



Industrial Assessment of Mudstone Deposits of Gercus Formation as a Raw Material for Bricks Industry in Erbil Governorate, Northern Iraq

Mohammed A Mohammed*¹ and Amara Ismael Hussain²

¹ Department of Geology, College of Science, Tikrit University, Tikrit, Iraq

* Correspondence: ameenalzaidi69@gmail.com

Abstract

Received:
23 March 2024

Accepted:
18 August 2024

Published:
31 October 2024

This paper evaluates the mudstone deposits' physical, chemical, and mineralogical properties and the possibility of use as a raw material to manufacture building bricks. Four sites are selected from the Gercus Formation in Shaqlawa district and the samples are tested. The mudstone samples are analyzed to define the grain size, Atterberg limits, chemical, physical and mechanical characteristics of the clay bricks. The grain size analysis of the mudstone samples showed they contained a high percentage of clay and silt and a low percentage of sand. The chemical analysis showed that silica (SiO₂) was the major component in the mudstones. XRD analysis showed the presence of non-clay minerals i.e. calcite, quartz, albite and clay minerals of illite, palygorskite and chlorite. Raw samples of all studied sites were treated to prepare brick samples without addition, and others with 10% standard sand added. The results showed that the bricks prepared from the B to B10 and C to C10 stations have varying water absorption and compressive strength, while the efflorescence has light salts. All these properties are within the requirements of the Iraqi specification for brick manufacturing. The sample sites A, D, A10, and D10 are not compatible with the Iraqi standard in terms of absorption and compression.

Keywords: Mudstone; Gercus Formation; Alternative raw material; Bricks; Shaqlawa

1. Introduction

Clays are the main raw materials invested in the manufacturing of various products such as bricks, tiles, abrasives, pottery, cement, and porcelain (Awadh and Al-Owaidi, 2020). Using recent sediments (agricultural soils) in industry caused the reduction of large areas of agricultural lands within Iraq, which affected and reduced many agricultural products. Finding another source such as claystone beds would be as new raw material resources is of great importance to keep a balance between using lands for food and construction. Brick factories are unfortunately less financially supported than cement in Iraq. The significant aim of the present work is to study and evaluate the suitability and compatibility of the exposed claystone beds of Gercus rocks in the Shaqlawa area for industry (Fig. 1). Claystone is considered one of the wide-spreading materials found on the earth's surface, depending on their physical and chemical properties, they are used in different kinds of industries (Suhael and Hussain, 2020; Hussain and Ibraheem, 2021). One of the most important previous studies on the subject of the study is Awad and Awadh (2020) studied reserve estimation of Late Miocene Injana claystone beds for portland cement and brick industry in Iraq determined as a proven reserve by using the triangle and GIS method. Awad and Awadh (2021) and Awadh and Awad (2021) manufactured perforated and ordinary bricks

DOI: [10.46717/igi.57.2D.18ms-2024-10-28](https://doi.org/10.46717/igi.57.2D.18ms-2024-10-28)

using Injana claystone in the Karbala-Najaf plateau in the middle of Iraq, the researchers concluded that Injana claystone is suitable for such purposes. Najim and Yousif (2021) studied the Synthesis of Industrial ceramics (Cordierite) from Iraqi raw materials through the solid-state sintering method in the Western Dessert using X-ray (XRD) to measure the best mixture for preparing cordierite ceramics. Al-Bayati (2011) dealt with a study evaluating the validity of the clays in the Al-Khanouka region for the production of clay bricks in four locations, and the results of the evaluation tests of the study samples and compared them with the Iraqi standard specification No. 25 (1993) showed that three of those sites were suitable.

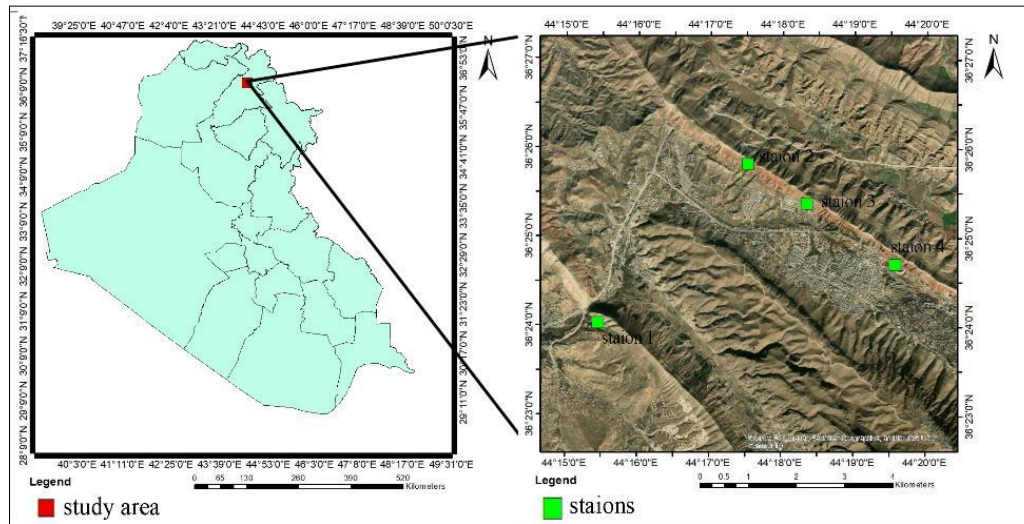


Fig.1. Location of the study area.

2. Geologic and Tectonic Setting

The study area is located within Erbil Governorate, NE-Iraq (Fig. 1), including red mudstone beds of the Gercus Formation. For industrial investigations, four locations were selected based on geological and mining properties, such as large bed thickness and low overburden sediments. Each section is limited, and the following coordinates of studied locations:

Table 1. Coordinates system of the study stations

Station no.	Latitude N	Longitude E
One	36° 24' 02"	44° 15' 28"
Two	36° 25' 30"	44° 18' 16"
Three	36° 25' 04"	44° 18' 05"
Four	36° 24' 28"	44° 19' 21"

Gercus Formation of the Mid-Late Eocene age belongs to tectonostratigraphic Megasequence AP10 of the Middle Paleocene-Eocene. (Jassim and Buday, 2006). It was deposited in the last stage of the Neo-Tethys Ocean closed, associated with renewed subduction and volcanic arc activity. The formation was first described by Maxon (1936) in the Gercus region of SE Turkey, the typical section in Iraq described by the world is Wetzel from the Dohuk area of N Iraq (Jassim and Buday, 2006). Based on the field and lithological description, a clear outcropped section in the NE limb of the Safeen anticline was selected. A brief description of the studied exposed succession is hereinafter.

Formation boundaries, gradational contact with the underlying Kolosh Formation, which is separated by well-marked successive fine-grained sandstones, grades upwards to siltstone and claystone, in fining upwards cycles. The upper contact is unconformable with the Pila Spi Formation represented

by conglomerates composed of various sizes of carbonate pieces supported with marly materials. Thickness; successions reveal about 46 m in thickness.

Lithology; Gercus Formation in the studied locations is composed of red medium to fine-grained sandstones, graded upwards to red to gray silty claystone. The beds range in thickness from 0.2 to 10 m. The sandstone beds are 1 to 2 m in thickness, reddish to grey, and thickly bedded. The successions are interbedded with white and drab color carbonate beds of 0.3 to 0.5 m in thickness. All lithologies together are arranged in fining upward cycles and capped with a carbonate bed.

Tectonically, the fold-thrust belt of Zagros contains multiple longitudinal tectonic zones, as defined by Buday and Jassim (1987), and Jassim and Goff (2006). The study area is located on the Outer Platform of the Arabian Plate in the high-folded zone. The Gercus Formation crops out in the Safeen anticline, the most complicated anticline in NE Iraq, with NW–SE trend.

3. Materials and Methods

Methodology includes two categories, the field works and the lab analysis. The field works included selection of the studied localities, sampling, determine the thicknesses of mining beds, and picking up of filed photographs, especially for mining beds.

Lab analysis included the following steps to determine the validity of the studied beds for the brick industry;

1. Grain size analysis to determine the suitable mixture for brick manufacture.
2. XRF analysis to determine the major oxide component in studied samples.
3. XRD analysis to determine the majority of minerals content in the studied samples.
4. Making bricks from the raw materials for industrial testing according to the results obtained from grain size, chemical and mineralogical analysis to determine the suitable mixture for brick manufacture for test of physical and mechanical properties.

Atterberg limit test to determine the water content in the tested samples relative to the plasticity and shrinkage crack.

4. Results and Discussion

4.1 Analysis of Grain Size

The studied samples are texturally wet analyzed to know the percentage distribution of the sediments compared to American Standard (ASTM- D, 422, 2004) to determine consequently the fineness modulus, effective size, and uniformity coefficient.

The distribution of the grain size was plotted on Folk triangular diagram showing sandy mud type of sediments (Table 2). The clay ranges from 49.4% up to 53.4% (20 μ m). Silt-size particles range from 36.5% up to 38.1% with the subordinate percentage of sand grains of 10.4% to 13.8%. The sediments are classified as sandy mud (Folk, 1974). The results of the grain size analysis of these gradients are suitable for making brick, because the silt and sand grains act as cement material through combustion, as well as, clay content also helps to cohesion the brick (Awad and Awadh, 2021).

Table 2. Grain size distribution of mudstone Samples (after Folk, 1864)

Sample Number	Sand %	Silt %	Clay %	Sample Name (Folk, 1974)
Station A	10.4	37.3	52.3	Sandy Mud
Station B	13.8	37.7	48.5	Sandy Mud
Station C	12.5	38.1	49.45	Sandy Mud
Station D	10.1	36.5	53.4	Sandy Mud

4.2 Atterberg Limits

Atterberg limits of Gercus clay deposits are displayed in Table 3. There is a clear correlation between plasticity and the size of tiny particles. Plasticity is an important property in clay industries a paste with good plasticity facilitates the molding process without appearing cracks (Grim, 1962). Based on the American Standard ASTM 4318 D, the soil that passed through a 425-micrometer screen, the plasticity and fluidity limits were measured, as low to high plasticity, due to their clay, silt and sand content. The high plasticity is due to the high clay content, and the low plasticity is due to the high silt content. plasticity affected particle size and the typology of the clayey minerals, plasticity increased due to the clayey minerals in which the layers are weakly bound e.g; minerals of montmorillonite and/ or illite nature (Surdashy and Aqrawi, 2021). That is a direct relationship between fine particle size and plasticity (Grime, 1968).

By comparing the results of the plasticity index (Table 3) with the classification of Budnikov (1964) (Table 4), it is clear that the study areas B, C, and D showed plastic, while the area (A) showed moderate plasticity. The tested Gercus samples are categorized as having ML or OL based on the chart of plasticity (Fig. 2), which illustrates the link between the plasticity index and the liquid limit. The types of clay, the granules' size, and the kind and proportion of non-clay minerals and organic compounds all have an impact on the plasticity index (Al-Khafaji, 2001).

Table 3. Results of Atterberg limits for the tested samples

Area	Liquid limit	Plastic limit	Plasticity index	Plasticity index depending on (Budnikov, 1964)
Station A	49	35	14	Moderately Plastic
Station B	47	28	19	Plastic
Station C	49	29	20	Plastic
Station D	46	29	17	Plastic

Table 4. Plasticity index depending on Budnikov (1964)

Plasticity Index (P.I)	Plasticity (P)
Super Plastic	>25
Plastic	15-25
Moderately Plastic	7-15
Poorly Plastic	<7
Non- Plastic	Non-forming plastic mass

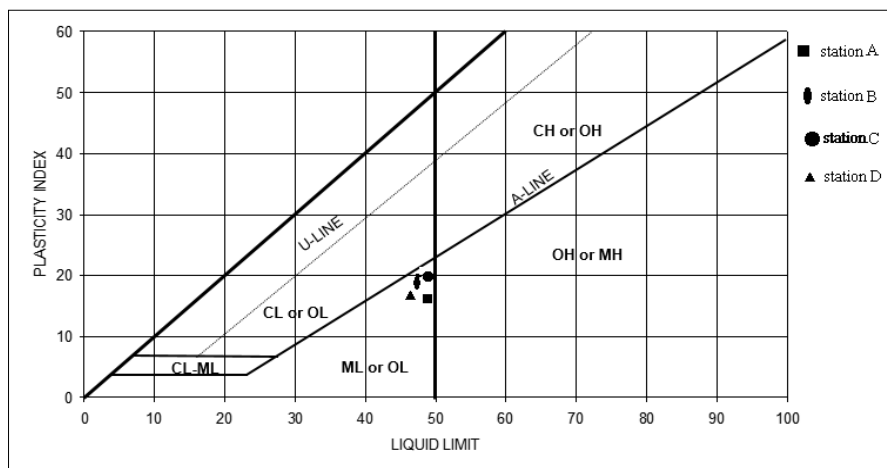


Fig. 2. Plasticity chart (ASTM 85-2487)

4.3. Chemical Analysis

Major oxides of SiO_2 , MgO , Fe_2O_3 , CaO , Al_2O_3 , L.O.I, Na_2O , K_2O , Cl and SO_3 are analyzed for the Gercus clay samples. It is important to specify competency for brick manufacture. The analysis results show that the highest percentage of oxides is SiO_2 , followed by CaO and MgO . The presence of SiO_2 is important in brick and tiles because of interferes with chemical reactions during burning by making a glassy substance that bridges the gaps in the clay particles and the molten materials and gives the product durability and increasing compressive resistance. In addition to that, some oxides affect the mechanical and physical properties of the brick product (Shreve and Brink, 1977), hence the chemical analysis data would give an idea about any characteristics that influence to a great extent the suitability of the clays used for application in brick industry and precaution informing and firing.

Fluxes play a key role in the vitrification of clay bodies by reducing the overall melting point (Surdashy and Aqrabi, 2021). CaO is present in calcite and montmorillonite and a high percentage acts to reduce the compressive resistance of bricks and tiles (Rashed, 2017). Fe_2O_3 is considered a coloring factor for brick products and Al_2O_3 is considered a melting resistant oxide. K_2O , Na_2O , SO_3 , and Cl , these oxides are found in the studied samples in small percentages (Table 5).

Table 5. Chemical element values of the analyzed samples

Oxides	Station A	Station B	Station C	Station D	Min.	Max.	Mean
	%						
SiO_2	36.17	38.34	39.1	36.97	36.17	39.1	37.635
Al_2O_3	5.7	7.89	8.63	6.07	5.7	8.63	7.165
Fe_2O_3	7.52	6.03	7.17	6.19	6.03	7.52	6.77
CaO	12.25	15.2	14.9	15.26	12.25	15.26	13.75
MgO	16.12	11.6	10.28	12.68	10.28	16.12	13.2
Na_2O	0.15	0.25	0.46	0.6	0.15	0.6	0.375
K_2O	0.13	0.24	0.54	0.43	0.13	0.54	0.33
SO_3	0.01	0.07	0.05	0.09	0.01	0.09	0.05
Cl	0.016	0.08	0.06	0.09	0.09	0.016	0.053
L.O.I	21.934	20.3	18.908	21.572	18.908	21.934	20.421

4.4 Mineralogy

X-ray analysis are carried out for four collected samples of the Gercus Formation to determine the mineralogical components using bulk sample running and for clay fraction only.

The results show that the non-clay minerals are quartz, calcite, dolomite and magnetite (Figs. 3, 4, 5 and 6), whereas the dominant clay minerals are palygorskite, montmorillonite, kaolinite, illite and chlorite (Figs. 7, 8, 9 and 10). The presence of montmorillonite particles causes swelling clay, which can lead to failure tests due to the tendency to perpetually displace sand in the mixture (Zoveidavianpoor, 2018).

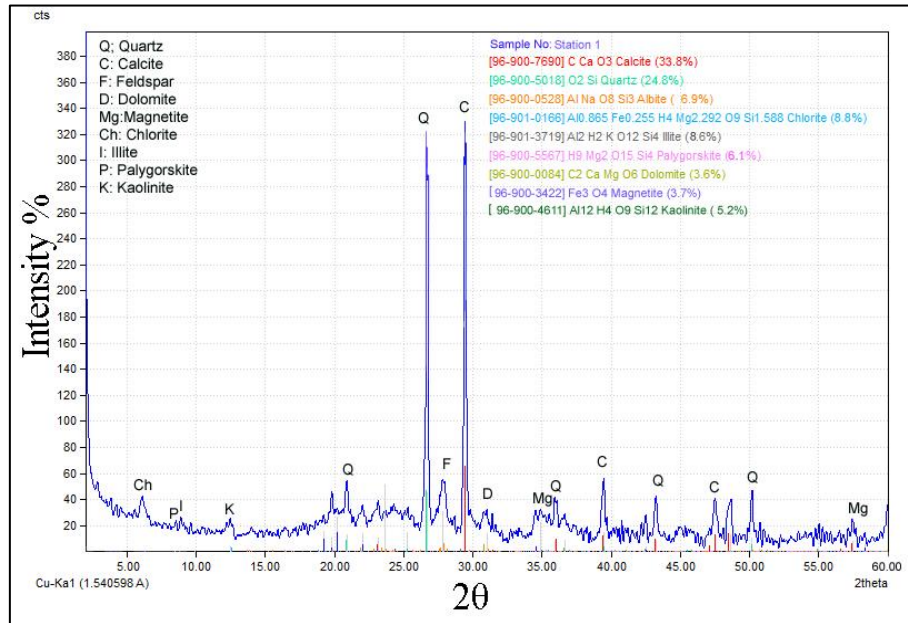


Fig. 3. X-ray diffraction of bulk sample station 1

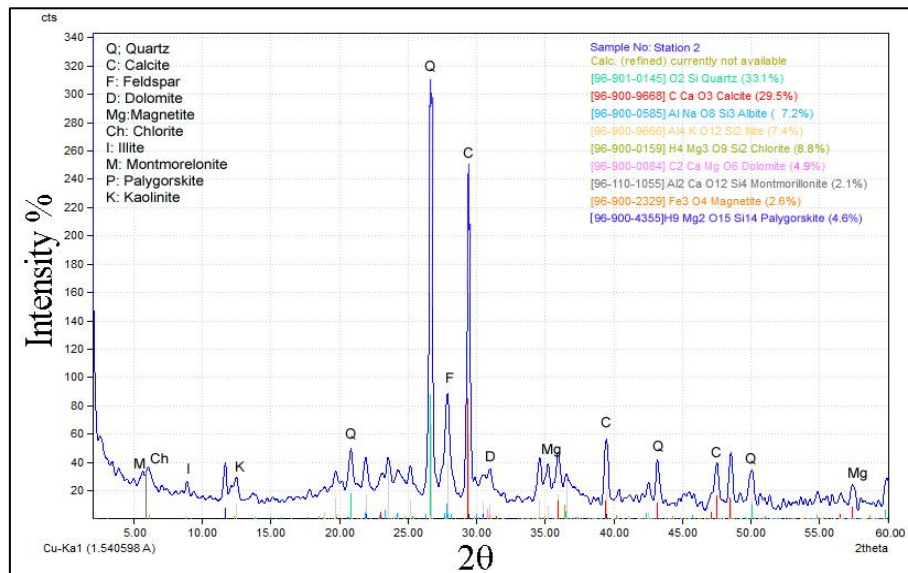


Fig. 4. X-ray diffraction of bulk sample station 2

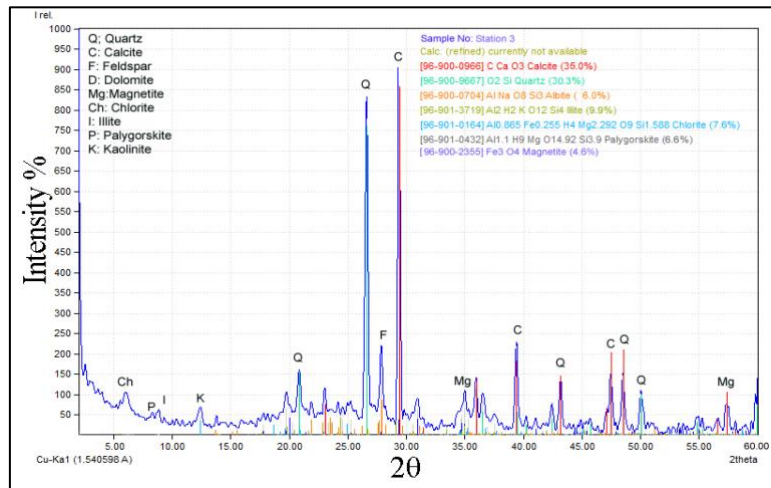


Fig. 5. X-ray diffraction of bulk sample station 3

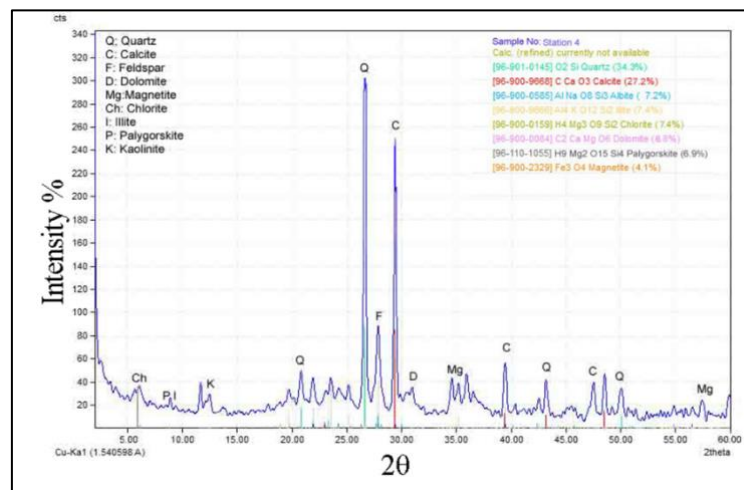


Fig. 6. X-ray diffraction of bulk sample station 4

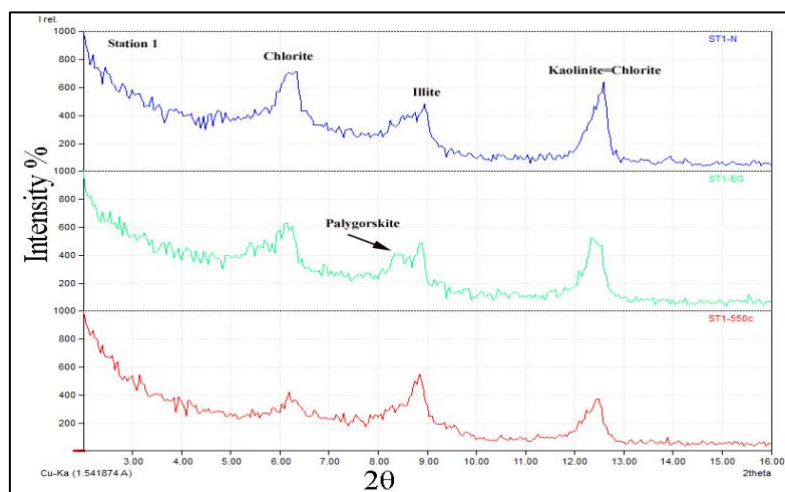


Fig. 7. X-ray diffraction of orientated sample station 1

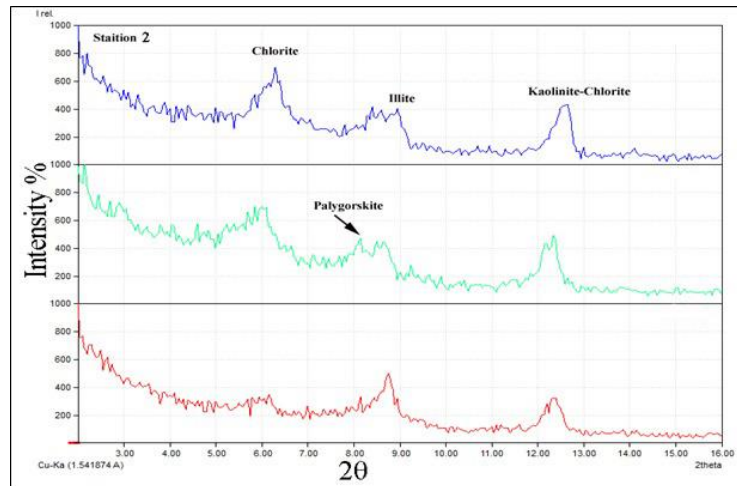


Fig 8. X-ray diffraction of orientated sample station 2

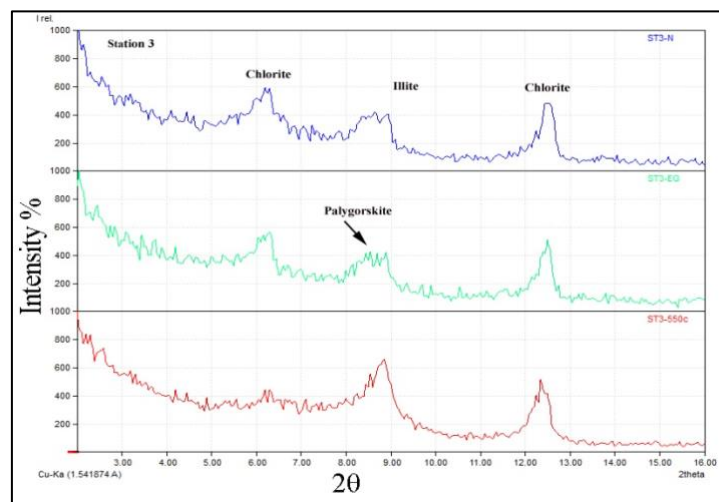


Fig 9. X-ray diffraction of orientated sample station 3

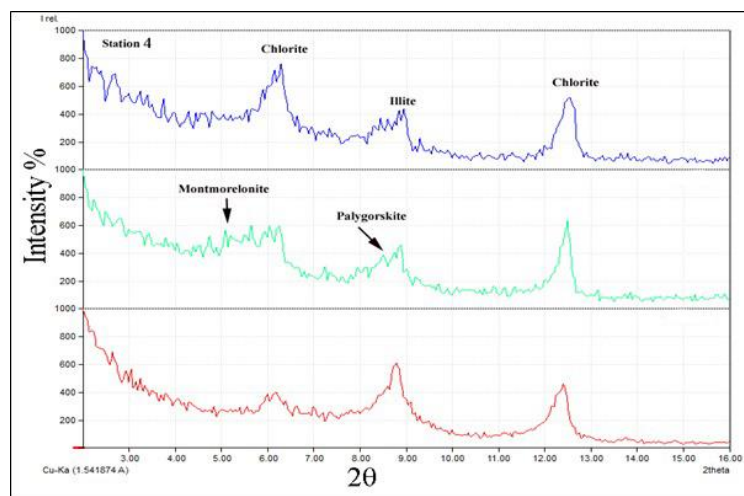


Fig 10. X-ray diffraction of orientated sample station 4

4.5 Brick Test

There are several ways to form ceramic objects, including the plasticity method, semi-dry method, dry method, and extrusion method, which is the most common method (Awad and Awadh, 2021). Two samples are prepared for each of the raw materials collected from the four studied localities for the manufacture of clay bricks using the semi-dry pressing method. The first sample was prepared from the raw materials without any added materials (A, B, C, and D). The second sample was added 10% (A10, B10, C10, and D10) of standard sand before mixing and washing samples to improve suitability for brick.

The samples were ground and sieved through a 0.015 mesh sieve, and 16% of water was added. The mixture was homogenized and placed in nylon bags for 24 hours, and then placed in a pressing device. After pressing, the samples were left for 24 hours and placed in a drying oven for 24 hours at a temperature of 100°C. The samples were burned at 950°C in the burning chambers and then weighed the samples. The samples were placed in water for 24 hours, and weight after immersion. The compressive strength performed and absorption are based on Iraqi standard specification No. 25, 1993 (Table 7).

4.5.1 Linear Shrinkage

It is the percentage of the decrease in the original length of the sample as a result of burning. It expresses the strength and quality of the bricks by measuring the change in the size and dimensions of the bricks produced after burning (Awad & Awadh, 2021). The longitudinal shrinkage depends on many factors, the most important of which is the size and shape of the grains involved in the manufacture of bricks, as the longitudinal shrinkage increases and reaches 15% in fine-grained clays with high plasticity, and is very little in non-plastic sandy clays.

The longitudinal shrinkage of the ceramic samples was calculated by applying the equation (1).

$$\text{Linear Shrinkage} = [(L1-L2)/L1] \times 100 \quad (1)$$

Whereas : L1 is the length before burning (mm), and L2 is length after Burning (mm).

Table 6 shows the results of linear shrinkage.

4.5.2 Water Absorption

It represents the percentage of water absorbed in the body of the product that fills the voids or pores in the brick and is considered one of the most important physical tests affecting building materials (bricks). Several factors control the amount of water absorption of burnt bricks, including the distribution of particle size, the percentage of clay minerals, and the percentage of non-clay minerals, especially calcite when free calcium oxide is released by burning, which has a great ability to absorb water and is formed in the body of the brick after burning, where it leads to the absorption of a higher percentage of water (Al-Hakim, 1998). It is one of the important tests in the ceramic industries, where the samples are placed after being prepared in a drying oven at a temperature of 110 degrees and left for 24 hours for drying, after that the samples are weighed and then burned. After the burning process, the samples are weighed, and the absorption percentage is calculated. The equations 2 are applied.

$$\text{Water absorption \%} = [(w2 - w1) / w1] \times 100 \quad (2)$$

Table (6) shows the absorption percentages of the samples.

4.5.3 Efflorescence Measurement

Efflorescence is the amount of salts that accumulate on the body of the burnt brick over time. The source of efflorescence is the presence of salts in the soil or water. Efflorescence results from wetting the brick and then drying it, so that white salt appears on the surface of the brick. Efflorescence is

expressed in degrees (light, medium, high) (according to the Iraqi standard specification No. 25 of 1993). Efflorescence was examined by placing the samples vertically and immersing them in distilled water to reach a quarter of the sample for three days. The water level is noted every day to add it if there is a decrease. Then the sample is placed in a well-ventilated room, and the results of efflorescence appear on the surface of the sample. Table 6 shows the results of efflorescence.

Table 6. Brick test analysis of the selected clay samples

Brick class	Efflorescence	Absorption %	Bearing load kg/cm ²	Linear Shrinkage %
A	Slight	32	61.17	4
A10%		31.7	65	3.7
B		26.8	119.32	2
B10%		27	124.7	1.9
C		25.3	111.9	1.4
C10%		25.9	115.1	1.1
D		36.8	62.9	4
D10%		36,5	66.8	4

4.5.4 Compressive Strength

It is considered one of the important mechanical tests for the produced ceramic objects, especially bricks. It determines the amount of pressure exerted on a specific area to determine the extent of the object's endurance before it breaks. It is measured in units of N/mm². The examination was carried out using an electro-hydraulic pressure machine, as the sample was put between the two surfaces of the hydraulic press, and the pressure was applied gradually until the collapse occurred in the sample, as at this limit it represents the highest pressure that the sample can withstand, and the compressive strength was calculated by the equation (3).

$$S = W/A \quad (3)$$

Whereas: S is compressive strength (nt./mm²), W is the stress amount applied when the collapse occurs (nt.), A is sample area (mm²)

The results of compressive strength (Table 6) are compared with the Iraqi standard specification No. 25 year 1993 (Table 7).

Table 7. Iraqi Standard Specification No. 25 (1993)

Class	Lower limit for pressure duration kg/cm ³		Upper limit for absorption %		Efflorescence
	Pressure duration for ten bricks	Pressure duration for one brick	Average absorption for ten bricks	Average absorption	
A	180	160	20	22	Slight
B	130	110	24	26	Moderate
C	90	70	26	28	--

4.5.5 Assessment of Clay Bricks

The sample's physical properties were performed for the clay samples to determine their suitability for the brick industry. Three tests were executed for the studied samples; linear shrinkage, mechanical and physical properties including uniaxial compressive strength (kg/cm²), water absorption and efflorescence. The results show that the tested samples of the 2 and 3 stations B, B10, C, and C10 are within Iraqi Standard No. 25, specification B in terms of pressure tolerance and water absorption for all

mixtures, while the samples from stations A, A10, D, and D10, do not match the Iraqi Standard in terms of absorption and pressure tolerance, as for all study stations were slightly of efflorescence.

5. Conclusions

The study area is considered a promising raw material resource area for the clay brick industry due to the enormous exposure of uncontaminated claystone beds. Grain size analysis showed that the claystone samples are graded from clay, silt to fine sand, low percentage of sand (10.4% up to 13.8%), a high percentage of clay (49.4% up to 53.4%) and silt (36.5% up to 38.1%). This culmination affects the suitability of tested samples. The studied clay samples are classified as sandy mud, which gives medium plasticity, and can shaped easily and suitable for making clay bricks. The results of the grain size analyses these gradients are suitable for making brick, clay content also helps to cohesion the brick. The chemical analysis rate shows SiO₂ (%37.6), Al₂O₃ (7.1%), Fe₂O₃ (6.77%), CaO (13.75%), and MgO (13.2%) content. The primary constituents of tested clay samples are of suitable proportions as significant oxides in raw materials used for brick manufacture, except for the high magnesium level. The non-clay minerals that are most prevalent in the tested samples are quartz, calcite, and dolomite. Magnetite has a lower content, while the clay minerals are palygorskite, illite, and chlorite. The compressive strength and absorption of the tested samples of stations B, C, B10, and C10 are identical to class b according to the Iraqi standard specifications 25, (1993). The compressive strength and absorption of the tested samples for stations A, D, A10, and D10 do not match the Iraqi standard specifications. All study stations were slightly effloresce.

References

- Al-Bayati, H. F., 2011. The Validity of Injana Clays for the Manufacture of Clay Bricks in the Khanouka Region, Salah al-Din Governorate, M. Sc Thesis, College of Science, University of Tikrit, 105.
- Al-Kass. R.M. and Hadi M.A. and Khalil N.I. and Al-Takarli S.F., 1985, Effect of Calcite Grains Present in the Soil on the Properties of Clay Brick, Building Research Center, Baghdad, Iraq, 53.
- Al-Hakeem, F.A., 1998. Evaluation of some Neogene Clays in North of Iraq for the Purpose of Ceramics, M. Sc Thesis, Collage of Science, University of Baghdad, 100.
- AL-Khafaji, S. J., 2001. Mineralogy and Geochemistry of Iraqi Flint Clays in the Western Desert and their Suitability for the Manufacture of Refractories, Unpublished Ph.D., Baghdad University,
- American Society for Testing and Material ASTM D 422, 2004. Standard Test Method for particle-size Analysis of, 1-63.
- American Society for Testing and Material ASTM D 4318, 2004, Standard Test Methods for Liquid limit, plastic limit, and plasticity Index of Soils,
- Awad, A.M. and Awadh, S.M., 2021. Manufacturing perforated and ordinary bricks using Injana claystone in Middle of Iraq, Iraqi Geological Journal, 54 (1A),11-22.
- Awad, A.M. and Awadh, S.M., 2020. Reserve estimation of Late Miocene Injana claystone beds for portland cement and brick industry, Middle of Iraq. Iraqi Geological Journal, 53 (1D), 1-16.
- Awadh S.M. and Al-Owaidi M.R., 2020, Application of triangles method for quantitative estimation of marl reserve in Euphrates formation, middle of Iraq, Iraqi Geological Journal, 53(2A), 35-49
- Awadh S.M. and Awad A.M., 2021, Evaluation of the Injana claystone from Central Iraq for the brick industry, Kuwait Journal of Science, 48(2), 1-12
- Budinkov, P.P., 1964. The Technology of Ceramics and Refractories, Massachusetts Institute of Technology, Edwar Arnold Ltd., London, 647.
- Folk, R. L., 1974, Petrography of Sedimentary Rocks, Hemphill Publishing, Austin, Texas, 182.
- Grim, R.E., 1962, Applied Clay Mineralogy, 20, McGraw-Hill, Book Co. Inc. New York, 422.
- Grim, R.E., 1968, Clay Mineralogy, 2nd edition, MCG raw-Hill, New York, 596.

- Hussain, A. I. and Ibraheem H. I., 2021, Evaluation of suitability of red clay from selected areas of Gercus Formation, Sulaimaniyah, North Iraq, for the construction of Embankment Dams. *Iraqi Journal of Science*, 62(9), 3417-3427.
- Iraqi Standard Specification (25), 1993, Clay Bricks (the other) Central organization for standardization and quality control, Baghdad, Iraq, 1-8.
- Jassim, S.Z. and Goff, J.C., 2006, *Geology of Iraq*. Published by Dolin, Prague and Moravian Museum, Brno, 341.
- Najim, M.M., Yousif, B.A., 2021. Synthesis of industrial ceramic (cordierite) from Iraqi raw materials through solid-state sintering method. *Iraqi Geological Journal*, 54 (1A), 23-34.
- Rashed, K. A., 2017, Study of raw materials for manufacturing perforated clay bricks, Chamchamal, and Qaradagh Regions in Sulaimani, Iraq, *Sulaimani Journal for Engineering Sciences*, 4 (4.S.J).
- Shreve, R.N. and Brink J.A., 1977, *Chemical Process Industries*, McGraw-Hill, Kogakusha, Ltd, 814.
- Suhael, F. J., and Hussain, A. I., 2020. Suitability Evaluation of mudstone of Injana Formation for dam filling materials in TaqTaq area/Erbil/Iraq, *Tikrit Journal of Pure Science*, 25 (3).
- Surdashy, A. A., and Aqrawi, A. M., 2021, Assessment of clay deposits quality from East of Erbil, Kurdistan Region, Iraq for some ceramic industries, *The Iraqi Geological Journal*, 54 (2F), 144-160.
- Zoveidavianpoor, M., 2018. Current topics in the utilization of clay in industrial and medical applications. *IntechOpen*.