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POTENTIAL USE OF THE EGYPTIAN PALEOZOIC RAW BUILDING MATERIALS AT ABU DARAG AREA GULF OF SUEZ FOR THE FIRED CLAY BRICKS PRODUCTION

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ABSTRACT

The research aimed to study the potential use of Egyptian Paleozoic raw building materials collected from the Abu Darag area, on the western side of the Gulf of Suez, for the manufacture of clay building bricks. Clay and sand samples have been collected from the Carboniferous Abu Darag Formation exposed in the investigated area and have been characterized mineralogically, chemically, physically using different analytical methods and techniques. Through the experimental work, three clay-based mixes have been formulated to prepare cylindrical briquettes with different proportions of sand (10%, 15%, and 20% by weight). The lab-made briquettes after drying were fired at 750 ºC, 800 ºC and 850 ºC in an electrical furnace. Physico-mechanical properties of the fired briquettes have been determined according to ASTM standards and evaluated according to the Egyptian Code 204-2014. The ceramic tests showed that the briquettes color changed to dark brownish red with increasing sand content and firing temperature and the sound of all briquettes are dull. The compressive strength increased with temperature and decreased with sand addition. Also, as iron content (found in sand) increased, the formed phases changed from amphiboles to pyroxenes. The findings indicated that the briquettes of 10% of sand at a sintering temperature equal / over 800 ºC have good technological properties and met the allowable requirements of the Egyptian code for building clay bricks that used as non-load bearing walls.

Key Words: Paleozoic clays; Raw materials; Fired clay bricks; Clay-based mixes; Gulf of Suez; Egypt

INTRODUCTION

Clays are considered to be one of the most important industrial materials used on the earth due to their various uses in different applications such as ceramic products, artifacts, decorative objects, electrical insulators, ovens, chimneys and roofing tiles **(Roudouane *et al.*, 2020)**. Clays and clay minerals are widely utilized in many facets such as, geology, constructions and environmental applications. Traditional applications for clays are many, but the most one is clay brick making. About 1500 billion red clay bricks are manufactured worldwide every year containing 4000 million tons of clay associated with 6.35–12.3 and from 0.52 to 5.9 kg per/1000 bricks for CO and SO_2 gases emission **(Sanad *et al.*, 2021)**. Clays are considered as cheap and sustainable resources for improving the building capacity of local population. Therefore, it is important to give care for energy type and source used in fired bricks manufacture to control environmental impact affected by traditional practices **(Hashemi *et al.*, 2015)**. Clays must be investigated mineralogically, chemically, and technologically to control the quality and type of the yield product. Hence, particular and appropriate characteristics are needed for each ceramic product **(Abdelmalek *et al.*, 2017)**. Particularly, in fired bricks manufacture based on clays, variable parameters can strongly affect the final ceramic product quality, i.e. particle size distribution, plasticity, drying shrinkage, green and dry strengths, water absorption, apparent porosity and wet and dry compressive strength **(Baccour *et al.*, 2009 and Ngun *et al.*, 2011)**. Sand addition in the clay brick mixes reduces a crack formation during the drying process but mainly increase crack amount during firing due to phase changes around 573 ºC, which creates unnecessary stresses in the clay body during the firing process **(Temga *et al.*, 2018)**.

In Egypt, the fired clay bricks manufacture is the most used building materials that can be used for increasing investment growth due to their availability, cost effective, its short process of treatment and technologically affordable. In the area studied (Abu Darag area, west of Gulf of Suez; Fig. 1) and neighboring, geological and geochemical investigation had been performed on the clays and limestones of the Qiseib (Abu Darag area) and Sannor (Qattamiya-Ain Sokhna road) formations for cement industry **(Harraz *et al.*, 2020)**. The results indicated the suitability of limestone of the Sannor Formation and kaolinitic clay of the Qiseib Formation for cement industry with considerable reserve **(Harraz *et al.*, 2020)**. The main objective of the present study is to evaluate suggested clay-based mixes containing different proportions of clay and sand, collected from the Abu Darag Formation (underlying the Qiseib Formation) for the potential use in clay brick industry. This study has been achieved via integrated mineralogical, physical, chemical and physico-mechanical investigations for the raw building materials taken from the area at Wadi Um Galawat between Abu Darag lighthouse and Wadi Araba (west Gulf of Suez, Egypt; Fig. 1), and their prepared fired briquettes.

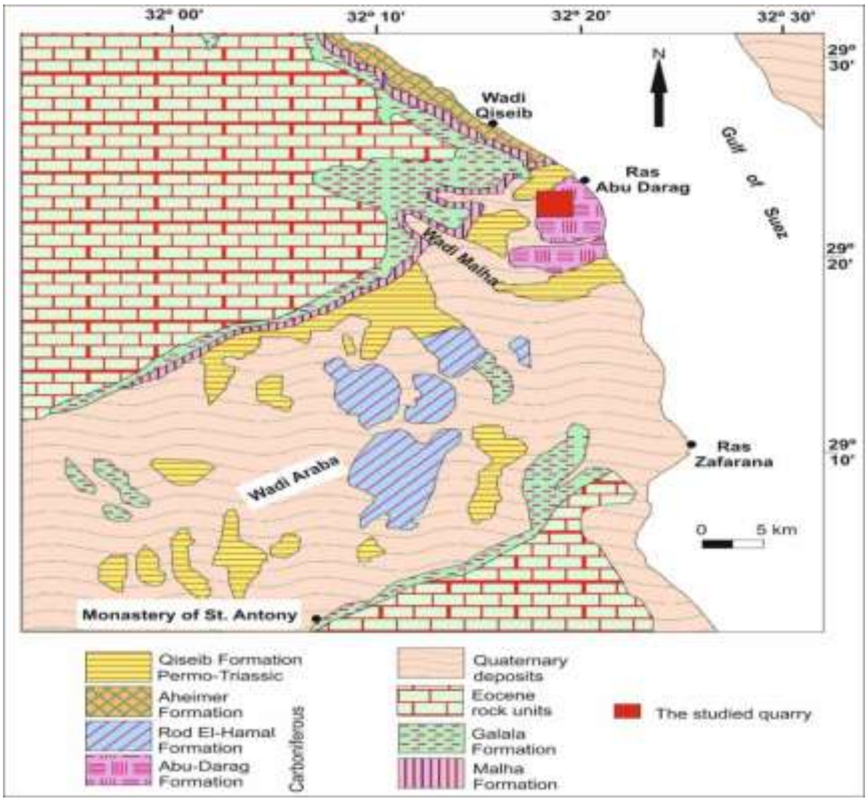

Figure (1). Geologic map of the study area and quarry exploited (after **Wanas and Soliman, 2018**).

2. Geologic Setting of the Study Area

In Egypt, a thick Paleozoic succession is well-exposed on both sides of the Gulf of Suez spanning Cambrian to Permo-Triassic **(Kora *et al.*, 2019)**. Along the eastern side of the Gulf of Suez (Sinai), this succession is well-exposed at the Um Bogma area, Abu Durba and Wadi Feiran. Whilst, along its western coast at the Northern Galala plateau, Abu Darag, Wadi Araba and in Wadi El-Dakhel, the Upper Paleozoic rock units (Carboniferous-Permo-Triassic) occurred. This succession is represented mostly by clastic rocks of conglomerate, sandstone and thick clay-mud rock-shale horizons especially in the Carboniferous rock units **(Kora, 1998)**. The quarry under investigation, where the studied samples were taken, is located between Abu Darag lighthouse and Wadi Araba (west Gulf of Suez, Egypt) where the Paleozoic rock units are represented by the Abu Darag and Qiseib formations (Fig. 1). The Abu

Darag Formation is represented by siliciclastic rocks forming horizons of claystone intercalated with sandstone and pebbly sandstone interbeds **(Kora, 1998)**. The claystone-sandstone horizons form the low-lying areas dragged from the highly faulted Northern Galala Plateau where the area is highly dissected by east-west valleys. These sandstone and kaolinitic clays are quarried by the RHI (Reliance Heavy Industries) quarry for the Arabian Cement Company (ACC) plant for cement and ceramic production **(Harraz *et al.*, 2020)**. The studied building materials (claystone and sandstone) were collected from the Carboniferous Abu Darag Formation at Wadi Um Galawat between Abu Darag lighthouse and Wadi Araba on the western side of the Gulf of Suez, Egypt (Fig. 1). This area is considered as a touristic place where many villages along the coast of the Gulf of Suez are built and no near factories for brick production were observed. Accordingly, evaluation of such materials in the big Paleozoic succession exposed in such area could help in constructing factories for brick industry in such touristic areas for low cost of transportation, investment demand and materials required are found in high reserve for such industry.

The studied samples were taken from a section at the quarried area where it measures about 45 m thick of claystone-sandstone intercalations in repeated cycles (Figs. 2, 3A and B). The claystone-mud rocks are thick-bedded to massive, dry, sandy, kaolinitic, dense, mottled and varicolored, i.e. violet, red, reddish brown, yellow, green and white and vary in thickness from 50 cm up to 10 meters thick (Fig. 3B). Pedogenic features, i.e. red coloration, mottling, desiccation cracking, ferrugination, and nodular fabrics are also common (Fig. 3C, D). These claystone beds are more kaolinitic to the upper part of the succession (Fig. 3E). The sandstones are reddish white, yellow and/or greyish white, thinly-laminated to cross bedded, fine to medium-grained, weakly cemented and kaolinitic (Fig. 3F) and measures up to 1 m thick.

EXPERIMENTAL PROCEDURES

1. Materials

In the present study, the used raw materials are represented by claystone and sandstone deposits which were collected from the Abu Darag Formation at Wadi Um Galawat, between Abu Darag lighthouse and Wadi Araba, western side of the gulf of Suez, Egypt (long. 32^{o} 32′ 52.1″ E and lat. 29^{o} 21′ 26.7″ N; Fig. 1). About fifty kilograms were collected from a thick horizon of claystone with few sandstone interbeds (Fig. 2) from a recent quarry exploited for ceramic and cement industries

(Fig. 1). In the field, the claystone appears as dry, massive and brownish grey while the sandstone occurs as weakly-cemented, faint red and cross-bedded horizon. The used raw materials were crushed and sieved to pass through 850-µm sieve diameter using electrical sieves shaker. The sand and clay samples were kept separately in plastic bags for their characterization and experimental work.

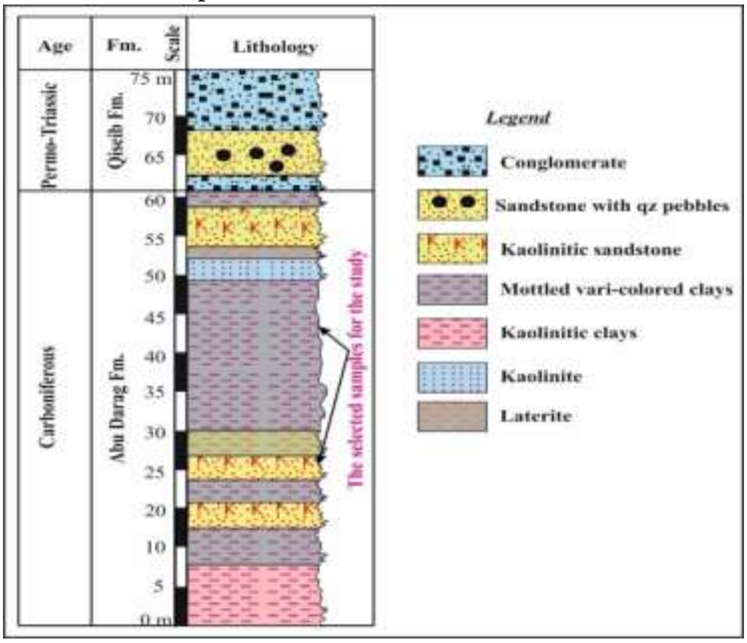

Figure (2). Columnar section showing the studied stratigraphic succession at the quarried area.

2. Methods and techniques

The used sieved clay and sand raw materials and the prepared fired briquettes were analyzed using X-ray diffraction (XRD) for mineralogical identification where the bulk and clay mineralogy of the studied samples have been achieved. The used XRD instrument was an X'Pert Pro PW3040/60 PANalytical diffractometer equipped with monochromatic Cu-Kα radiation source run at 40 kV and 30 mA. The acquired data were identified using X'Pert high score software works with a pdf-2 database. Chemical composition of the raw materials were also determined using X-ray fluorescence (XRF) with an Axios sequential spectrometer manufactured by PAN-alytical, Netherlands. In addition, loss of ignition (LOI) has been determined following a traditional manual method prescribed in the American society of testing and materials **(ASTM, 2013)**. Plasticity coefficient of the studied mixes was determined using the

Pfefferkorn's method (1924) to explore the required water for the briquettes shaping. It was calculated according to the formula: a = h_0 / h_1, where (a) refers to compression, (h_0) refers to the initial height of the test specimen and (h_1) refers to the height of the test specimen after compression. The Plasticity coefficient was determined at a compressibility = 3.3. Thermal analyses tests for the clay sample were performed using differential thermal analysis (thermal analyzer: DT 50, Schimadzu Co., Kyoto, Japan) at a nitrogen atmosphere and 10^o/min as a heating rate. Total dissolved salts (TDS) was measured using TDS meter (RTC-TDS 1000-100). The sound of the fired brick was evaluated by knocking the fired product with a porcelain sticks and evaluating the emitted sound that may be dull or metallic [1]. Particle size distribution of the used sand sample was determined using laser diffraction analyzer (manufactured by Horiba, LA-950, France). All tests, measurements, and applied work were conducted at the Housing and Building National Research center (HBRC) testing laboratories, Cairo, Egypt and Geology Department of the Faculty of Science, Benha University, Egypt.

3. Mix preparation and briquettes processing

Three mixes of different proportions from the ground clay and sand materials were used for each composition (wt. %). For mix 1, 90% of clay were mixed with 10% sand. For mix 2, 85% clay were mixed with 15 % sand. Whilst, for mix 3, 80% clay were mixed with 20% sand. The sand material has a high content of the total dissolved salts (6270 ppm) consequently the used sample should be washed by tap water to be suitable before mixing (the TDS after washing was 1420 ppm). The prepared mixes were mixed with the calculated water obtained from the Pfefferkorn test before molding until obtaining a homogeneous clay-sand paste. The different mixes were then hand-molded in a cylindrical steel mold to prepare green briquettes of 30 mm diameter and 50 mm height. The shaped briquettes were covered by perforated plastic sack for a week in a protected place at the lab ambient conditions (winter season) then they were left for a month uncovered in a protected place at room temperature until drying taking in consideration turning the briquettes every two days to keep their shape regular. Then after the natural drying, they were re-dried for 48 hours gradually until reaching 110 ºC in an electrical drier before firing. Finally, the completely dried briquettes were fired in an electric furnace at a firing rate of 3 $^oC.min^{-1}$ at 750 ºC, 800 ºC, and 850 ºC. The test briquettes were left to soak for 2 hours at the maximum temperature as a holding time then left to cool inside the furnace overnight after finishing the firing program.

4. Testing procedures for the briquettes

To measure the quality and technological properties of the fired briquettes of different mixes, the tests of bulk density, water absorption, compressive strength and apparent porosity were determined according to

ASTM **(Raheem, 2017; ASTM C67/C67M, 2020)**. Each test was applied for at least three fired briquettes. The test results were evaluated according to the building **Egyptian Code (2014)** and the passed briquettes were suggested for the clay bricks manufacture for suitable applications as building units.

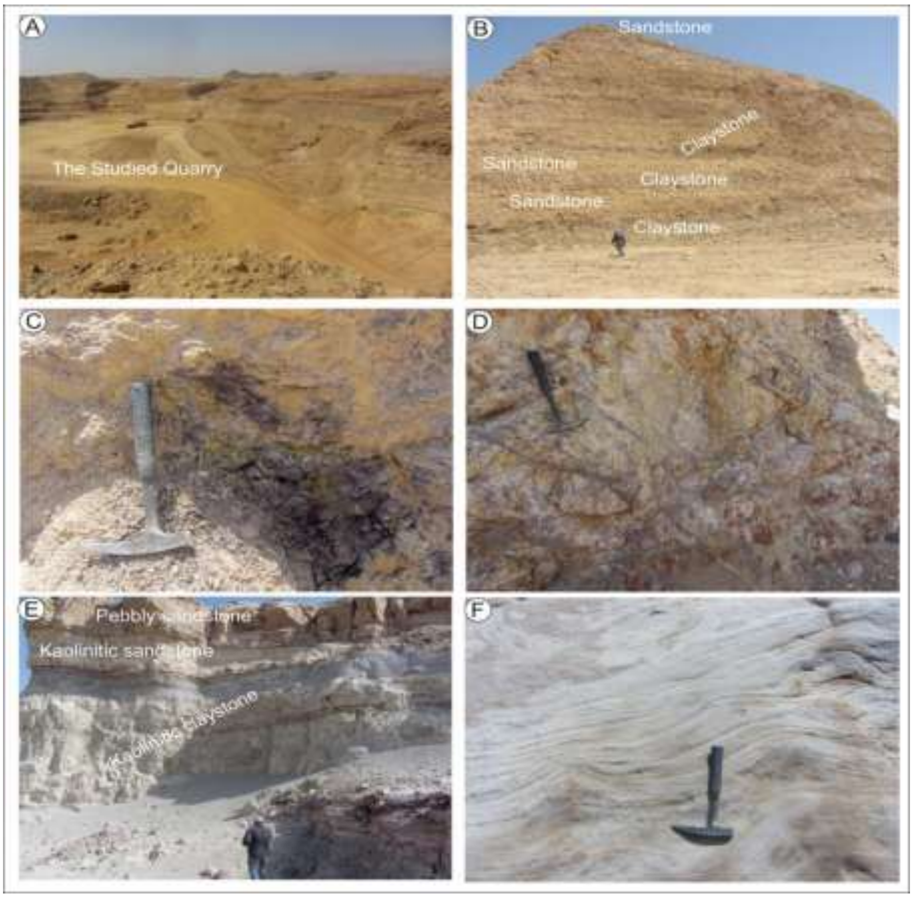

Figure (3). Field photographs showing, A- Open quarry in the Abu Darag area. B- Claystone with sandstone intercalations. C- Violet colored compacted clays. D- Pedogenic features (desiccation cracks, nodular fabrics and red mottling) in the compacted clays. E- White and grey kaolinitic clays in the upper part of the studied horizons. F- Thinly-laminated kaolinitic white sandstone.

RESULTS AND DISCUSSION

1. Characteristics of the raw materials

The bulk chemistry of the studied clay and sand samples (major oxides) and loss of ignition (LOI) are given in Table 1. The result revealed that the tested clay sample consists mainly of SiO_2, Al_2O_3 and Fe_2O_3 as the main major oxides besides few other elemental oxides (Table 1). The silica and alumina contents indicate that the clay silica is dominated by quartz and clay minerals. Moreover, the studied clay sample is also characterized by its high Fe_2O_3 content that in turn suggests that the source rocks are basaltic and/or mafic rocks **(Masheane *et al.*, 2018)**. The SiO_2/Al_2O_3 ratio is greater than one (3.07), which may be indicative to the presence of the silica (quartz or clay minerals) in appreciable amounts **(Roudouane *et al.*, 2020)**. The content of fluxing oxides (CaO, MgO, Na_2O, K_2O, MnO) equal to 10.3 wt.% reflecting the vitreous phase formation ability during firing. The ingredient of aluminum oxide content for good brick earth should be in the range of 20–30 wt.% **(Duggal, 2003)**. So, the low content of this oxide (7.31 wt.%) in the clay sample will not be used as a rendering assistance for the plasticity.

Table (1). Chemical composition and LOI (in wt. %) of the used solid materials (clay and sand).

Samples used	Major oxides in wt.%												
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Cl^-	SO_3	LOI	SiO_2/Al_2O_3
Clay	44.30	1.61	14.40	10.80	bdl	2.17	3.15	1.65	3.28	bdl	4.34	0.13	13.96	3.07
Sand	71.44	0.63	7.31	4.18	0.06	0.45	2.14	3.11	0.43	0.04	4.56	2.66	2.83	9.77

The sand material is composed mainly of SiO_2 (71.44 wt.%) with minor amounts of Al_2O_3 (7.31 wt.%), Fe_2O_3 (4.4.28%), Na_2O, K_2O and Cl^- (8.1 wt.%) as shown in Table 1. The total salt contents (Na_2O, K_2O, Cl^-) are high reaching up to 8.1 wt. % (Table 1). Therefore, the used sand sample should be washed by water before using otherwise it will affect negatively the properties of the fired briquettes. The TiO_2 is high reaching up to 1.63 wt. % giving an indication about the anatase amount in the clay-sand used raw materials **(Kieufack *et al.*, 2021)** and suggests a mafic source rock for clay used material **(Fouateu *et al.*, 2016)**.

The studied clay sample has been analyzed for bulk mineralogy using XRD where it is composed of quartz, halite as non-clay minerals (Figure 4A). This sample has been studied as well for clay mineralogy where three oriented mounts were prepared and illustrated in Figure 4B. Montmorillonite, kaolinite and illite represent the main clay minerals in this sample (Fig. 4B). The clay sample has been studied for differential thermal (DTA) and thermo-gravimetrical analyses (TGA) as shown in Fig. 5. The test results were interpreted according to **(Ramachandran *et al.*, 2002)**. A marked symmetrical endothermic effect appeared at 93.3 °C and it could be related to the removal of moisture (dehydration) from kaolinite, montmorillonite and illite. Oxidation of goethite to hematite occurred as endothermic peak at temperature of 300 °C accompanied by a corresponding weight loss 3.5%. The large broad endothermic effect at 587.28 °C represents the initial removal of the structural OH^-group from montmorillonite, kaolinite and illite lattices and the production of disordered phase of kaolinite. The relatively low peak temperature of de-hydroxylation of the clay sample may be attributed to the presence of excess of structural iron in the octahedral layer of the montmorillonite. The last endothermic effect temperature that takes place at 818.83 °C is due to the de-hydroxylation of clay minerals which had not fully removed. All the detected endothermic peaks in the temperature peak between 0-1000 °C are accompanied by a corresponding total loss of weight equal to 18.53 %.

The results of particle size distribution of the clay sample show that the clay fractions (<3 µm) is of 52.8 wt.%, the silt fractions (<63 µm–3 µm) is of 47.2 wt.% and the sample has no sand fractions (<2 mm–63 µm). The good fired clay bricks should have raw mixes of granulometric compositions of particles > 20 µm (silt and sand fractions) of 60% or more, particles 2–20 µm should < 40% and particles < 2 µm should be less than 30% **(Mcnally, 1998)**. It is obvious that the clay sample has no sand proportion, so a suitable content of sand should be added in the range between 25–35% in the factory manufacture process for the manufacture of vertical perforated clay bricks **(Winkler, 1954)**. In addition, this will be useful for shaping and reduce deformation arising from shrinkage.

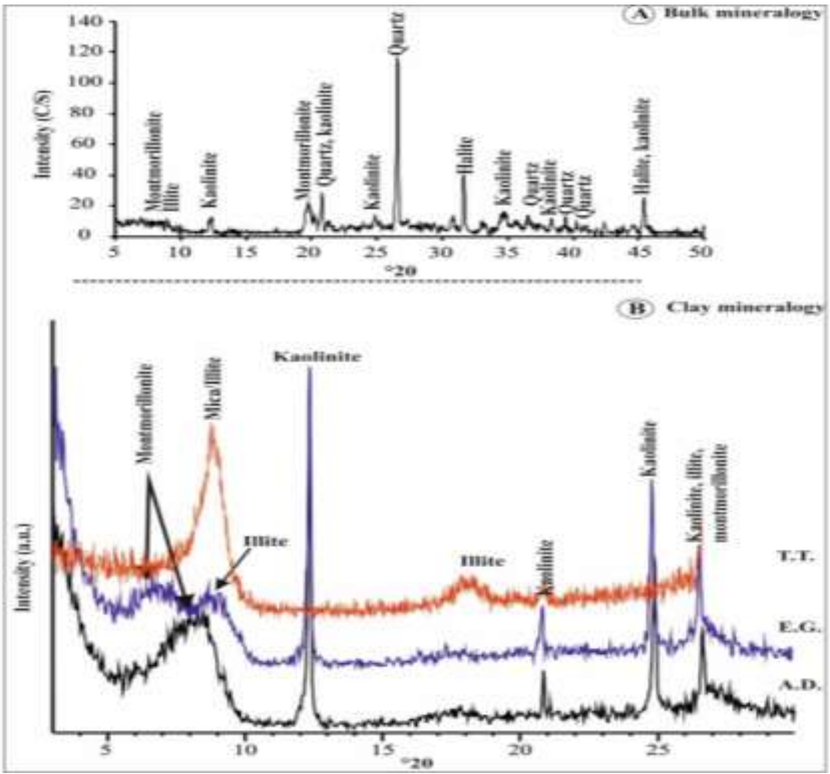

Figure (4). X-ray patterns (A- bulk mineralogy, B- clay mineralogy) of the studied clay sample.

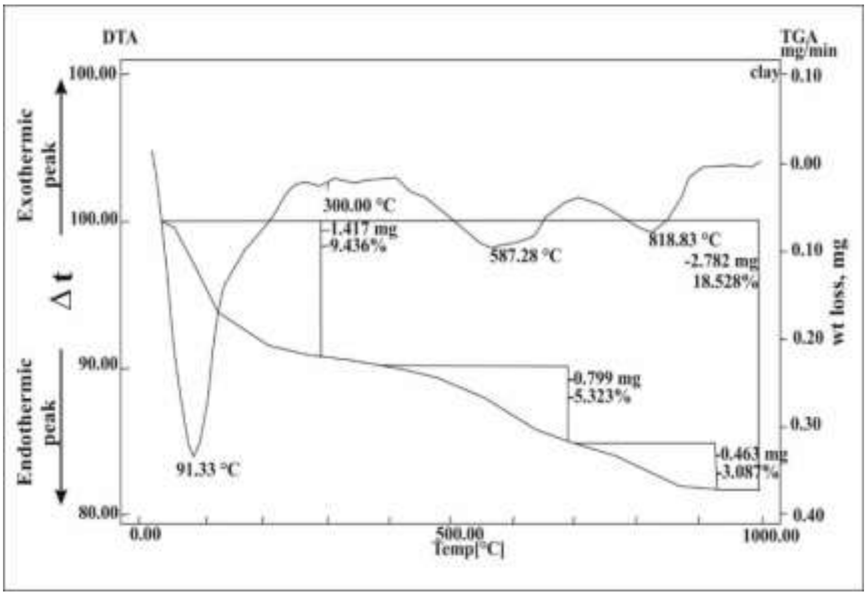

Figure (5). Results of thermal analyses (DTA-TGA) of the clay sample.

The studied mixes containing different percentages of sand have been studied for plasticity tests (Fig. 6). It was noticed that as sand content increased (0–20%), the plasticity coefficient decreased (26.5 until 21). Mix 1 that has no sand content achieved the maximum plasticity coefficient meaning that the addition of sand as a non-plastic material reduced the amount of water needed for workability.

2. The mineralogy and technological properties of the fired briquettes

The mineralogy of the fired briquettes has been studied for the three mixes after firing at three different temperatures; 750 ºC, 800 ºC and 850 ºC (Fig. 7). The mineralogy of these mixes is mainly displayed by quartz, anatase, hematite, illite, actinolite, augite and albite. Illite mineral is found in all mixes up to 800 ºC. Anatase crystallinity decreased with temperatures in all mixes while, hematite peaks intensity increased up to 800 ºC then disappeared as shown in mixes 1 and 2 but in mix 3 the hematite phase is observed at 850 ºC and this may be due to the high content of iron associated with sand addition (30% by wt.). As temperature increased at 850 ºC, the actinolite phase is formed in mix 1, while augite and albite phases are observed in mixes 2 and 3 at the same temperatures and this is attributed to the increase in iron and silica contents associated with sand additions (20 % and 30%, respectively).

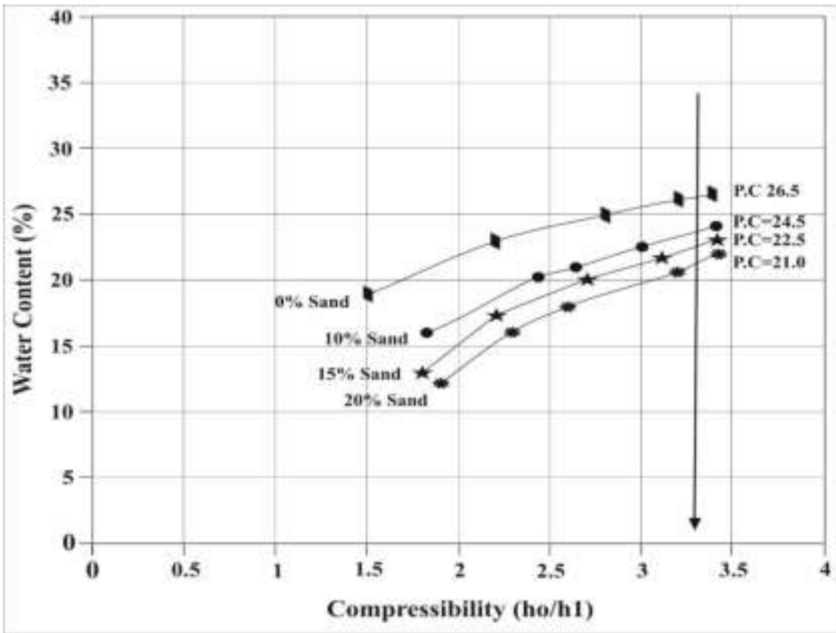

Figure (6). Results of plasticity test for the studied mixes containing different sand percentages.

All the physico-mechanical test results in terms of the bulk density, water absorption, compressive strength, apparent porosity and efflourocense of the fired briquettes of the three studied clay-based mixes as a function of temperature are shown in Figure (8) and in Table (2). Water absorption is a measure of densification and vitrification extent in the fired briquettes. Fig (8A) pointed that water absorption is inversely proportional to firing temperature as well as flux content, and directly proportional to sand content, which mostly proposed poor vitrification and low densification with sand content **(O'Farrell *et al.*, 2004)**. In addition, water absorption decreases with clay content increases (the binding source) due to the increase in the rate of glassy phase formation (closing of the pores) with the increase in temperature and this binds the particles and improve strength of the fired briquettes **(Masheane *et al.*, 2018 and Kocyigiti & Cay, 2019)**. Therefore, the best results have achieved for the briquettes of mix 1 fired at temperature 850 ºC. Since, the durability of bricks is closely related to water absorption and can be used to judge on the brick quality. Water absorption of all fired briquettes fulfilled the limits of the Building **Egyptian Code (2014)** for the fired clay bricks used for non-load bearing walls.

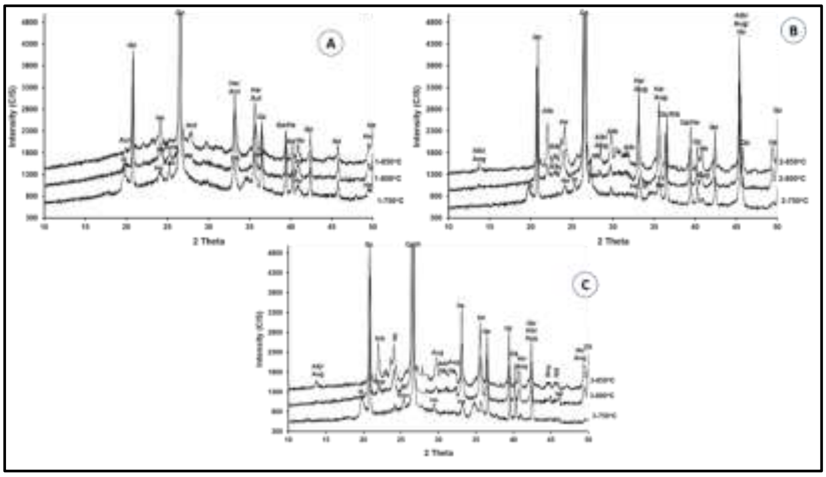

Figure (7). X-ray patterns of different mixes (Mixes 1, 2, 3) fired at different temperatures. (Abbreviations: quartz (Qz), hematite (He), augite (Aug), actinolite (Act), illite (Ill), anatase (Ana), albite (Alb)).

The bulk density values for the fired briquettes were between 2.19 gm/cm^3 and 2.49 gm/cm^3 (Fig. 8B), which are acceptable for ceramic products **(Kieufack *et al.*, 2021 and El-Mahllawy *et al.*, 2013)**. These values increased with increasing the temperature and with the clay content, which enhanced sintering properties and glassy phase formation. This is related to the briquette densification increasing during firing progressing. In addition, the density decreased with increasing the sand where it promotes the formation of gaseous channels which contributes to increase voids in the fired body and provides less dense structure affecting on the mechanical strength **(Guzlena *et al*, 2019)**. The highest value of bulk density was recorded for briquette of mix 1 fired at 850 ºC that represents the lowest value of water absorption.

The apparent porosity of the studied fired briquettes increases with increasing sand content (Fig. 8C) and decreases with increasing firing temperature that enriches densification. Moreover, the apparent porosity and water absorption show the same trend of each other's indicating an increase in the glassy phase, which filled the open pores of these fired briquettes and progressed with increasing the firing temperature. Furthermore, the low content in clay fraction as in the mix 3 (80% clay) is also responsible for the low content of the formed glassy phase and high apparent porosity.

Figure 8D indicated the compressive strength progresses with increasing of firing temperature. This was due to the phase changes and reactions that occurred in the clay body **(Pardo *et al.,* 2018)**. On the contrary, the compressive strength decreases with sand increasing because of the porosity and voids increasing that reduced mechanical properties of the fired specimens **(El-Mahllawy, 2004)**. Therefore, compressive strength is conversely proportional to water absorption that reduce the strength **(Sanad *et al.,* 2021).** Therefore, the mix that has the lowest water absorption value has the highest compressive strength value as confirmed by briquettes of mix 1 (10% sand) fired at temperature 850 ºC. Compressive strength results of briquettes of mixes 1 and 2 that were fired at 800 ºC and 850 ºC, respectively are only within the acceptable limits of the Building **Egyptian Code (2014)**. Results of other briquettes are out and may be due to low vitrification, which is associated with the firing regime (vitreous phase formation) and sand content. Addition of suitable additives in the mixes is suggested to be a solution to develop their ceramic properties **(Gencel *et al.,* 2021 and El-Hammouti *et al.,* 2022)**.

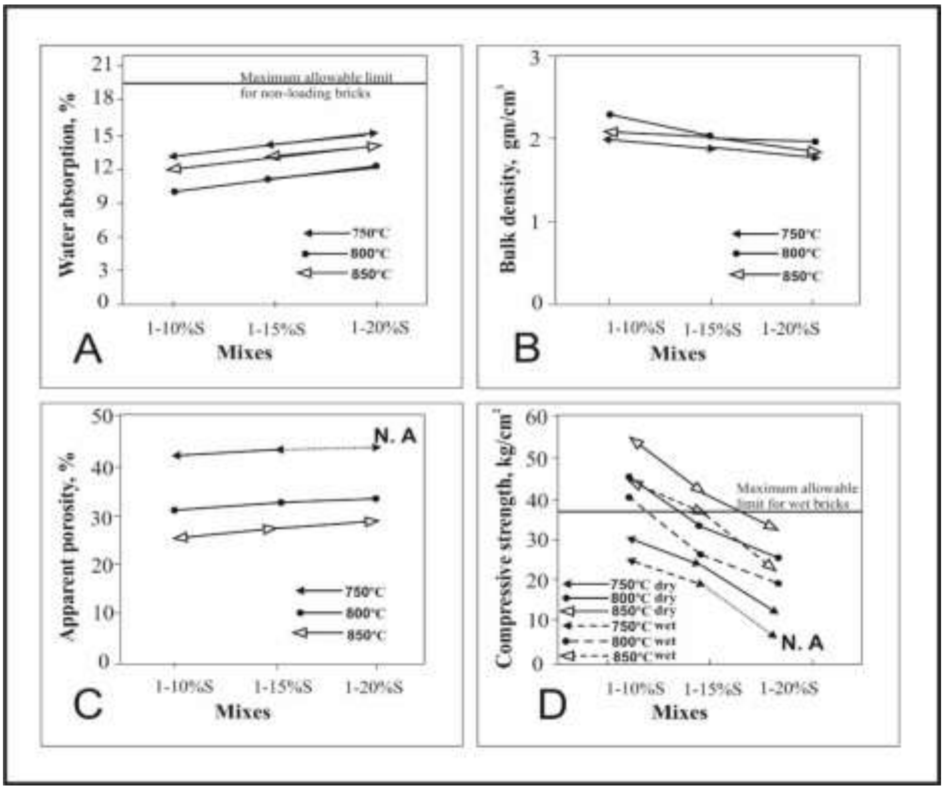

Figure (8). Physico-mechanical properties of the fired clay briquettes: (a) water absorption, (b) bulk density, (c) apparent porosity, (d) compressive strength.

Table (2). Results of technological properties of different briquettes (bulk density, water absorption, compressive strength, apparent porosity) at different firing temperatures.

Mix No.	Water absorption, %			Bulk density, gm/cm^3			apparent porosity, %			Compressive strength, kg/m^2					
										Dry state			Wet state		
	750℃	800℃	850℃	750℃	800 ℃	850 ℃	750℃	800℃	850℃	750℃	800℃	850℃	750℃	800℃	850℃
1-10% S	18.2	12.92	10.11	2.33	2.39	2.49	42.41	30.88	25.17	29.74	44.57	54.71	24.51	40.62	44.68
2-15% S	19.31	13.8	11.55	2.25	2.34	2.35	43.43	32.29	27.14	23.61	33.96	41.38	18.41	25.25	35.78
3-20% S	N.A.	14.61	12.39	2.19	2.27	2.31	N.A.	33.16	28.62	11.92	25.34	32.32	N.A.	18.98	22.67

N.A. Not applicable.

Efflourocense test for the fired briquettes show that the fired briquettes have slightly efflourocense degree (Fig. 9), which means that the fired clay briquettes have very little soluble salts, and all are within the limits of the Egyptian Code. The sound test results of the fired briquettes (Table 3) showing that all the tested briquettes emit a dull sound. This could indicate a low vitrification and low densification phenomena. To reach a metallic sound for the fired briquettes of different mixes, high firing temperatures should be considered to improve the densification of the products **(Damle, 2008)**.

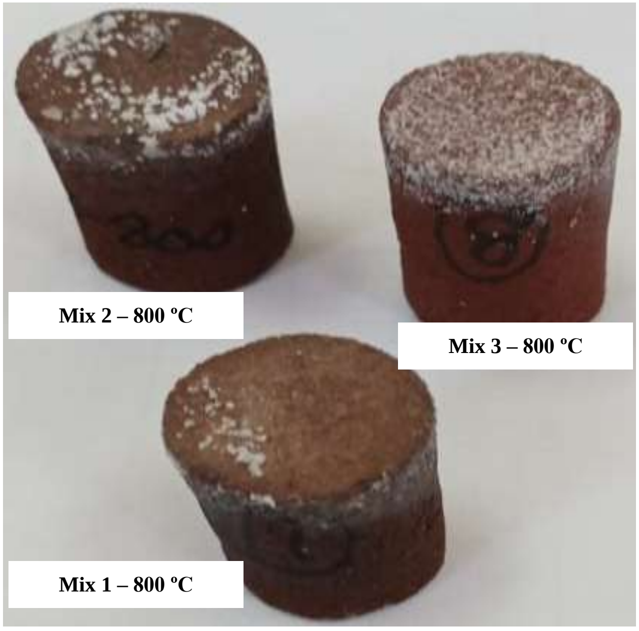

Figure (9). Results of efflourocense test for the fired briquettes.

The color of fired briquettes by the visual detection is shown in Table (3) and Figure (10). The colors were between reddish yellow, reddish brown and dark brown, which highlights that color of the fired briquettes are turned more darker as firing temperature increased due to the iron content oxides transformations **(Khoiroh *et al.*, 2013)** and as confirmed by the XRD results of the fired briquettes where, the hematite increased with temperatures and sand content. The pink color of briquettes of mixes 2 and 3 fired at 750 ºC may be due to the low hematite content at low firing temperature.

Table (3). Colors and sounds of briquettes at different temperatures.

Mix no.	Temperature	Sound	Color
Mix 1	**750 ºC**	**dull**	**Reddish yellow**
	800 ºC	**dull**	**Reddish yellow**
	850 ºC	**dull**	**Moderate reddish brown**
Mix 2	**750 ºC**	**dull**	**Pink**
	800 ºC	**dull**	**Blackish red**
	850 ºC	**dull**	**Very dark greyish brown**
Mix 3	**750 ºC**	**dull**	**Pink**
	800 ºC	**dull**	**Blackish red**
	850 ºC	**dull**	**Dark brown**

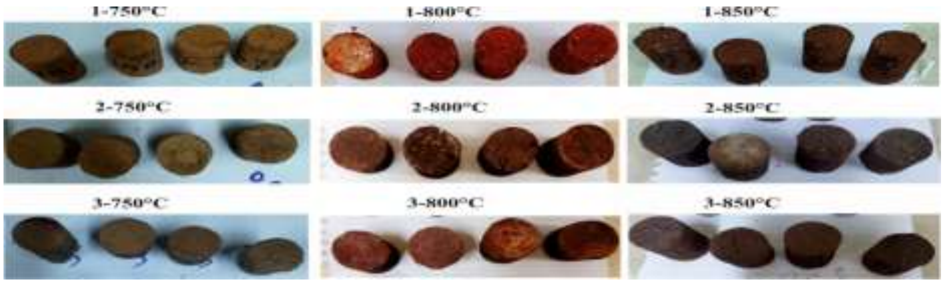

Figure (10). Color of briquettes of different mixes at different temperatures with different ratios of sand.

To sum up, the technological properties of the fired briquettes suggested that making of non-load bearing clay bricks are possible only after the sand addition at low content (10%) and firing the clay-based mixes at high temperatures (≥ 800 ºC).

CONCLUSION

The objective of this study was to investigate the potential use of Egyptian Paleozoic raw building materials at the Abu Darag area (Gulf of Suez province) for the fired clay bricks manufacture. The used clay and sand raw materials were characterized mineralogically, chemically and physically. Lab-made briquettes of different clay-based mixes were dried, fired, tested and evaluated for the building purpose in accordance with the **Egyptian Code (2014).** The results indicated that the higher the firing temperature, the improved physico-mechanical properties are obtained. It was also observed that, the more percentage of sand that replaced the clay material, the lower the compressive strength and the higher the water absorption. The findings showed that the replacement of more than 10% sand for the clay brought the worst ceramic properties even in the high temperature (850 ºC) compared to 10% sand replacement. As a result, from the lab manufacture process, sand is a good replacement material for the clay in the studied mixes only at 10% by wt. % at the high temperature. Also, it is believed that as iron content (found in sand) increased, the formed phases changed from amphiboles (actinolite) to pyroxenes (augite). The briquettes of the mix 1 that contained 10% sand and fired at over 800 ºC are acceptable for the production of non-load bearing bricks from the area studied.

Declaration of conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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احتمالية استخدام خامات مواد البناء من حقبة الحياة القديمة بمنطقة أبو الدرج، خليج السويس لانتاج طوب البناء الطفلي المحروق

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يهدف البحث إلى دراسة الاستخدام المحتمل لمواد البناء المستخرجة من صخور حقبة الحياه القديمة والتي تم جمعها من منطقة أبو الدرج ، على الجانب الغربي من خليج السويس ، مصر، لتصنيع طوب البناء الطيني. تم جمع عينات الطين والرمل من تكوين أبو الدرج الكربوني المكشوف في منطقة الدراسة وتم توصيفها معدنيا وكيميائيا وفيزيائيا باستخدام طرق وتقنيات تحليلية مختلفة. من خلال العمل المعملي ، تمت صياغة ثلاث خلطات أساسها الطين لتحضير قوالب اسطوانية بنسب مختلفة من الرمل (10٪ ، 15٪ ، 20٪ وزناً). تم حرق القوالب المعملية بعد التجفيف عند 750 درجة مئوية و 800 درجة مئوية و 850 درجة مئوية في فرن كهربائي. تم تحديد الخواص الفيزيائية الميكانيكية للقوالب المحروقة وفقًا لمعايير ASTM وتقييمها وفقًا للكود المصري 204-2014. أظهرت الاختبارات الخزفية أن لون القوالب تغير إلى الأحمر والبني الغامق مع زيادة محتوى الرمل ودرجة حرارة الاحتراق وصوت جميع القوالب أصبح باهتًا. تزداد مقاومة الانضغاط مع درجة الحرارة وتقل مع إضافة الرمل. أيضًا ، مع زيادة محتوى الحديد (الموجود في الرمل) ، تغيرت الأطوار المعدنية المكونة من الأمفيبول إلى البيروكسين. أشارت النتائج إلى أن قوالب 10٪ من الرمل عند درجة حرارة تلبيد تساوي / تزيد عن 800 درجة مئوية تتمتع بخصائص تكنولوجية جيدة وتلبي المتطلبات المسموح بها في الكود المصري لبناء الطوب الطيني الذي يستخدم كجدران غير حاملة.