Samarra Journal of Pure and Applied Science

www.sjpas.com

p ISSN: 2663-7405
e ISSN: 2789-6838

Evaluation of Clay Deposits for the Manufacture of Bricks in the Bazian Basin, Northern Iraq

Omer H. Mohammed [1*], Sawsan H. Al-Hazaa[2]
1- Ministry of Education, Baghdad, Iraq
2- Department of Applied Geology, College of Science, Tikrit University, Tikrit, Iraq

https://doi.org/10.54153/sjpas.2025.v7i1.1004

Article Information

Received: 31/07/2024
Revised: 25/08/2024
Accepted: 30/09/2024
Published: 30/03/2025

Keywords:

Bricks Clay, Bazian Basin, Gercus Formation, Kolosh Formation, and Absorption.

Corresponding Author

E-mail: omerhameed503@gmail.com
Mobile: 07700297859

Abstract

The study area is located in northeastern Iraq within the borders of Sulaymaniyah, about 30 km west of Sulaymaniyah Governorate. This study aims to evaluate the mud deposits for the manufacture of clay bricks. A group of formations exposed back to the Tertiary period is revealed in this area: the Kolosh Formation, which consists of a sequence of dark-colored clay deposits, the Sinjar Formation, which consists mainly of limestone, the Gercus Formation, which consists of sequences of red clay and marl, and the Pila Spi Formation, which consists of limestone, in addition to the quaternary deposits consisting mainly of clay. The physical properties were studied, which included the grain size, atterburg limits, and moisture content. The chemical properties were also studied using the technique of (XRF). The mineral properties of the clay in the study area were studied using the technique of (XRD). The study of physical and chemical properties showed that the Kolosh Formation deposits are unfitious for the manufacture of bricks due to the lack of clay, which helps in the formation of models, in addition to the very high magnesium ratio 22%. These properties are infectious for the manufacture of the bricks. As for the clays of Gercus Formatin, the physical properties showed that they contained a high percentage of clay, up to 52%, then sand, which up to 31%, and contained a low percentage of clay, up to 17%. The physical properties also showed that the plasticity limit is high and needs additional amounts of water to form bricks. The mineral study showed that it contains paleogorskite, this was chemically reflected, as the results of (XRF) showed that it contains a high percentage of magnesium up to 9% and a high percentage of iron. The study also showed the failure of the samples prepared from the Gercus Formation samples due to the high absorption rate and low compressive strength. As for the quaternary deposits, they consist mainly of clays up to 60%, a high percentage of silt 47%, and a small percentage of sand 6%. The physical properties also showed that the plasticity limit is low, which helps in the formation of bricks. The mineral study also showed the presence of clay minerals (montmorillint, ilite, paleogorskite, and chlorite). As for the chemical properties, they contain a good percentage of alumina up to 9% and a percentage of iron up to 5% to a low percentage of magnesium. The study showed that bricks using Quaternary deposits fall into category

A according to Iraqi Standard Specification No. 25.

Introduction:

A brick is a large, engraved solid building unit consisting of an inorganic material of mineral origin fired by heat **[1]**. Brick is considered one of the oldest building materials that are abundant and abundant because it is cheap and durable to work with. Clay bricks are used in the construction of external and internal walls, sidewalks, multi-story buildings, and other necessary materials**[2]**. In the first stage, the bricks used from the floors were sun-dried bricks. Burnt bricks replaced sun-dried bricks and are reported to have been used in different parts of the world**[3]** Thus, Iraq's industry in the middle and southern regions due to the abundance of clay, while in the northern regions, the use of stone in construction due to its abundance**[4]**. The study area is located within the borders of Sulaymaniyah Governorate in northeastern Iraq, within the administration of Bazian District, and is about 30 km to the Northwest of the center of Sulaymaniyah. It is bordered to the west by the Takiya area and to the east by the Tasluja area. It is geographically located between two longitudes ($45^{o}10^{/}00^{//}$E-$45^{o}00^{/}00^{//}$E) and two latitudes ($35^{o}40^{/}00^{//}$N - $35^{o}32^{/}00^{//}$N). Fig. 1 represents the location of the study area in relation to Iraq. There are many studies that dealt with the manufacture of clay bricks, including a study **[5]**, that differs from the evaluation of overflow clay in the Salman region in southern Iraq for the manufacture of clay bricks. The study showed that choosing fired clay bricks at temperatures of 1100º C showed good results for compression and absorption values. It is also true **[6]** after the passage of time after the formation of composite sediments of the era in Al-Muthanna Governorate / southern Iraq, and the study . Theat the bricksThat the bricks that were produced by pressing method and thermally fired 1100^{0}, 950^{0} C are of type A and B. Also mineralogy, geochemical, and geotechnical evaluation of the soil of Suwayra for the manufacture of building blocks in Iraq. The study showed that the percentage of gypsum is not high and is within its geographical limits, but there is a separate field useful in reducing the required temperature. **[8]** conducted a study to determine the physical and chemical properties of soil in Babylon and Al-Qadisiyah for the manufacture of bricks in The Hague. The study showed that the physical properties of the largest samples for the manufacture of bricks and their preparation are within the specifications required for the manufacture of bricks and are within classes A and B according to the specifications. Iraqi Standard Specification (ISS)No. 25**[9]** . Due to the lack of brick factories in the northern regions of Iraq and the use of stone in construction, this study aims to qualitatively evaluate clay deposits as raw materials for the manufacture of bricks by studying their physical and chemical properties, studying the common minerals in these deposits, preparing samples of these clays using the semi-dry pressing method, and studying the physical and mechanical properties of the prepared brick samples and comparing them with Iraqi Standard Specification No. 25 for the year 1988 and also a study of formed minerals using X-ray diffraction (XRD).

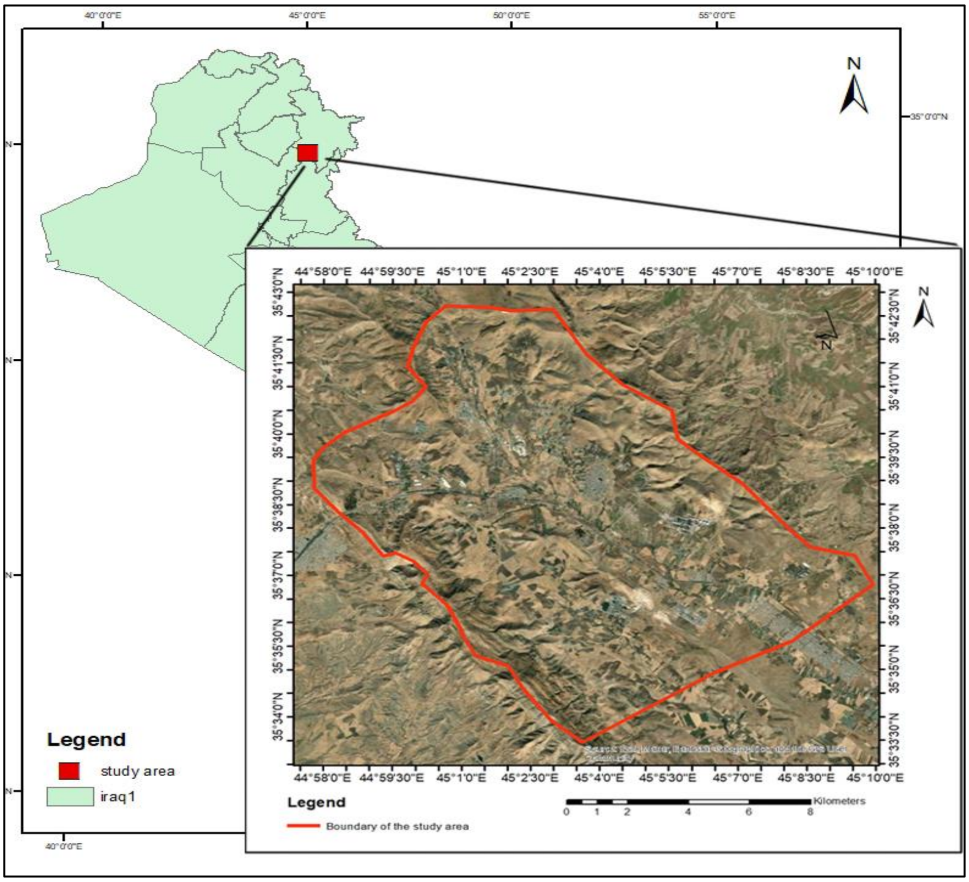

Fig. 1 *Location of the study area.*

Geology of the study area

A group of formations containing clastic deposits and clays are exposed in the study area, namely the Kolosh Formation, which consists of layers of different thicknesses of clastic sedimentary rocks, as it contains grey sandstone and layers of dark black mudstone [10]. The age of this formation dates back to the Palaeocene Epoch [10][11]. The boundaries of this formation are compatible with the next formation, which is the Sinjar Formation, which consists of limestone and dates back to the Palaeocene - Eocene [12]. This formation overlaps with the Gercus Formation, which dates back to the late Lower Eocene - Upper Eocene cycle, formation sequences. Gercus represents the typical facies of molasses in Iraq (Northern and Northeastern Iraq). The formation sequences are divided according to [13] into the lower sequence, and the sequence limit is represented by Sequence Boundary 2 (SB2), and the upper sequence and the sequence limit are represented by Sequence Boundary 1 (SB1). The lower sequence, which represents 90%, contains on the Shelf Marginal system tract (SMST), which consists of red mudstone and successive marl, and the second middle tract Transgressive System Tract (TST), which consists of leaden to yellowish-green marl with friable limestone, whose thickness reaches 6 meters. The third tract Highstand System Tract (HST), consists of sequences of red mudstone with thin layers of sand, limestone, and muddy limestone. The upper sequence, which represents the tract Lowstand System Tract (LST), which falls below the boundary between the Gercus Formation and The Pila Spi Formation, which consists of a layer of conglomerate [13], then the Pila Spi Formation, which dates back to the late Lower Eocene - Upper Eocene cycle and covers a wide area of the study area and consists of limestone, as sediments dating back to the era appear. The Quaternary in the lowlands of the region, where the valleys are filled, consists mainly of pure clay, which is the product of the erosion of the older rocks mentioned above. The thickness of these deposits varies from one place to another and according to the slope of the area. In the highlands, the thickness of the sediments does not exceed a few centimetres, while in the lowlands, it reaches 150 meters [14]. The geological map in Fig. 2 shows the formations exposed in the study area.

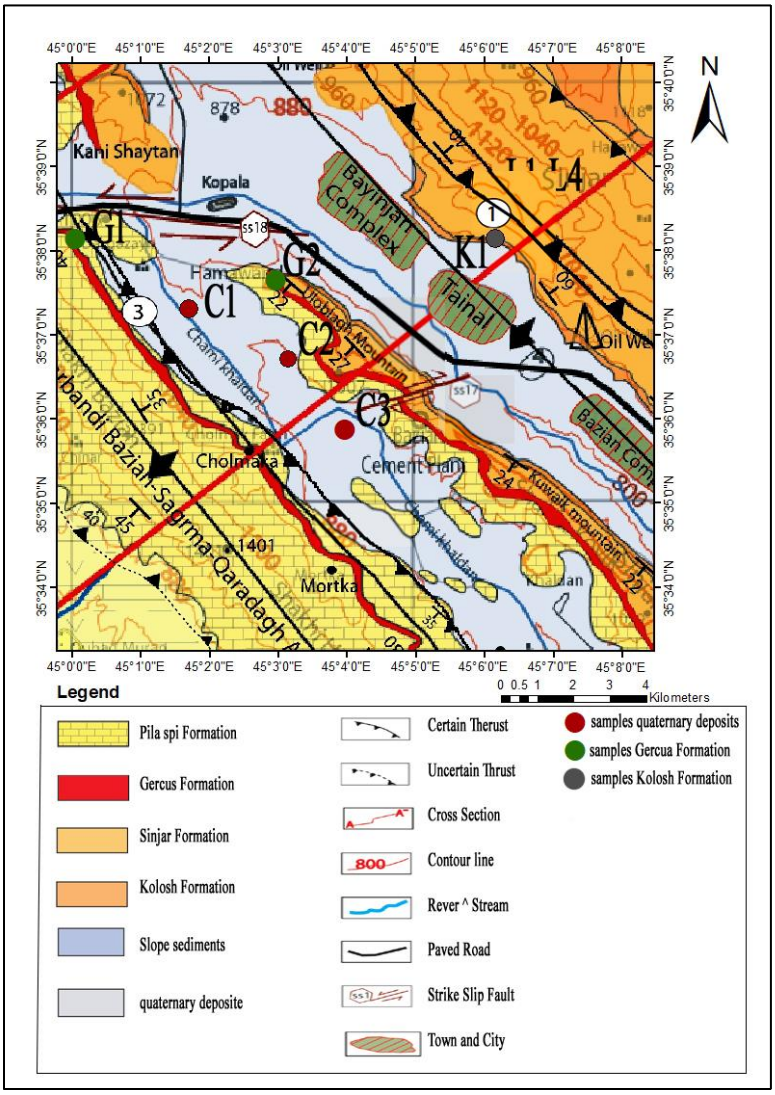

Fig.2 *Geological map of the region showing sample locations* [15]

Materials and Methods

Samples were taken from the clay layers based on the vertical change in the nature of the rock by making a channel (1-2 meters long * 10-30 cm wide * 5-10 cm deep). Three samples were collected from different stations for the clay of the Quaternary deposits, two samples for the clay of the Gercus Formation, and one sample of the Kolosh Formation. The volumetric analysis, consistency, and moisture content of clay samples were examined according to the method contained in the British Standard (BS 1377-2: 1990)[16]. Chemical analysis was performed to determine the percentage of major oxides in the samples using X-ray spectroscopy (XRF), and the percentage of loss by burning was determined. Based on the method contained in Reference Guide No. 472 of 1993. As for the mineralogical study, the mineralogical study was conducted after separating the clay from the coarse particles; according to Stokes' law, the first slide was examined under normal conditions, the slide was treated with ethylene glycol, and the third slide was heated at a temperature of 550 degrees

Celsius. At least one hour. Scanning Electron Microscope (SEM) imaging was also used to diagnose clay minerals in the Al-Khora Company laboratory in Baghdad. The brick samples were formed using a semi-dry pressing method using a hydraulic press and two types of molds. 40 brick samples were formed using the initial mold with dimensions of (80 * 40 * 1.5) mm to conduct examinations of absorption, efflorescence, shape, longitudinal shrinkage, and density. 24 samples were formed using the second mold, with dimensions of (80 * 40 * 30) mm, which was used to examine the compressive strength. The prepared brick samples were burned using an electric box furnace in the inorganic chemistry laboratory in the Department of Chemistry at Tikrit University. One group of samples was burned at a temperature of 950 degrees Celsius, and the second group was burned at a temperature of 1050 degrees Celsius with a burning program of 200 degrees per hour with a curing time of two hours. All evaluation tests of the brick samples were conducted according to Iraqi Standard Specification No. 24 for the year 1988[17], and a bulk density examination was conducted according to the method contained in the American Standard ASTM C 134[18]. An examination was conducted. Longitudinal shrinkage according to American standard ASTM C 326[19].

Results:

Physical properties:

The physical properties of clays play an important role in all stages of brick manufacturing, as the granular size of the clays used in making bricks affects the behavior of the clay during the drying and burning processes. It also affects the properties of the final products, such as the microstructure, and also affects the operational properties of the bricks [20]. The high percentage of clay and silt in clay samples of Quaternary deposits, which reaches 47%, is a good indicator, as increasing the percentage of fine grains improves the flexibility of the clay and its ability to be molded and compressed [21]. As for the clays of the Gercus Formation, they contain a percentage of sand reaching 31%. These coarse grains help provide pore space to help escape the gases generated during combustion[2], but increasing this percentage of coarse grains to the size of sand gives a high porosity to the bricks, and thus the absorption rate increases. Also, the increase in the proportion of coarse particles requires an increase in the proportion of mixing water to obtain the plastic state of the clay during molding and thus causes cracks in the bricks during drying [1]. In terms of plastic properties, the results of examining the plastic limits of the samples showed that the clays of the Quaternary deposits show more plasticity than the clays of the Gercus Formation, and this is due to the presence of a high percentage of fine grains whose size is less than (2µm) where the clay percentage reaches 60% and the silt percentage reaches 47% as in the table 1, this helps in forming the samples easily with the addition of a small amount of water, as for the clays of the Gercus Formation, they require larger quantities of water to form brick samples.

Table 1. Physical properties of the clay samples

samples	Formation	moisture content	Grain size			Atterburg Limits		
			Sand %	Silt %	Clay %	Liquid limit	Plastic limit	Plasticity index
C1	Quaternary deposits	5.6%	4%	47%	49%	41	24	17
C2	Quaternary deposits	10%	4%	47%	49%	43	26	17
C3	Quaternary deposits	12.74%	6%	34%	60%	42	27	15
G1	Gercus Formation	13.44%	31%	19%	50%	65	51	14
K1	Kolosh Formation	5.6%	31%	52%	17%	-	-	-

Chemical Analysis :

The clay used in the manufacture of bricks must contain silica, which comes from sand or clay minerals (hydrated alumina silica). The presence of silica helps the bricks maintain their shape and prevents shrinkage, cracking, or deformation of the bricks, in addition to increasing the heat resistance of the clay [22]. The chemical properties have been shown. The clay deposits of the Quaternary deposits and the clays of the Gercus Formation consist primarily of silica, which is considered the main component of the clay used in the manufacture of bricks. Increasing the percentage of silica destroys the cohesion between the particles, which makes the bricks brittle when burned [1]. Clay samples also contain a degree of calcium oxide, which comes from carbonaceous minerals (calcite and dolomite). This percentage of lime helps bind the brick particles together by dissolving the sand particles, in addition to reducing shrinkage upon drying. The size of the lime particles also affects the properties of the bricks, as the presence of lime particles of a larger size 3mm leads to cracks in the bricks and thus the bricks disintegrate as a result of absorbing large amounts of water[22]. The presence of iron oxide in the clay samples, which ranges from 3.99% to 5.5% in the Quaternary clays and reaches 7.98% in the clays of the Gercus Formation, helps the silicates to merge during the combustion process and bind the brick particles together and gives the iron oxide the distinctive color of the bricks that it ranges from light yellow to red, depending on the amount of iron oxide present in the clay, which ranges in percentage in the bricks 5-7%. Iron also contributes to improving permeability and durability and gives strength and hardness to the bricks [2]. As for alumina, it is considered the main component of clay. Its percentage in the Quaternary clays reaches 9.62%, and in the Gercus Formation clays, its percentage decreases to 4.66%. Its source is a source of clay minerals. It helps in shaping the bricks in the desired shape when they are formed, and they maintain their shape when dried and become It is solid [1]. The presence of alumina in excessive quantities leads to shrinkage and warping of the bricks during burning, in addition to increasing heat resistance. This condition can be treated by adding sand [2]. The ratio of alumina to iron (Al_2O_3/Fe_2O_3) is considered an indicator. It is important to determine the use of clays for a specific industry. If the percentage is greater than (5.5), these clays are considered heat-resistant and can be used in the manufacture of heat-resistant ceramics. However, if the percentage is less than 5.5, it means that they are rich in iron and can be used in the manufacture of building materials and bricks [23]. The presence of magnesium oxide adds a yellow tinge to the bricks and reduces shrinkage, and if it is present in large quantities, it causes the bricks to decompose. As for alkalis, they help to melt and thus help to integrate alumina silicates. However, their presence in large quantities causes white deposits called efflorescence, as alkalis crystallize upon contact with moisture, and upon drying, the water evaporates, leaving these white deposits

[2]. Therefore, its presence in a high percentage makes it unsuitable for the manufacture of bricks.

Table 2: Results of chemical analysis using X-ray spectroscopy (XRF) for the limestone and clay samples under study

Simple	Oxide										
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Cl	L.O.I	**Total**
C1	41.7	9.62	5.5	15.95	3.9	0.08	0.142	1.621	0.005	21.42	**99.97**
C2	39.0	9.1	4.79	15.54	3.75	0.07	0.135	1.41	0.007	26.14	**99.97**
C3	37.0	8.52	3.99	25.89	3.59	0.11	0.10	1.21	0.007	19.44	**99.93**
G1	38.3	4.66	7.98	10.1	9.36	0.09	0.03	0.55	0.009	28.83	**99.94**
G2	38.5	5.45	6.89	14.32	7.96	0.03	0.035	0.67	0.007	26.11	**99.97**
K1	33.6	2.93	8.66	6.06	20.88	0.86	0.077	0.23	0.007	26.61	**99.96**

Mineralogy :

Through the X-ray diffraction patterns of the bulk clay samples, the minerals in the Quaternary deposits samples are quartz, calcite, feldspar, and gypsum. Fig. (3: a, b, and c) while the Gercus Formation shows the presence of minerals: dolomite, quartz, and feldspar, Fig. (3, d).

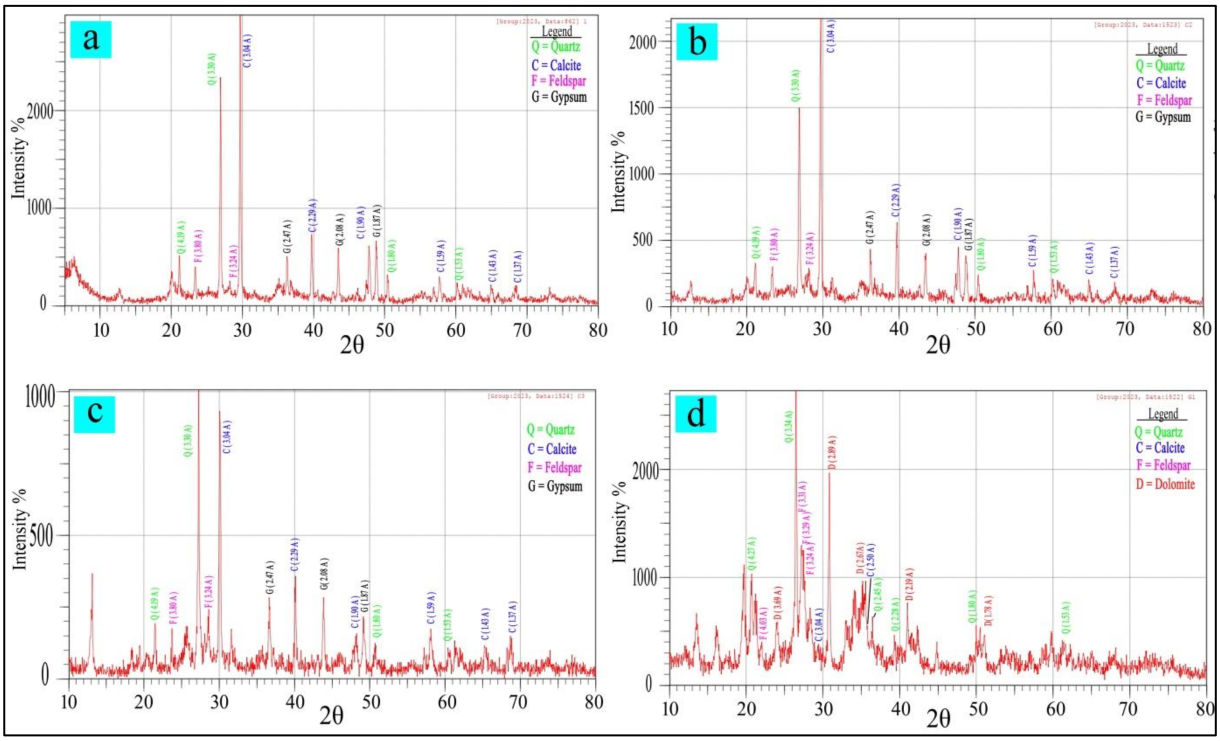

Fig 3. *X-ray diffraction pattern of bulk sample (a) sample C1 (b) sample C2 (c) sample C3 (d) sample G1*

X-ray diffraction patterns also show that the clay minerals that appear in the clays of the Quaternary deposits are: smectite, illite, palygorskite, and chlorite Figures (4: a, b, and c) (5: a, b) As for the clays of the Gercus Formation, the common clay mineral is palygorskite, in addition to a small amount of smectite and palygorskite Figures (4.d) (5: c, d).

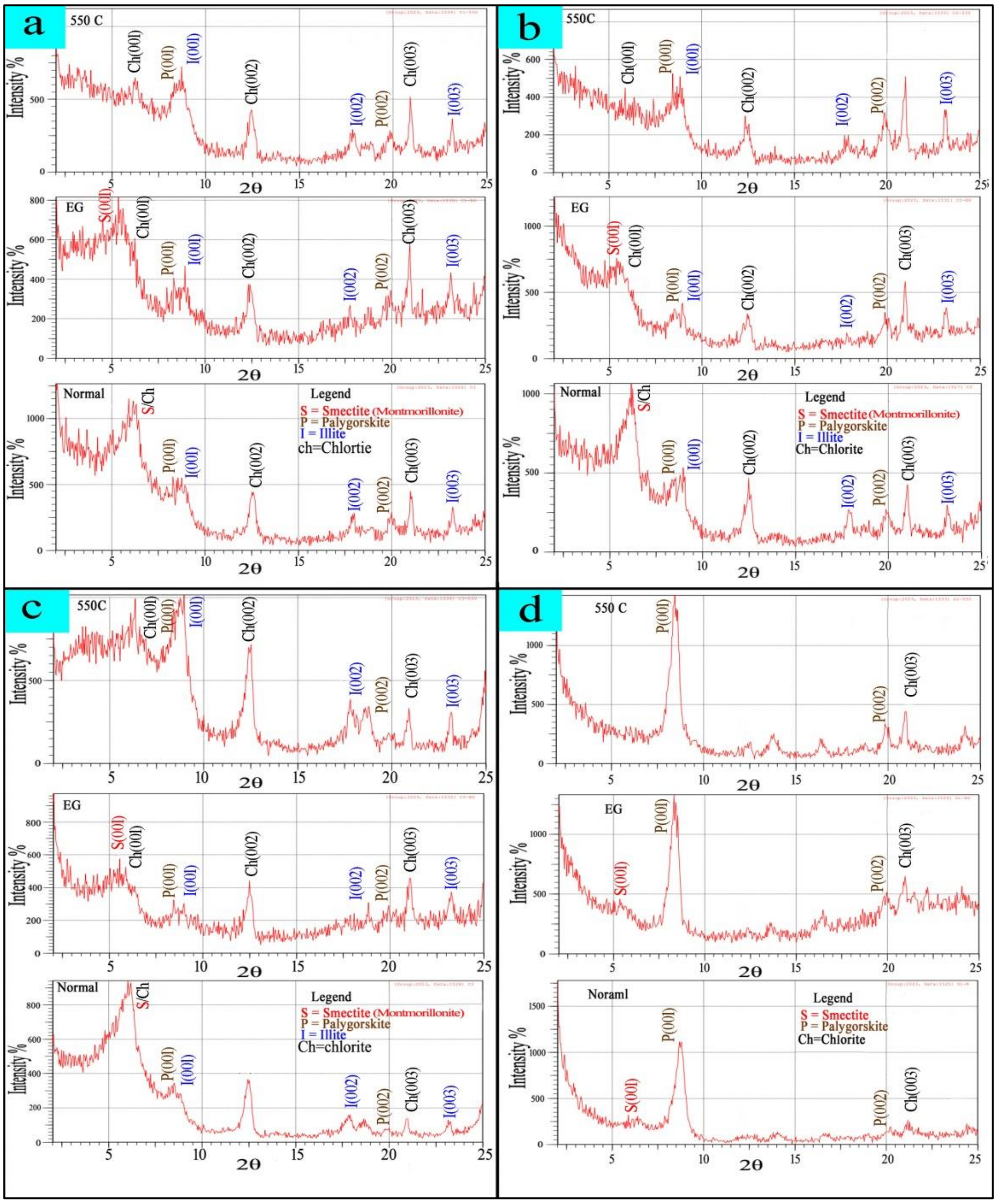

Fig 4. *(XRD) of clay minerals. (a) sample C1 (b) sample C2 (c) sample C3 (d) sample G1*

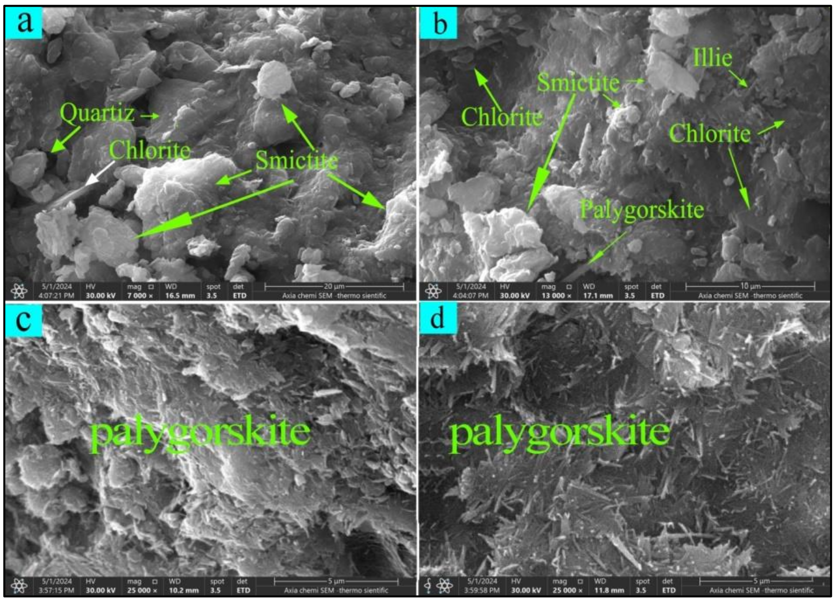

Fig 5. *SEM displays clay minerals. (a) and (b) Quaternary deposits (c) and (d) clays of the Gercus Formation*

Evaluation of brick samples

Size and shape

Good bricks are characterized by having a fixed size, flat shape, and flat surfaces with parallel sides and straight edges, free of cracks and fractures. Cracks form as a result of the presence of lumps of lime or an increase in the proportion of water during the formation process. In the first case, when the brick comes into contact with water, it absorbs the water and reacts with the lime contract, which leads to its expansion and the resulting disintegration of the bricks [2]. All the brick models that were prepared from the clays of the Quaternary deposits have a flat surface, free of cracks and limestone blocks, and have straight edges Fig. (6: a, b, c). As for the clay models of the Gercus Formation, the edges are not straight, and when fired at a temperature of 950^{o} C they appear. Some cracks occurred when burning at a temperature of 1050^{o} C. The percentage of cracks increased and this is due to the percentage of sand in the sample and also the percentage of water added Fig.(6: d, e,)

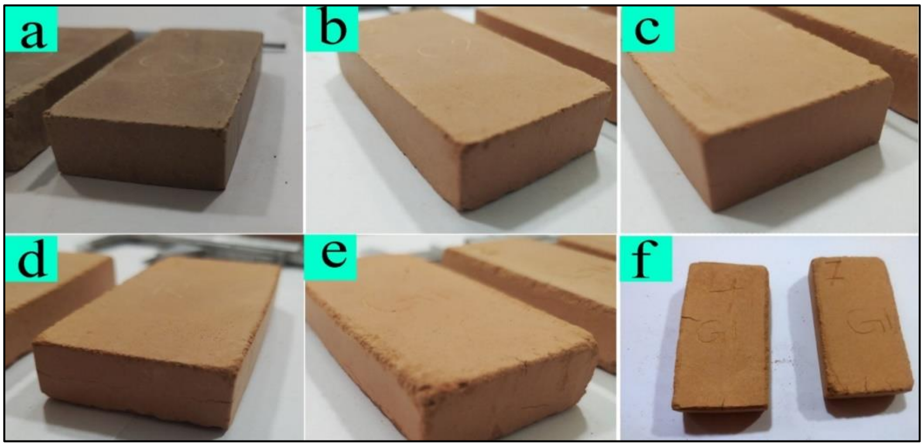

Fig. 6 *The shape and edges of the brick samples (a) A brick sample of the Quaternary deposits before burning (b) A brick sample of the Quaternary deposits after burning at a temperature of 950^{0} C (c) A brick sample of the Quaternary deposits after burning at a temperature of 1050^{0} C (d)) The mixed brick sample (C2 + G1) after burning at a temperature of 950^{0} C (e) The brick sample prepared from the Gercus Formation (G1) and burned at a temperature of 950^{0} C (f) The brick sample prepared from the Gercus Formation and burned at a temperature of 1050^{0} C*

Color

One of the distinctive features of bricks is the color, which is evidence of homogeneity in chemical composition and precision in burning. The main component responsible for the color is iron oxide. Burning under oxidizing conditions transforms the iron into iron (Fe III), and the distinctive color of the bricks becomes red. However, in the case of burning bricks under conditions of reduction in the final stages of bricks, the iron is reduced to ferrous iron (Fe II) or is mixed (Fe II/III), resulting in other colors blue and black [24]. The color of bricks that were fired at a temperature of 950^{o}, 1050^{o} C is red.

Linear shrinkage

The results of examining the linear shrinkage shown in Fig. (7) for brick samples that were prepared using clays of Quaternary deposits and prepared by a semi-dry pressing method ranged from 1.22% to 1.26%. As for the brick samples prepared from the clays of the Gercus Formation (G1), the linear shrinkage rate reaches 3.15%. As for the samples that were prepared by mixing the clays of the Quaternary deposits and the Gercus Formation (R1), the shrinkage rate is 1.25% for the samples that were fired at a temperature of 950º C. As for the samples, burned at a temperature of 1050º C, the linear shrinkage rate for Quaternary clay samples ranges from 1.26% to 1.91%. As for the Gercus Formation samples, the linear shrinkage rate is 4.18%. As for samples (R1), the linear shrinkage rate is 1.41% at temperature 1050º C This is due to the high linear shrinkage rate in the Gercus Formation samples.

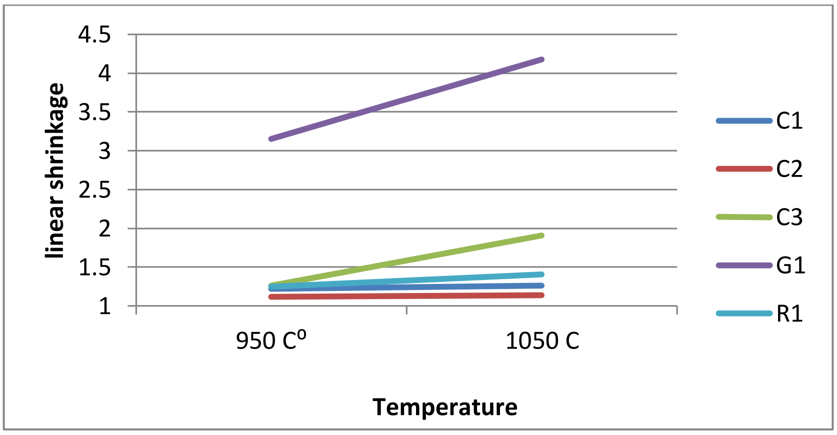

Fig. 7 *Results of the linear shrinkage ratio of brick samples prepared by the pressing method*

Bulk Density

The bulk density results showed that the samples that were prepared from the clays of Quaternary sediments were characterized by a higher density than the samples that were prepared from the clays of the Gercus Formation. The bulk density of the samples of Quaternary deposits ranged from 1.75 gm/cm3 to 1.82 gm/cm3 for the burnt samples. At a temperature of 950º C, this density decreases with increasing burning temperature, reaching a temperature of 1050^0 C to 1.6 gm/cm^3. As for the samples prepared from clays of the Gercus Formation, the bulk density ranges from 1.2 gm/cm^3 when burned at a temperature of 950^0 C to 1.22 gm/cm^3. As for samples (R1), their density ranges from 1.57 gm/cm^3 at a temperature of 950^0 C to 1.47 gm/cm^3 at a temperature of 1050^0 C. Fig.(8) shows the relationship of bulk density with burning temperature.

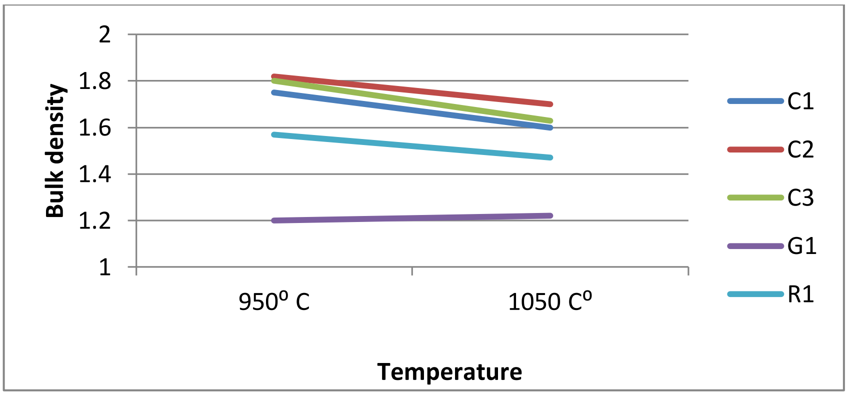

Fig. 8 *Results of examining the bulk density of brick samples*

Absorption

The presence of fine pores gives the bricks a capillary property. Therefore, all types of bricks absorb water through the capillary property. The absorption rate is an indicator of the absorption value, as high temperatures help close the pores and thus reduce the absorption rate [2]. The results of the absorption test showed that the samples that were prepared using clay of Quaternary deposits showed a lower absorption rate, as the lowest absorption value was obtained for samples burned at a temperature of 950^0 C, from 16.5% to 18.1%, while for samples burned at a temperature of 1050º C showed a higher absorption rate, ranging from 18.2% to 20.47%. As for the samples of the Gercus composition, the absorption rate reached 48.03% when burned at a temperature of 950^0 C and 51.2% when burned at a temperature of 1050^0 C. For samples (R1), the absorption rate ranges from 24.22% when burned at a temperature of 950^0 C to 27.65% when burned at a temperature of 1050^0 C. Fig. (9) shows the absorption percentage of brick samples**.**

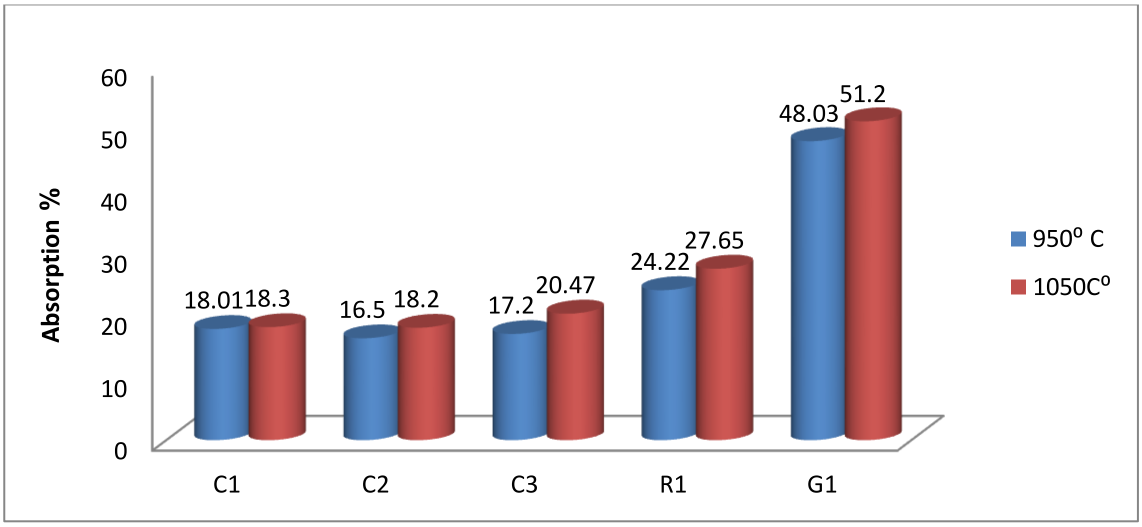

Fig. 9 *Absorption percentage of brick samples prepared using the semi-dry pressing method*

Efflorescence

Sometimes, during modern construction processes, white deposits are formed on the surface of the bricks, called efflorescence. These deposits are transferred to the surface of the bricks through water and are deposited through evaporation. The origin of these salts may be from the surrounding soil, which is transferred to the bricks, but in many cases, the origin of these salts is the salt is the brick itself. The brick may contain a percentage of sulfate salts such as sodium, potassium, magnesium, and calcium sulfate. The percentage of these salts may reach 5% of the weight of the brick, but the most common is 1-0.1%, and chemical analysis cannot be relied upon as evidence. Despite the presence of efflorescence, the appearance of efflorescence may be affected by the movement of salts, which depends on the ceramic composition of the bricks and the structure of the pores in the bricks. Therefore, it is best to evaluate them directly by wetting and drying the bricks [1]. The results of the efflorescence test showed that all brick samples showed a slight efflorescence rate. Fig. (10) shows the brick samples after 10 days.

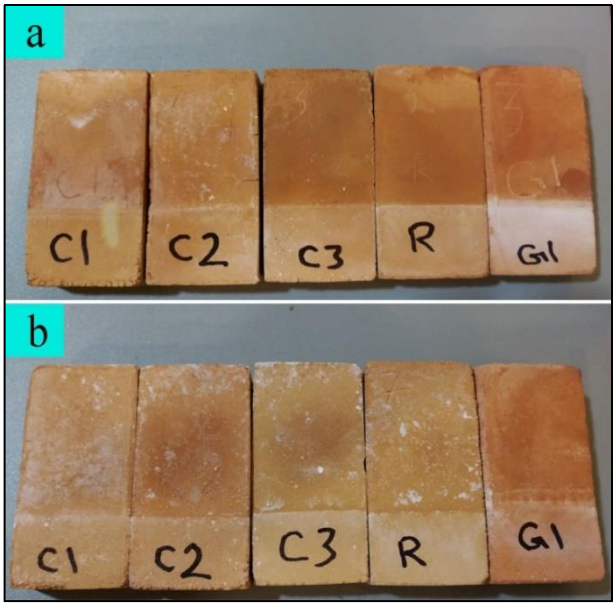

Fig. 10 *efflorescence of brick samples (a) samples fired at a temperature of 950^0 C, (b) Samples burned at a temperature of 1050^0 C*

Compressive Strength

There is no doubt that compressive strength is one of the important mechanical properties that are taken into consideration for building materials and is known as the ability of the material to resist failure under the influence of pressures resulting from loads [2]. The results of the compression strength test for brick samples prepared by the semi-dry pressure method using Quaternary deposits clays and burned at a temperature of 950⁰ C showed that it ranged from 21.56 Mpa to 28.35 Mpa, and it is classified according to Iraqi Standard Specification No. 25 as ClassA Table (3). As for the samples prepared using the Gercus Formation clays, the compressive strength decreased to 8.43 Mpa but it showed failure in the absorption rate, so it is out of the limits of Iraqi Standard Specification No. 25. As for the samples prepared by mixing Gercus Formation clays with Quaternary deposits clays, the compressive strength reached 16.80 Mpa and it is classified according to Iraqi Standard Specification No. 25 as ClassB. With the increase in the burning temperature to 1050⁰ C, the compressive strength increased to reach the brick samples prepared from the clays of the Quaternary deposits ranged from 27.87 Mpa to 33.85 Mpa and it is classified according to Iraqi Standard Specification No. 25 as ClassA Table (4). As for the samples that were prepared from by mixing the clays of the Quaternary deposits with the clays of the Gercus Formation, their compressive strength reached 19.5 Mpa, but it showed failure in absorption rate.. As for the samples that were prepared from the clays of the Gercus Formation, they showed failure due to the cracks that appeared on the body of the brick due to shrinkage. Therefore, the compressive strength test was not conducted on them, considering them to have failed. Tables. (3) and (4) shows the results of the compressive strength test for the soft bricks.

Table 3: Results of evaluation tests for brick samples fired at a temperature of 950^0 C

Samples	Bulk Density	Absorption	Compressive Strength (Mpa)	Efflorescence	Class according to the Iraqi standard (25)
C1	1.75	18.0	28.35	light	A
C2	1.82	16.5	27.84	light	A
C3	1.80	17.2	21.56	light	A
G1	1.2	48.0	8.43	light	failure
R1	1.57	24.2	16.80	light	B

Table 4: Results of evaluation tests for brick samples fired at a temperature of 1050^0 C

Samples	Bulk Density	Absorption	Compressive Strength (Mpa)	Efflorescence	Class according to the Iraqi standard (25)
C1	1.60	18.3	33.85	light	A
C2	1.70	18.2	33.36	light	A
C3	1.63	20.4	27.78	light	A
G1	*1.22*	51.2	-	light	failure
R1	1.47	27.6	19.5	light	failure

Mineralogical analysis

X-ray diffraction (XRD) data for two samples of bricks fired at a temperature of 950^0 C, and 1050^0 C showed the presence of quartz as the main crystalline phase in the sample fired at a temperature of 950^0 C, as well as the presence of wollastonite ($CaSiO_3$) and the appearance of the mineral anorthite ($CaAl_2Si_2O_8$) is this group of minerals that formed the main mineral framework of the bricks fired at a temperature of 950^0 C, Figs (11, 12, and 13) and is responsible for the physical and mechanical properties of the bricks [25] and as the temperature increases to 1050^0 C, the intensity of the peaks of the mineral Gehlenite ($Ca_2Al_2SiO_7$) and the mineral anorthite Figs. (14, 15, and 16) increases, which indicates that part of the quartz and calcite interacted with them [25], forming the mineral Gehlenite, which it consists of a mixture of illite, silica, and carbonate [26]. This mineral can arise from burning calcium carbonate with free quartz [27]. The second mineral is diopside ($CaMgSi_2O$), which is formed at temperatures 1050^0 C in clays containing lime due to the decomposition of calcium carbonate [28]. Fig(14)

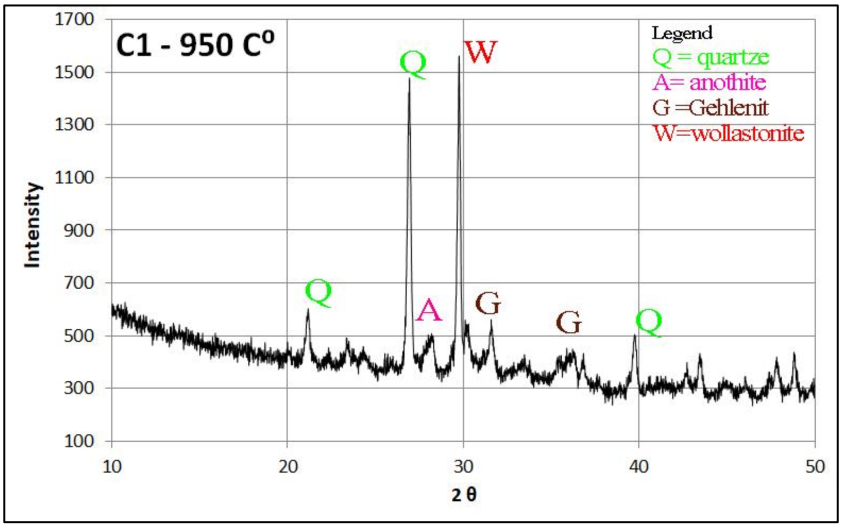

Fig. 11 *X-ray diffraction pattern of a brick sample (C1) fired at a temperature of 950^0 C*

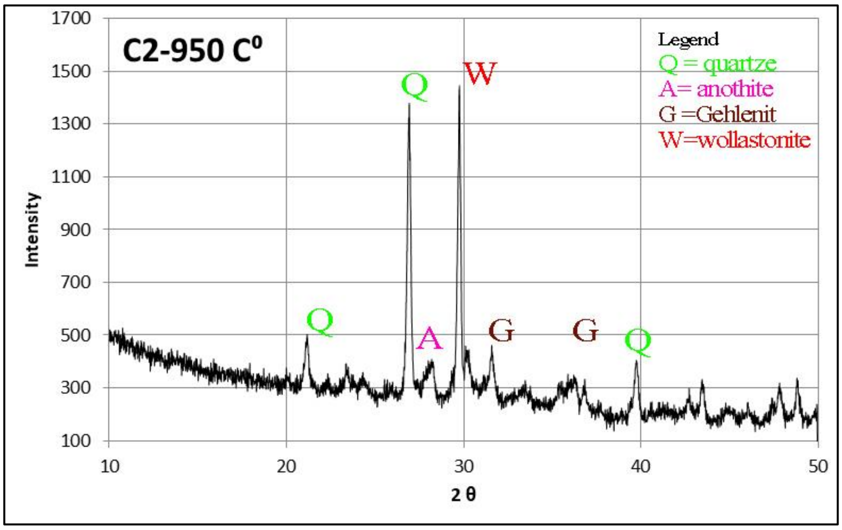

Fig. 12 *X-ray diffraction pattern of a brick sample (C2) fired at a temperature of 950^0 C*

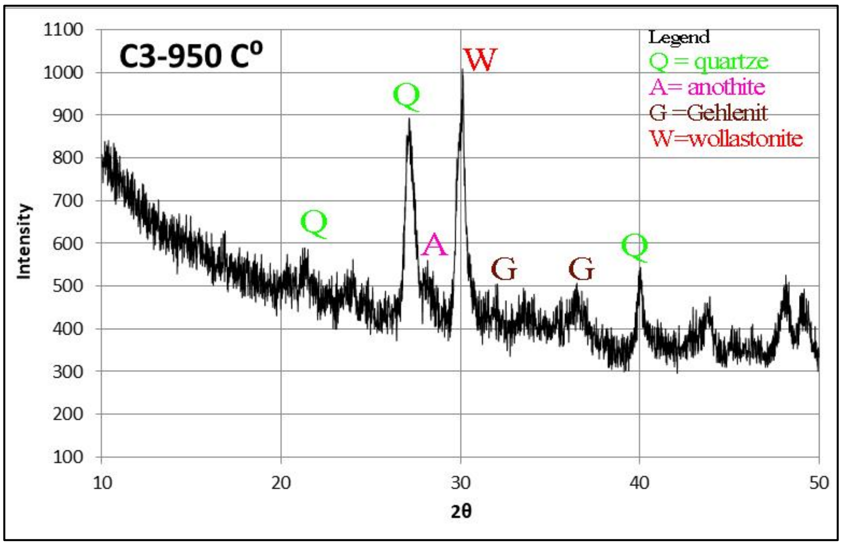

Fig. 13 *X-ray diffraction pattern of a brick sample (C3) fired at a temperature of 950^0 C*

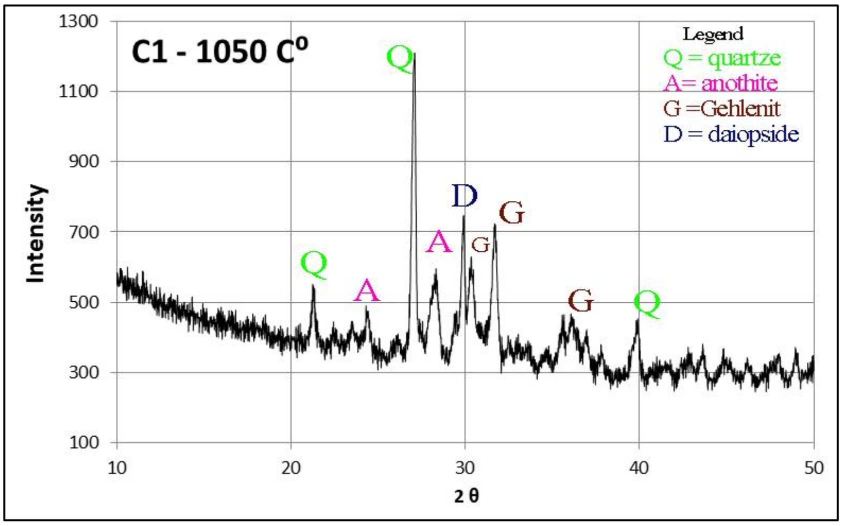

Fig. 14 *X-ray diffraction pattern of a brick sample(C1) fired at a temperature of 1050^0 C*

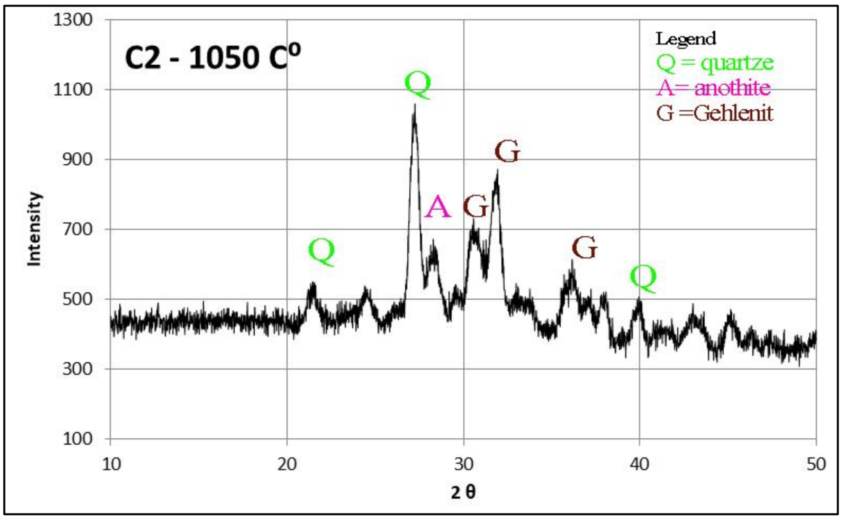

Fig. 15 *X-ray diffraction pattern of a brick sample(C2) fired at a temperature of 1050^0 C*

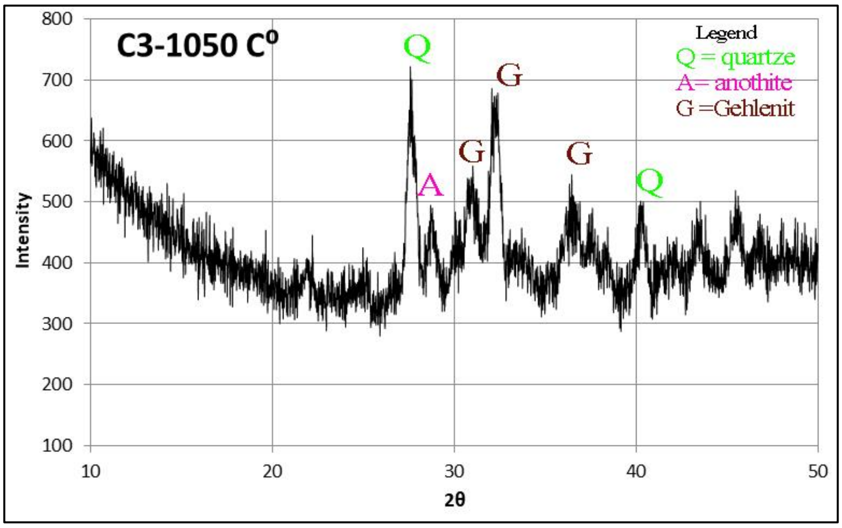

Fig. 16 *X-ray diffraction pattern of a brick sample(C3) fired at a temperature of 1050^0 C*

Discussion:

The brick samples prepared from Quaternary sedimentary clay and burned at two temperatures (950 C⁰) have sufficient strength to meet the requirements and standards of the brick industry specified in the Iraqi Standard Specification No. 25 of 1988 in terms of compressive strength, absorption, ratio and bloom, where Class A bricks were obtained. The compressive strength of the Quaternary deposits samples is due to the formation of the mineral gehlenite, which is characterized by a hardness of up to 6 according to the Moho hardness scale, which begins to crystallize at temperatures of 1050⁰ C and the percentage of this mineral increases with increasing temperature, where X-ray diffraction patterns of the brick samples showed an increase in the intensity of the reflection of this mineral with increasing temperature.

Since diopside and anorthite have many advantages for manufacturing and applications, such as suitable strength and low sintering temperature, the compressive strength of the Quaternary deposit samples reached 33.85 MPa. Table (4) shows the results of the evaluation tests of the brick samples and the permissible limits according to the Iraqi Standard Specification No. 25 of 1988. The results of examining the brick samples prepared using Quaternary deposits also showed that there is a relationship between the firing temperature and the physical properties of the bricks prepared using Quaternary deposit samples, as increasing the firing temperature leads to an increase in the percentage of loss in firing and thus leads to an increase in porosity in the bricks, as the clay samples contain a high percentage of calcium carbonate ($CaCO_3$) which loses 44% of its weight in the form of (CO_2) during burning leaving pores and spaces between the brick particles, which leads to an increase in the absorption rate and a decrease in density.

As for the samples prepared from the clays of the Gercus Formation (G1), they showed failure in compressive strength, absorption rate, and an increase in the linear shrinkage rate. The results also showed that the decrease in the percentage of alumina and the increase in the percentage of iron in the Gercus Formation clays led to the failure of the brick samples due to shrinkage, which led to the distortion of the samples, and the increase in the percentage of sand led to an increase in porosity and thus an increase in the absorption rate.

As for adding the clays of the Gercus Formation at a rate of 25% to the clays of the Quaternary deposits, we obtain Class B bricks burned at a temperature of 950⁰, 1050⁰ C according to the Iraqi standard specification No. 25.

Conclusions

1- The Quaternary deposits are dominated by fine sizes (clay and silt), so their use in the cement industry reduces the cost of grinding. As for the clay deposits of the Gercus Formation, the percentage of clay in them reaches 52%, while the silt is a small percentage reaching 17%, and the percentage of sand reaches 30%. As for the sediments of the Kolosh Formation, the most prevalent sediments are silt, sand and a small percentage of clay.
2- The deposits of the Kolosh Formation cannot be used in the manufacture of bricks due to the low percentage of alumina and the high percentage of magnesium.
3- Due to the low percentage of sand in the Quaternary deposits, they exhibit a plastic property, which positively helps in forming bricks with smaller amounts of water. As for the clay sediments to form Gercus, they require a large amount of water to form bricks due to the presence of a high percentage of sand.

4- The presence of coarse grains with a sand size of more than 10% negatively affects the formation of bricks due to increased porosity and thus requires large amounts of water to form samples and may lead to cracking of the bricks during burning.
5- Quaternary deposits can be used to manufacture bricks to obtain Class A bricks according to Iraqi Standard Specification No. 5 of 1988 and burned at a temperature of 950^{o} C.
6- The clays of the Gercus Formation are not suitable for brick making and cannot even be used as additives due to the high percentage of sand in addition to the low percentage of alumina, which caused the bricks to shrink during firing.

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Samarra Journal of Pure and Applied Science
SJPAS
مجلة سامراء للعلوم الصرفة والتطبيقية
www.sjpas.com
p ISSN: 2663-7405
e ISSN: 2789-6838

تقييم رواسب الأطيان لصناعة الطابوق في حوض بازيان شمال العراق

عمر حميد محمد [1*]، سوسن حميد الهزاع [2]

1-وزارة التربية، بغداد، العراق
2- قسم علوم الأرض التطبيقية، كلية العلوم، تكريت، العراق

البحث مستل من رسالة ماجستير الباحث الأول

معلومات البحث:

تأريخ الاستلام: 2024/07/31
تأريخ التعديل: 2024/08/25
تأريخ القبــول: 2024/09/30
تأريخ الــنشر: 2025/03/30

الكلمات المفتاحية:

الطابوق الطيني، حوض بازيان, تكوين جركس ،تكوين كولوش, والامتصاص.

معلومات المؤلف

الايميل:omerhameed503@gmail.com
الموبايل:07700297859

الخلاصة:

تهدف هذه الدراسة إلى تقييم رواسب الأطيان في منطقة حوض بازيان لصناعة الطابوق الطيني, تقع منطقة الدراسة في شمال شرقي العراق ضمن حدود محافظة السليمانية والتي تبعد حوالي(30)كم غرب محافظة السليمانية، ينكشف في هذه المنطقة مجموعة من التكاوين التي يعود عمرها إلى العصر الثلاثي وهي تكوين كولوش الذي يتكون من تسلسل من الرواسب الفتاتية ذات اللون الداكن وتكوين سنجار الذي يتكون بشكل رئيس من الحجر الجيري وتكوين جركس الذي يتكون من تتابعات من الحجر الطيني الأحمر والمارل الرصاصي المتعاقبة وتكوين بيلا سبي الذي يتكون من الحجر الجيري بالإضافة إلى رواسب العصر الرباعي التي تتكون بشكل رئيس من الطين النقي, تم دراسة الخواص الفيزيائية التي شملت الحجم الحبيبي وحدود القوام والمحتوى الرطبي وأيضًا تم دراسة الخواص الكيميائية باستخدام تقنية (XRF) وتمّت الدراسة المعدنية للأطيان في منطقة الدراسة باستخدام تقنية (XRD), وقد أظهرت دراسة الخصائص الفيزيائية والكيميائية أن رواسب تكوين كولوش غير صالحة لصناعة الطابوق وذلك لعدم وجود طين يساعد في تشكيل النّماذج، بالإضافة الى نسبة المغنيسيوم العالية جدًا حيث وصلت إلى (22%) وهذه الخصائص غير صالحة لصناعة الطابوق. أمّا بالنسبة لأطيان تكوين جركس فقد أظهرت الخصائص الفيزيائية أنّها تحتوي على نسبة عالية من الطين حيث وصلت إلى (52%) ثم الرمل الذي وصل إلى (31%) وتحتوي على نسبة منخفضة من الغرين حيث وصلت إلى (17%)، كما أظهرت الخصائص الفيزيائية أن حد اللدونة مرتفع ويحتاج إلى كميات إضافية من الماء لتشكيل الطابوق، وأظهرت الدراسة المعدنية أنّها تحتوي على الباليغورسكايت, وقد انعكس ذلك كيميائياً حيث أظهرت نتائج (XRF) أنّه يحتوي على نسبة عالية من المغنسيوم تصل إلى (9%) ونسبة عالية من الحديد كما أظهرت الدراسة فشل عيّنات الطابوق المحضرة من نماذج تكوين جركس بسبب ارتفاع معدل الامتصاص وانخفاض قوة الضغط أمّا بالنسبة لرواسب العصر الرباعي فإنّها تتكون بشكل رئيس من الطين التي تصل إلى (60-47%) ونسبة عالية من الطمي (47-34%) ونسبة قليلة من الرمل(4-6%) كما أظهرت الخواص الفيزيائية أنّ حدّ اللدونة منخفض ممّا يساعد في تشكيل الطابوق كما أظهرت الدراسة المعدنية وجود المعادن الطينية (المونتموريلنايت والاليت والباليجورسكايت والكلورايت) أمّا الخواص الكيميائية فهي تحتوي على نسبة جيدة من الألومينا تصل إلى (9%) ونسبة من الحديد تصل إلى (5%) إلى ونسبة منخفضة من المغنسيوم. وأظهرت الدراسة أنّ الطابوق باستخدام رواسب العصر الرباعي تقع ضمن الفئة (أ) بحسب المواصفة القياسية العراقية رقم (25) .