilization techniques. *Construction and Building Materials*, *197*, 705–715. https://doi.org/10.1016/j.conbuildmat. 2018.11.123

Lee, H. K., Kim, H. K., & Hwang, E. A. 2010. Utilization of power plant bottom ash as aggregates in fiber-reinforced cellular concrete. *Waste Management*, *30*(2), 274–284. https://doi.org/10.1016/j.wasman.2009.09.043

Mahamadou, Saley, Abdoulatif, A. S., Abdou, K. djibo, Nourou, M. L. S., & Mounir, and Z. M. 2024. Sustainable Use of Recycled Plastic and Coal Bottom Ash in the Development of Construction Material. *International Journal of Environment and Climate Change*, *14*(12), 104–114. https://doi.org/https://doi.org/10.9734/ijecc/2024/v14i124610 Open

Mahamadou, SALEY, Mahamadou, I., Abdoulatif, A. S., Nourou, S., & Zibo, G. 2021. Introduction to the development of a hydraulic road binder based on mineral coal bottom ash. *IJAR*, *9*(02), 766–772. https://doi.org/10.21474/IJAR01/12510

Men, E., & Argiz, C. 2021. Reactivity of Ground Coal Bottom Ash to Be Used in Portland Cement. *Multidisciplinary Scientific Journal*, 223–232.

Menéndez, E., Álvaro, A. M., Hernández, M. T., & Parra, J. L. 2014. New methodology for assessing the environmental burden of cement mortars with partial replacement of coal bottom ash and fly ash. *Journal of Environmental Management*, *133*, 275–283. https://doi.org/10.1016/j.jenvman.2013.12.009

Omar, Y. B. 2022. *Caractérisation et valorisation des mâchefers du charbon minéral de la Sonichar*. Ecole des Mines, de l'Industrie et de la Géologie.

Oruji, S., Brake, N. A., Nalluri, L., & Guduru, R. K. 2017. Strength activity and microstructure of blended ultra-fine coal bottom ash-cement mortar. *Construction and Building Materials*, *153*, 317–326. https://doi.org/10.1016/j.conbuildmat.2017.07.088

Shahbaz, M., Yusup, S., Inayat, A., Patrick, D. O., & Ammar, M. 2017. Cleaner Production of Hydrogen and Syngas from Catalytic Steam Palm Kernel Shell Gasi fi cation Using CaO Sorbent and Coal Bottom Ash as a Catalyst. *Energy & Fuels*. https://doi.org/10.1021/acs.energyfuels.7b03237

Siddique, R. 2013. Compressive strength, water absorption, sorptivity, abrasion resistance and permeability of self-compacting concrete containing coal bottom ash. *Construction and Building Materials*, *47*, 1444–1450. https://doi.org/10.1016/j.conbuildmat.2013.06.081

Sigvardsen, N. M., & Ottosen, L. M. 2018. Characterization of coal bio ash from wood pellets and low-alkali coal fly ash and use as partial cement replacement in mortar. *Cement and Concrete Composites*, *95*, 25–32. https://doi.org/10.1016/j.cemconcomp.2018.10.005

Singh, M., & Siddique, R. 2016. Effect of coal bottom ash as partial replacement of sand on workability and strength properties of concrete. *Journal of Cleaner Production*, *112*, 620–630. https://doi.org/10.1016/j.jclepro.2015.08.001

Singh, N., & Bhardwaj, A. 2020. Reviewing the role of coal bottom ash as an alternative of cement. *Construction and Building Materials journal*, *233*.

****