Thermal, Mineralogical and Chemical Properties of Soil Building Blocks for Eco-Habitat Sustainable

A. AMMARI[1,2*], N. ZAKHAM[1], K. BOUASSRIA[3], H. BOUABID[1], M. CHERRAJ[1], S. CHARIF D'OUAZZANE[4], M. IBNOUSSINA[5]

[1]National School of Architecture of Marrakech

[2]Laboratory of Mechanics and Materials, Faculty of Science, Mohammed University, Rabat, Morocco

[3]LSIMO, Faculty of Science, Ibn Tofail University, Kenitra, Morocco

[4]LMTM, National School of Mineral Rabat, Morocco

[5]Université Cadi Ayyad, Lab. Géoenvironnements/Géorisques/Géotechnique, Marrakech, Morocco

* abdelmalek09@gmail.com

Keywords: Earth, Mineralogical, Chemical, Thermal Conductivity, Eco-Habitat

Abstract. The purpose of this study is to investigate the relationship between the thermal conductivity of Compressed Earth Block Stabilized (CEBs) by cement and the results of mineralogical and chemical examinations of the soil. The soil was taken from the Moroccan city of Fez. That; determination of the thermal conductivity of CEBs plays an important role when considering it's suitability for energy saving insulation. The measurement technique used in this study to determine thermal conductivity is hot ring method the thermal conductivity of the tested samples is strongly affected by the quantity of the cement added. The mineralogical and chemical analysis show the soilof Fez, mainly composed of the calcite, quartz and dolomite improved the behaviour of the material by the addition the optimum content of cement. The findings suggest that to manufacture lightweight samples with high thermal insulation properties, it is advisable to use clays that contain quartz. Ina ddition, quartz has high thermal conductivity.

1. Introduction

This paper recommends a more technical and scientific approach to sustainable housing, which acknowledges its multiple functions as a socio-cultural system and physical. In order to guarantee prosperous residential areas, it seeks to enhance and harmonize the environmental, material, cultural, and economic dimensions of eco-habitat sustainability. Sustainable housing is often considered primarily from an ecological point of view.

Since the earliest ages, the human has been keen to provide an environment suitable for housing. The human has developed his treatments for the surrounding environmental conditions through continuous experiments and accumulated experience in the practice of construction, has developed his treatments for the surrounding environmental conditions through continuous experiments and accumulated experience in the practice of construction. And we sable to recognize the characteristics of building materials and then use them to the maximum extent to meet his needs and requirements, because the internal environment of the building is very important for human comfort and this environment depends on several factors and the disruption of one of these factors upset the balance of this environment, and the temperature is at the top of the factors that must be controlled within the ranges of human comfort.

The present study investigates the impact of the initial raw material mixture mineralogical and chemical composition on the dry state thermal conductivity of eco-habitat sustainable CEB samples [1]. Furthermore, a study was conducted to examine the impact of varying proportions of cement addition on the thermal conductivity of material composed of soil reinforced by compression at a pressure of two MPa [2]. The need of developing soil stability with materials is low cost and environment friendly is necessary, with simple rates of stability and limited and according to the standards, we have used cement for stabilization because they are safe, effective and affordable soil stabilizers.

2. Materials and methods

2.1 Material

A leftover natural soil that came from the Fes city, Morocco site centre that F mentioned in this work. The materials used were soil and cement. The soil came from the Moroccan region of Fez, which is well-known for its earthenware industry and traditional stability pottery production, and the cement type used was CPJ 35 Portland. The compressed earth block samples, we have mixed soil used and stabilised with content of cement, with a mechanical compressive strength of 2 MPa and placing the mixture into moulds that is compressed by machine, and then left it to dry away from the ambient temperature for a 28 days to allow the cement to reach its maximum strength. In this study, we used cement dosing to manufacture soil block, with also a few ratios doses of cement (0%;4%; 7% and 10% of cement). Every sample is cylinder-shaped, measuring 12 cm in height and 8 cm in diameter. Every sample was split into two halves. Prior to testing, the samples were dried. This took place over the course of 72 hours in an electric oven set to 60 °C until the mass of the samples stabilized. Utilizing a hot ring method apparatus, the thermal conductivity was calculated. The device consists of a hot ring probe that uses a kapton slab to measure the thermal conductivity.Positioned between two test pieces of the CEB samples to be characterized or submerged in the medium, the hot-ring device works on the slab of kapton principle. After that, a heat flow is created by injecting current in the ring. This movement of heat eliminates the specimen's CEBs over a predetermined period of time before reaching the ring's centre, where the measurement is made. The heating period of 400 s, the measurement time of 500 s, and the heating power of 2 W were the same for every sample in our experiment.

2.2 Methods

2.2.1 Measurement of thermal conductivity

The specimens' thermal conductivity was determined in this work using the process of hot rings. the process of hot rings predicts the CEB specimens' thermal conductivity by using the temperature evolution. The thermal conductivity is determined using the hot ring probe, also known as the hot-ring apparatus slab of kapton. The hot-ring apparatus's slab kapton is positioned in the middle of the CEB specimens between two components, and current is subsequently pumped into the ring to create a heat flow. The heat flow within the CEB sample diminishes and eventually reaches the centre of the ring, where a thermocouple is positioned for temperature measurement (fig. 2).The element that needs to be described is thought of as an isotropic, homogenous, infinite medium. Thermal measurements were performed on the dry specimens. The drying process was done in an electric laboratory oven at 60 °C until the specimens' mass stabilized (i.e., there was no water present). The drying period for each test was 72 hours. In our experience, the hot ring method's thermal parameters were as follows: heating power of 2 W, measurement time of 500 s, heating time of 400 s, and probe resistance of 2.5 Ω. These parameters remained consistent for every specimen during the experiment. We used a multimeter (hot ring method) (Fig.1)[1].

Fig. 1. Hot ring method

3. Results and discussion

3.1 Chemical and mineralogy analysis

3.1.1 Analysis of X-ray fluorescence [2]

The table 1 show that the chemical composition of clay in clay F.

Table.1: Thechemical elements of clay F

Composition	**clay of Fez (%)(*)**
Cao	**31,8**
SiO_2	**22,3**
Fe_2O	1,72
K_2O	0,536
SO_3	1,29
Al_2O_3	5,96
TiO_2	0,226
P_2O_5	0,753
MnO	0,0503
Na_2O	0,323
SrO	0,0125
Loss on ignition at975°C)	32,9

3.1.2 X-ray diffraction analysis of clay F

The soil F (Fig. 2) stabilised at 0% and 4% cement with X-ray analysis revealed the formation of high peaks of calcite; quartz; and dolomite. The calcite, quartz, and silicate of aluminum that make up the majority of the block of the same earth of F (Fig. 3), enhance the material enhanced thermal conductivity and behavior [2].

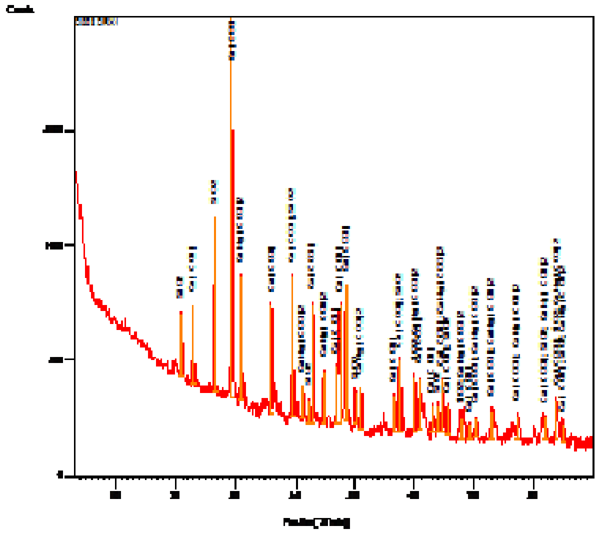

Fig. 2: X-ray diffractogram of studied clay of the soil F[2]

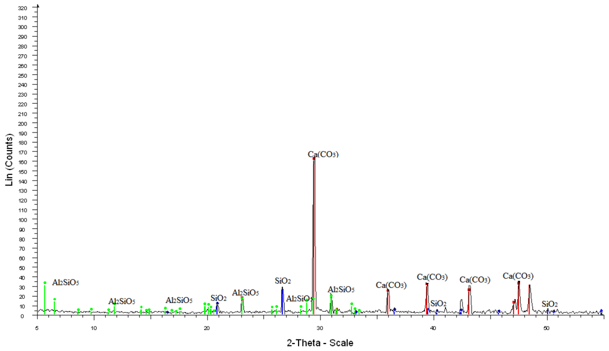

Fig. 3: X-ray diffractogram of studied clay stabilized with 4% of cement for the soil F block[2]

3.2 Thermal results and discussion

The hot-ring technique is a temporary approach for establishing a material thermal conductivity. Samples are heated to a higher temperature when the hot-ring apparatus's kapton slab begins to heat them.

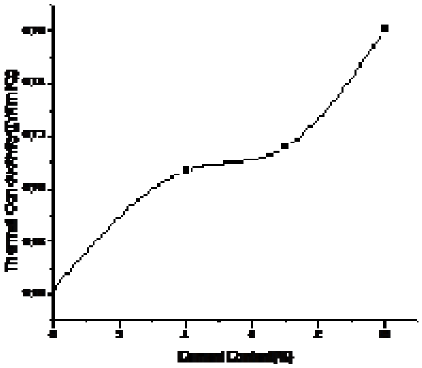

Fig.4 Impact of cement dosage in thermal conductivity

Figure 4 shows that stabilizing samples with cement increases their thermal properties; increased cement content in the blocks results the increased thermal conductivity

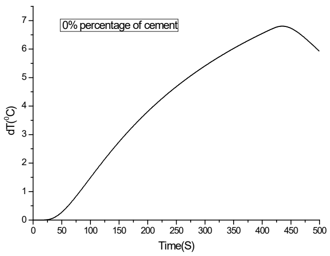

Fig.5. The temperature variation curve, dT(0C), in the CEBs at 0% cement dose versus time (s) .

The temperature evolution in sample 1 with 0% cement content is depicted in Figure 5. Sample 1's density is 1654,6 (kg/m3), Specific heat is 1023,4 (J/kg.k) and thermal of conductivity is 0,662 (W/m.K).

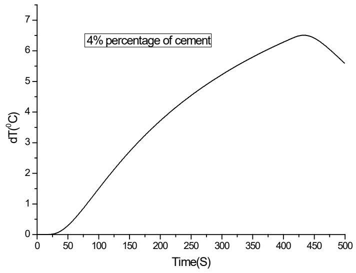

Fig.6. The curve of the temperature variation dT(^{0}C) in the CEBs at 4% dose of cement versus time (s).

The temperature evolution in sample 2 with a 4% cement dosage is depicted in Figure 6. The density is 1722,6 (kg/m3), Specific heat is 1029,4 (J/kg.k) and thermal of conductivity is 0,707 (W/m.K).

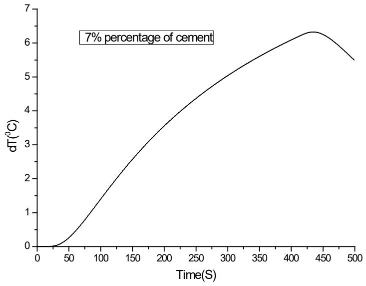

Fig.7. The curve of the temperature variation dT(^{0}C) in the CEBs at 7% dose of cement versus time (s).

Figure.7, shows that the evolution of the temperature in sample 3 with 7% dosage of cement, density of sample 3 =1749,9 (kg/m3) ,thermal conductivity =0,716 (W/m.K), specific heat= 1035,8 (J/kg.k).

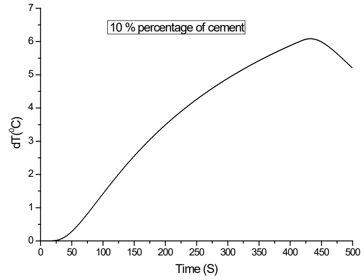

Fig.8. The curve of the temperature variation dT(^{0}C) in the CEBs at 10% dose of cement versus time (s).

The temperature evolution in sample 4 with a 10% cement dosage is depicted in Figure 8. The density is 1822.6 (kg/m3), specific heat is 1040.7 (J/kg.k) and thermal of conductivity is 0.761 (W/m.K).

The heat transfer is affected when the hot-ring measuring method is applied to samples of CEBs, from the figures 5 to 8, as can be observed, the temperature variation curve for the CEBs specimens with varying cement stabilizer contents. Thermal conductivity vary with the temperature difference, in this experiment we used the same parameters for all the samples, which there were as follows the heating time= 400s, the measure time=500s and the heating power = 2 W, for the reason all that is necessary to understand is how cement dosage affects thermal conductivity. According to the behaviour of temperature in the curves 5,6,70 and 8, the high temperatures continue the increase in to 450°C, after that start it to decrease, because in the experimental parameter the heating time was 400s for each sample.

The main mineral in sand and gravel is quartz, which has a significantly higher thermal conductivity than other minerals. Consequently, variations in the mineral composition lead to variations in thermal conductivity. The quartz content of the material used in Lei Zhang et al. study was significantly higher than ours, and their research revealed a more noticeable quartz decrease for the same porosity increase, causes a more noticeable decrease in thermal conductivity [3]. The percentage of $CaCO_3$ rises with the addition of cement; it reacts with H_2O to produce $Ca(OH)_2$ + CO_2, the CO_2 gas that is produced during the breakdown. This probably explains why, in 0% of the cement content, the real part of the conductivity decreased [4]. Zhaoyu Wang et al. [5] found an excellent linear correlation between thermal conductivity and average $CaCO_3$ content. According to research by A. Ammari et al., in order to fix inert clay particles, the amount of lime needed between 1% and 3% by weight of soil must be greater than the fixation limit. Furthermore, a portion of the fine sand makes up the quartz, which is not a binder [2,6,7,9]. As a result, the carbonation of the lime cements the quartz grains in the clay Fez. It is commonly known that the presence of SiO_2 results in significantly higher thermal conductivity and an enhanced heat transfer rate. Quartz increases heat conductivity as a result.

It should be highlighted that adding a small amount of cement does not stabilize the sand and gravel fraction (80%) of soil F. This consequences in a slight variation in the thermal of conductivity, ranging from 0% to 4%. The thermal conductivity value grows to 0.75 W/m.K. above 4% of cement. Additionally, the cement has a good coating over the soil F.

Dolomite and calcite decrease the thermal conductivity of the block when process elements are kept constant. This is due to porosity is greatly increased when dolomite and calcite break down at specific temperatures. higher than 700°C. However, dolomite and calcite improve heat conductivity. The crystalline phases of aluminium silicate, calcium and magnesium silicate, and magnesium silicate form in these compositions at temperatures higher than 860°C [8].

Moreover, Eq. 1 provides a summary of the dolomite element powder reaction in cement.

$$6CaMg(CO_3)_2+2Al(OH)_4^-+8OH^-+5H_2OMg_6 \rightarrow Al_2CO_3(OH)_{16}\cdot 5H_2O + 6CaCO_3+ 5CO_3^{2-}. \text{ Eq. 1}$$

Conclusions

The conclusions of this study are as follows:

-The soil of the Fez (F) earth formed by CaO with a high SiO2 (22.3%) mainly because there is a peak of quartz and kaolinite.

- The proportion of the calcite and the small amount of aluminum silicate present in the earthen F test pieces are both increased by the addition of cement.

- The determination of thermal conductivity and the enhancement of soil building blocks for the sustainability of eco-habitats are determined by the mineral and chemical compositions, such as dolomite, quartz, and to a certain extent dolomite.

-Increase thermal conductivity of samples as temperature rises and cement content increases due to cement's ability to interact with soil contents.

- The thermal conductivity is significantly increases due of presence higher percentage of SiO_2

-Increasing the thermal conductivity of the earth's building blocks for eco-habitat sustainability is dependent on the mineralogical and chemical compositions, such as quartz and dolomite.

References

[1] N. Zakham, A. Ammari, Y. El Rhaffari, M. Cherraj,H. Bouabid, K. Gueraoui, A. Samaouali , The Effect of Cement Content ontheThermo-Mechanical Performance of Compressed Earth Block, International Review of Civil Engineering (I.RE.C.E.), Vol. 11,N.6 ISSN 2036 - 9913 November 2020. https://doi.org/10.15866/irece.v11i6.17438

[2] Ammari A., Bouassria K., Cherraj M., Bouabid H., Charif D'ouazzane S., "Combined effect of mineralogy and granular texture on the technico-economic optimum of the adobe and compressed earth blocks", Case Studies in Construction Materials 7 (2017) 240–248. https://doi.org/10.1016/j.cscm.2017.08.004

[3] Lei Zhang, Arild Gustavsen, Bjørn Petter Jelle, Liu Yang, Tao Gao, Yu Wang,. Thermal conductivity of cement stabilized earth blocks., Construction and Building Materials 151 (2017) 504–511. https://doi.org/10.1016/j.conbuildmat.2017.06.047

[4] Štefan Csáki, Tomáš Húlanb, Ján Ondruška, Igor Štubňab, Viera Trnovcováb, František Lukáča,c, Patrik Dobron, Electrical conductivity and thermal analyses studies of phase evolution in the illite – CaCO3 system, Applied Clay Science 178 (2019) 105140. https://doi.org/10.1016/j.clay.2019.105140

[5] Zhaoyu Wang, Nan Zhang, Jinhua Ding , Qi Li, Junhao Xu , Thermal conductivity of sands treated with microbially induced calcite precipitation (MICP) and model prediction, International Journal of Heat and Mass Transfer

[6] Ammari A., Bouassria K., Zakham N., Cherraj M., Bouabid H., Charif D'ouazzane S., "Durability of the earth mortar: Physico-chemical and mineralogical characterization for the reduction of the capillary rise " MATEC Web of Conferences 149, 01024 (2018). https://doi.org/10.1051/matecconf/201714901024

[7] Bouassria K., Ammari A., Tayyibi A., Bouabid H., Zerouaoui J., Cherraj M., Charif D'ouazzane S., "The effect of lime on alumino-silicate and cement on the behavior of compressed earth blocks"., J. Mater. Environ. Sci. 6 (12) (2015) 3430-3435(JMES)

[8] J. Garcı ́a-Ten, M.J. Orts , A. Saburit, G. Silva, Thermal conductivity of traditionalceramics Part II: Influence of mineralogical composition, Ceramics International 36 (2010) 2017–2024. https://doi.org/10.1016/j.ceramint.2010.05.013

[9] Ammari A. , Bouassria K, Tayyibi A, Bouabid H, Cherraj M., Charif D'ouazzane S., Ibnoussina M., "Promotion de la technique du bloc de terre comprimée dans le secteur de la construction par l'amélioration de son comportement mécanique", Journal of Materials and Environmental Science(JMES).