Physico-chemical and Geotechnical Properties of Moroccan Phosphate Mining By-Products for the Application of Compacted Earth Bricks

M. Dadda, L. Saadi, K. Abdelouhadi, Y. Daafi, and M. Waqif

Abstract

This work aims to evaluate the potential use of phosphate mine waste rock as a base material for compacted earth brick (CEB) production. Thus, a by-product generated in significant quantities by exploiting deposits in El Youssoufia in Morocco was the subject of the present investigations. First, it was necessary to proceed to the mineralogical analysis of our samples by XRD, FTIR, and X-ray fluorescence. Then, other types of analysis were performed, such as DTA/TGA and morphological analysis by SEM–EDX. Finally, geotechnical characterization was performed by standard tests. The physico-chemical and geotechnical characterization results showed that the by-product consists mainly of quartz, limestone, and a small percentage of clay minerals. The specimens were prepared from a mixture of 70% of the by-product, 30% crushed sand, 1% Filasse fiber, and 8% cement. Mechanical and physical characterization tests were performed after 7 and 28 days of curing. The results of the mechanical compression tests revealed that the adopted mix achieved optimal mechanical properties. In addition, water absorption tests by capillary action showed a reduction in water absorption by increasing the percentage of cement.

Keywords

Waste rock · Phosphate mines · Compacted earth bricks · Compressive strength · Capillarity · Geotechnical characterization · Filasse

M. Dadda (✉) · L. Saadi · K. Abdelouhadi · M. Waqif
IMED-Lab, Faculty of Sciences and Techniques, Cadi Ayyad University (UCA), 40000 Marrakech, Morocco
e-mail: dadda.mohamed.b@gmail.com

Y. Daafi
UMP6, 43150 Benguerir, Morocco

1 Introduction

Morocco's building sector is the second most energy-intensive sector, accounting for 33.6% of total final energy consumption (AMEE), resulting in the depletion of natural resources and major environmental problems like global climate change. Therefore, interest in alternative building materials like the earth has increased to satisfy environmental and economic demands. Earthen construction can take many forms like adobes, cob, CEB (Hubert Guillaud, 2015)… However, the disadvantage of earthen constructions is the low resistance to humidity, which is the subject of several researches (Abid et al., 2021).

Several pieces of research have focused on utilizing the waste mining generated by the phosphate (El Machi, 2020) industry. The present work is aimed at the valorization of the phosphate waste mine on manufacturing compacted earth blocks (CEB). The specimens were prepared from a mixture of waste rock, crushed sand, the filasse fiber. This later allows CEB to be prepared with high mechanical and physical characteristics and reduce the water absorption ratio.

2 Materials and Technical Methods

2.1 Identification of Materials

The materials used are waste rock, crushed sand, and filasse fiber. The properties of these starting materials were performed according to the characterization methods detailed by Ajouguim et al. (2020). The properties are shown in Tables 1, 2, 3 and 4.

A. Çiner et al. (eds.), *Recent Research on Environmental Earth Sciences, Geomorphology, Soil Science, Paleoclimate, and Karst*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-031-42917-0_12

Table 1 Compositions of the different formulations prepared

Code	Earth%	Sand%	Cement%	Fiber%
Ar	100	–	–	–
ArSa	70	30	–	–
ArSaF	70	30	–	–
ArSaC8%	70	30	8	–
ArSaCF8%	70	30	8	1
ArSaC6%	70	30	6	–
ArSaCF6%	70	30	6	1
ArSaC4%	70	30	4	–
ArSaCF4%	70	30	4	1

Sample codifications: Ar (earth), ArSa (earth + sand), ArSaF (earth + sand + filasse fiber), ArSaC (earth + sand + cement), and ArSaCF (earth + sand + cement + filasse fiber)

Table 2 Physical characteristics of the earth

Grain size distribution	Atterberg limits	The methylene blue test
Clay <2 μm: 32.8% Silt 2–20 Cμm: 19.62% Sand 20–0.2 μm: 47.58%	Liquid limit, WL = 70 The plastic limit, WP = 48 Plasticity index IP = 22	VBS = 4.21

Table 3 Chemical composition of the earth

Elements	Values%
SiO_2%	58.64
CaO%	20.34
Al_2O_3%	9.709
MgO%	7.728
Fe_2O_3%, MnO%, K_2O%, Na_2O%, TiO_2%, P_2O_5%	3.58

Table 4 Characteristics of the sand crashed

Characterization	Values
Apparent density (kg/m^3)	1.49
Specific density (kg/m^3)	2.67
Fines model (%)	9.29
Sand equivalent (%)	60.22

The soil is intercalated clays generated in significant quantities by exploiting deposits located in El Youssoufia in Morocco, Fig. 1.

The sand used to prepare specimens is crushed sand (0/5). The physical characteristics are grouped in Table 3.

2.2 Preparation of the Specimens

Based on the specimen preparation methodology proposed by Ajouguim et al. (2020), mass percentages of filasse fiber and cement were used in the earth and crushed sand mixture to prepare CEB blocks. The compositions of the different formulations of CEB are shown in Table 1.

3 Results and Discussions

The mechanical and physical properties of the CEB blocks were performed according to the characterization methods detailed by Ajouguim et al. (2020). The mechanical and physical characterization of the CEB bricks prepared are shown in Table 5.

The addition of the fibers led to an increase in compressive strength. This is due to the incorporation of the fibers in the composites, which will prevent the propagation of cracks.

The stabilization of the specimens by cement decreased the moisture content, Bruno et al. (2017) as well as an improvement in the behavior of the specimens with respect to capillarity, Fig. 2. which is a normal result because cement increases moisture resistance.

4 Conclusions

This work has shown the possibility of manufacturing CEB blocks using phosphate waste stabilized by cement and reinforced by filasse fibers. The obtained results allowed for getting interesting mechanical properties. However, the behavior of the porosity remains weak, which leads us to other studies to enhance the behavior of the CEB blocks in the presence of moisture and porosity.

Fig. 1 Visual aspect of the earth studied

Table 5 Mechanical and physical characterization of CEB bricks

Specimens	Mechanical properties				Physical properties
	Compressive strength at 7 days (Mpa)	Compressive strength at 28 days (Mpa)	Young's modulus (Mpa) at 7 days	Young's modulus (Mpa) at 28 days	Absorption test (%)
Ar	3,25	10,57	621,83	590,72	10
ArSa	5,25	9.32	404,9	504,1	5
ArSaF	7,55	19,55	239,37	761,84	4
ArSaC4%	7,06	12,66	487,06	570,6	3
ArSaCF4%	9,50	22,30	301,34	969,19	3,2
ArSaC6%	10,11	12,14	635,41	646,98	4
ArSaCF6%	8,67	27,16	261,15	1108,68	4
ArSaC8%	11,43	13,41	505,6	723,95	3
ArSaCF8%	11,50	31,90	386,61	1241,09	3.1

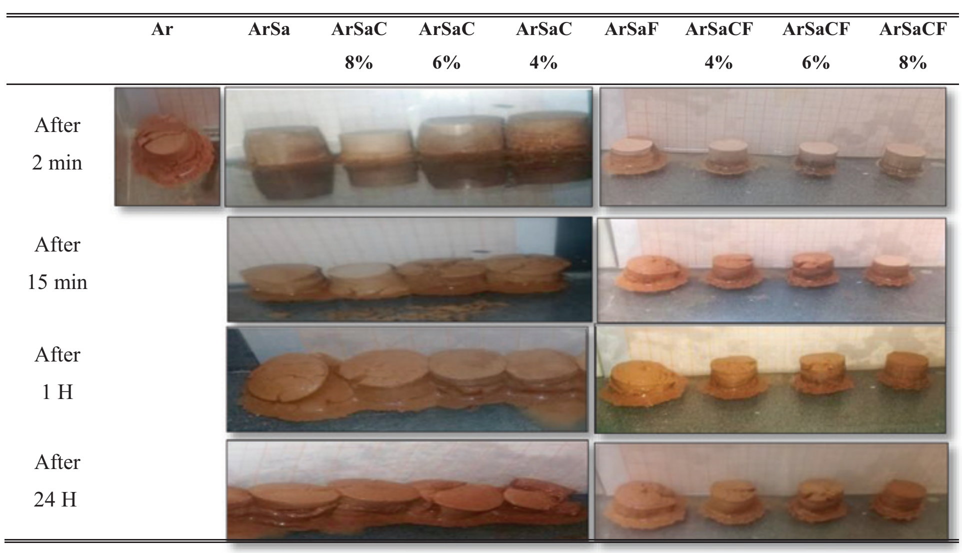

Fig. 2 Results of water absorption by capillarity

References

Abid, R., Kamoun, N., Jamoussi, F., & El Feki, H. (2021). Fabrication and properties of compressed earth brick from local Tunisian raw materials. *Bol la Soc Esp Ceram y Vidr*, 1–11. Published online.

Ajouguim, S., Talibi, S., Djelal-Dantec, C., et al. (2020). Effect of Alfa fibers on the mechanical and thermal properties of compacted earth bricks. Materials Today: Proceedings. Published online.

AMEE Homepage. Retrived from, Jul 30, 2021, http://www.amee.ma

Bruno, A. W., Gallipoli, D., Perlot, C., & Mendes, J. (2017). Effect of stabilisation on mechanical properties, moisture buffering and water durability of hypercompacted earth. *Construction and Building Materials, 149*(September), 733–740.

El Machi, A., Mabroum, S., Taha, Y., Tagnit-Hamou, A., Benzaazoua, M., & Hakkou, R. (2020). Valorization of phosphate mine waste rocks as aggregates for concrete. *Materials Today: Proceedings, 37*, 3840–3846.

Hubert Guillaud, H. H. (2015). Traité de construction en terre. *J des Africanistes*, *60*(1), 165–167.