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Manufacture Of Brick Tiles From Local Raw Materials, N & NE Iraq.

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Abstract

This study established to investigate the feasibility of using many types of local raw materials in Kurdistan for brick manufacture. In this work fourteen types of clay were selected from different localities in the region. The plasticity values of raw materials are indicate the direct relation to mineralogical composition. The samples, which contain high perecent of smectite and illite, have high to moderate plasticity; on the other hand the samples with high quartz content show low plasticity. The grain size analysis indicates the suitability of using raw materials from some localities in the studied area for manufacturing the perforate bricks, and others for roofing tiles and some others for thin wall product. Semi-dry method of forming eighty-four tiles under load 78kN/mm^2 were adapted and fired at 850, 950 and 1050 °C. Four characteristics of the prepared tiles which are; linear shrinkage, water absorption, bulk density and compressive strength are determined and found that some of these raw materials are suitable for manufacturing the solid and perforate bricks.

Kewords: *Perforate bricks, roofing tiles, briquettes, and efflorescence.*

Introduction

Clays have traditionally been used for manufacturing bricks and other ceramic building materials. Many recent studies were carried out in this direction. Gindy and Al -Rawi [1] used the Gaara clays for manufacturing engineering bricks, floor tiles, acid –resistant tiles and sewer pipes . The various characteristics of the end product show that they are compatible with the international specifications. Dondi and others [2] used seventy five clays belonging to Quaternary alluvial deposits for production of Italian heavy-clay industry. The results show that roofing tiles and paving bricks are produced through complex bodies which are mainly constitueted of non carbonatic clay, while carbonate-free clay is never employed for the hollow products. Barson and Ferro [3] studied the process change in the ceramic industries over the past ten years. The change are mainly due to shorter firing clays, new glaze and decoration application methods and restriction on the use of glaze raw materials. They concluded that the changing be made in composition as well as the suspension of ceramic glazes. Al-Hazaa and Tammer [4] evaluated the kaolinite clay from Amij Formation (M.Jurassic), silica sand from Rutba Formation(Cenomanian) and glass pieces from Rumady factory for manufacturing of ceramic unglazed acid resistance tile. The result shows that some of tiles which are fired at temperature 1200°C are suitable for this purpose. Merza [5] evaluated some clay deposits from the upper part of Gercus Formation (M.Eocene) , NE Iraq, for brick manufacture. The various characteristics of the end product show that some of the samples that are fired at 900°C, 1000°C and 1100°C are useful in brick manufacture. Recently, Merza[6] used the recent deposits ,silty clay around the Aliawa village , south of Sulaimani city for production of glazed ceramic tiles

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through mixing recent deposits, Sirwan river deposits and groge. She found that some of the raw materials are suitable for manufacturing ceramic tiles for covering the walls of kitchens, public building balaconies and baths. The research programme concerning the raw materials from different localities in Kurdistan. Fourteen samples were collected which are representing the clays from Gercus, Sarmord, Tanjero, Kolosh, Qulqula, Red Bed Series, Fatha and Injana Formations. The locations of studied samples are shown in figure 1.

In order to point out the different parameters, which are conditioning the behavior of the raw materials and their suitability for ceramic industry, especially brick industry, many tests are made on the collected raw materials such as plastic properties and grain size distribution. Qualitative mineralogical investigations were carried out by means of X-ray diffraction (with Cu kα radiation) on random powder samples. Quantitative mineral composition was then calculated through rational computing method [7].

Geological Descriptions

The raw materials were collected from different formations and localities in Kurdistan (Fig. 1). The geological descriptions are listed in table 1. Many references are used for age determinations as well as for detailed descriptions such as [8, 9].

Methodology

Eighty-four rectangular sample briquettes measuring 80 x 40 x 10 mm. were formed from the collected raw materials after crushing and grinding the samples by mortar and pestle to grain size below 0.18mm. by using semi-dry pressing 78kN/mm^2 and about 20% moisture content. The samples are fired in kiln at temperatures of 850, 950 and 1050°C (rising temperature in 50 °C and soaking time 1 hour).

Physical and mechanical properties of tested tiles namely linear shrinkage [10], porosity, water absorption and bulk density [11], compressive strength [12] and efflorescence [13] are established.

Results And Discussions

The X-ray diffractograms show that the samples are consist of clay minerals, quartz, calcite, dolomite, plagioclase, talc and hematite. As far as the clay minerals are concerned, smectite, illite, palygorscite and chlorite are prevalent, while kaolinite seem to be present only in trace (Fig.2).

Rational mineralogical data confirm the quantitative indication deduced from the diffractograms, quartz 3.3-45%, calcite 3-71%, dolomite 3-27%, plagioclase 0-0.9%, talc 0-10.3%, hematite 1.25-6 %, illite 0-70%, smectite 0-59%, kaolinite0-5%, palygorskite 0-4% and chlorite0-39% (Table 2).

The results of particle size analyses based on [14] were grouped into three fractions(< 2μm, 2-20 μm and >20 μm)(Table 3) for plotting on the Winkler diagram for evaluating the suitability for different ceramic products [15] (Fig. 3). It can be concluded that the samples 2, 4, 7, 10 and 13 used to manufacture perforate bricks, the samples 5, 9, 11 and 12 are used to manufacture roofing tiles and samples 3 and 14 could be used for manufacturing thin wall products.

The plasticity values (Table 4) are directly related to the mineralogical composition [16, 17]. Based on the classification of Budnikov[18] which is depending on plastisity index, the sample no.7 is super plastic, samples 13 and 14 are poorly plastic and the rest of samples are moderately plastic.

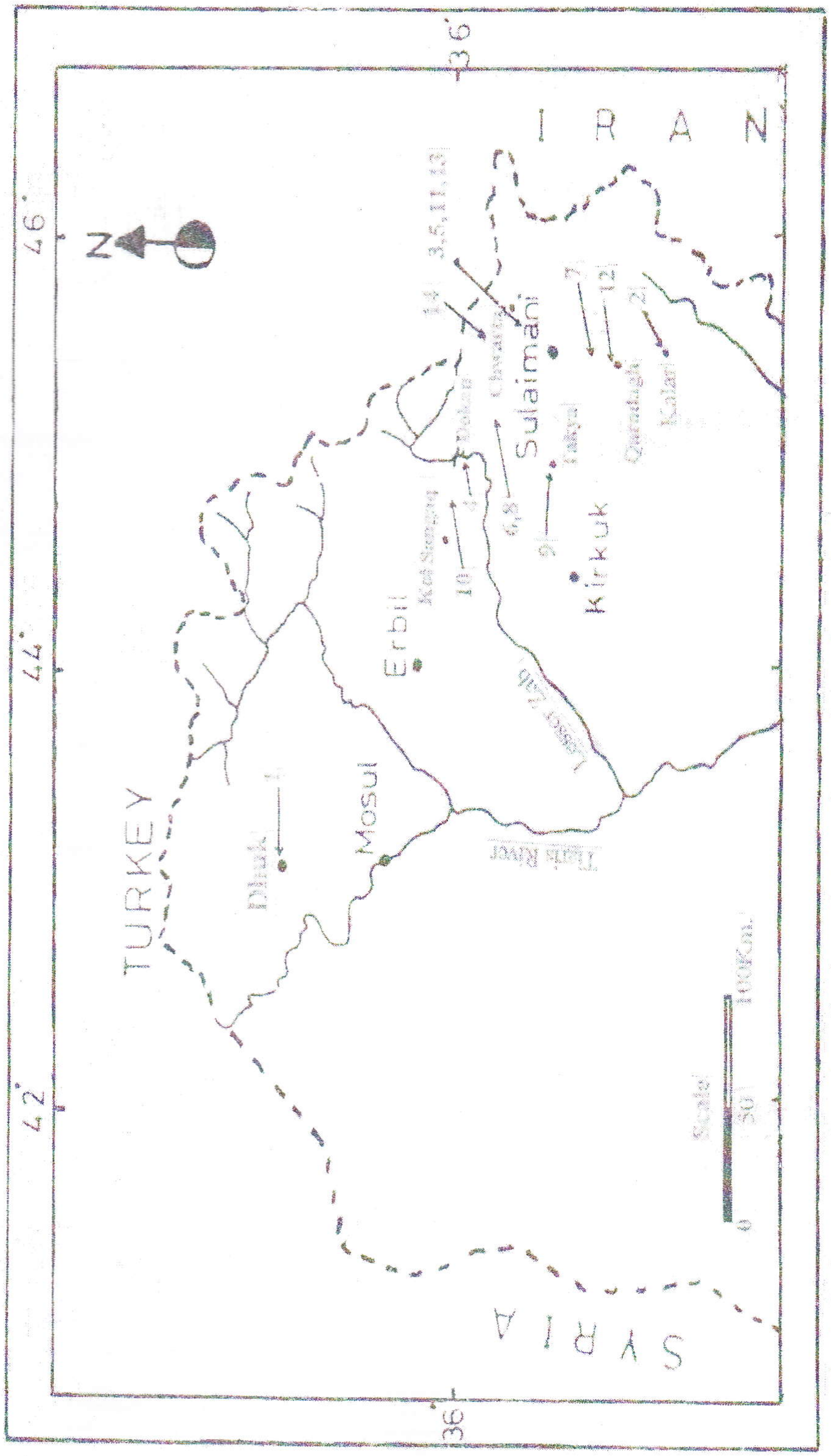


Fig 1. Index map showing the location and number of studied samples.

Table 1. Geological description of the studied raw materials (studied samples) from youngest to oldest..

S.No.	Formation	Description of the samples	Age	Locality
5	White soil	Composed of white , friable lime-rich soil, Its thickness ranged from 3 to 3.5m. The mineralogical analysis indicate to calcite as essential mineral .	Quaternary	Sulaimani, Chwarta, Seramerg.
2	Injana	The lithology is mostly composed of red or grey coloured silty marlstone, claystone and siltstone, which have thicknesses ranged from 1 to 2m. The essential mineral is illite , while smectite, kaolin, and chlorite are less common.	Late Miocene	Kirkuk, Kalar
9	Fatha	Characterized by red beds of clastics which are composed of reddish mudstone and siltstone. The thickness about 1 to 1.5m. The essential clay mineral is illite, while smectite, kaoline, and chlorite are present as traces.	Middle Miocene	Sulaimani, Takya.
1, 10, 12	Gercus	Composed of red and purple shale, mudstone, sandy and gritty marl. The thickness of red mudstone beds are ranged between 1 to 2m. The essential clay mineral of these samples is illite, while smectite, chlorite and palygorskite are less common.	Eocene	S.No1 Duhok near the dam. S.No.10 , Haibat Sultan Mountain. S.No12 Sulaimani, Qaradagh(Baranan mountain).
3	Lower part of Red bed Series	Composed of dark red and ferrogineous-silicious silty shale with beds of bluish grey siltsone. The thickness is 3.5m. The essential clay mineral is smectite while chlorite is less common.	Paleocene-Early Eocene	Sulaimani, Chwarta, near Tagaran village.
7	Kolosh	Composed of brown shale which has thickness ranged from 1 to 2m. The essential minerals are chlorite and calcite while illite is common and kaolin with quartz are less common.	Paleocene-Eocene	Sulaimani, Zirguez village
11, 13	Middle part of Red bed Series	Composed of purple and dark reddish siltstoneand mudstone and shale. The thicknesses renged from 2 to 3m. The common clay minerals of s.no.11 are smectite and chlorite, while for s.no.13 are illite and chlorite.	Paleocene	Sulaimani, S.No.11, Maukaba area. S.No13, Kanarwe village.
4	Tanjero	Composed of clayey siltstone which has thickness about 50cm to 75cm. The essential minerals are chlorite and calcite, while illite, kaolin and quartz are less common.	L.Campanian - Mastrichtian	Sulaimani, Dokan
14	Qulqula	Composed of dark reddish ferroginous-silicious shale and mudstone. The thickness is about 80cm to 1m. The common minerals are quartz and smectite while calcite, hematite and illite are less common.	M.Cretaceous	Sulaimani, Kanarwe village.
6, 8	Sarmord	They are consist of marls and clayey limestone, the colour is varied between white to grey. Thickness ranged from 50cm to 75cm. The essential mineral is calcite, the common clay mineral of s.no.6 is illite while for s.no.8 is smectite.	Albian	Sulaimani, Piramagroon, Zewe gorge.

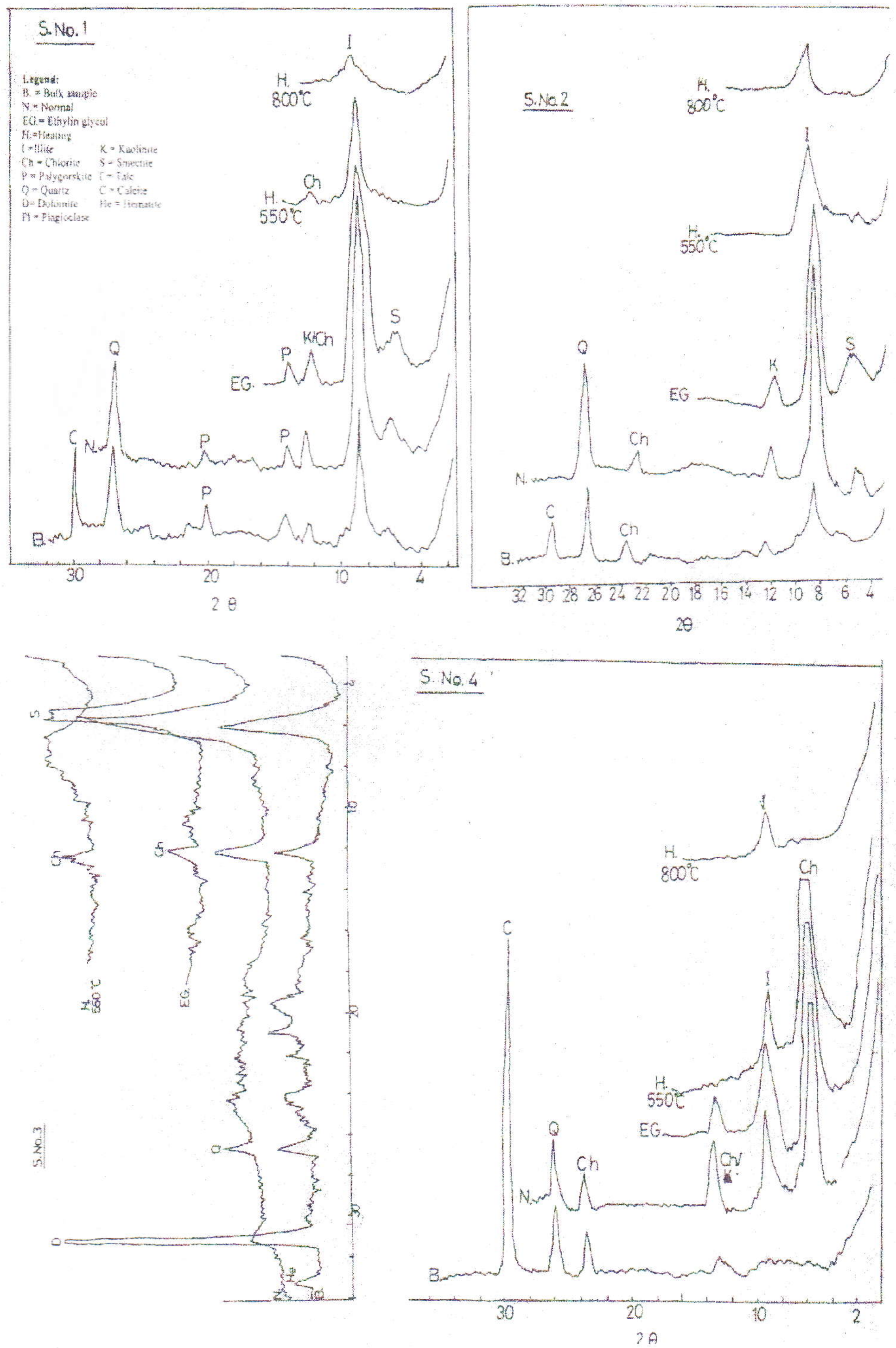
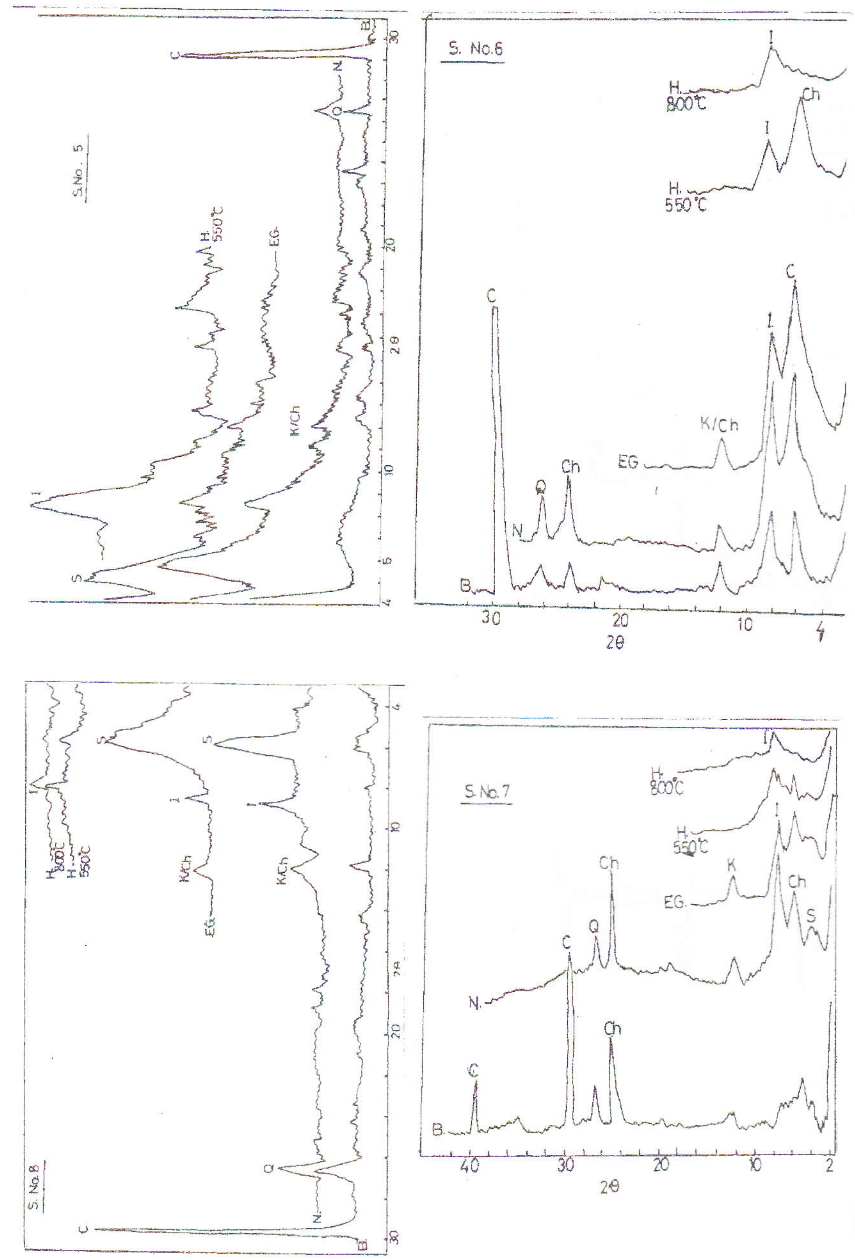


Fig.2 : XRD charts for the studied samples.



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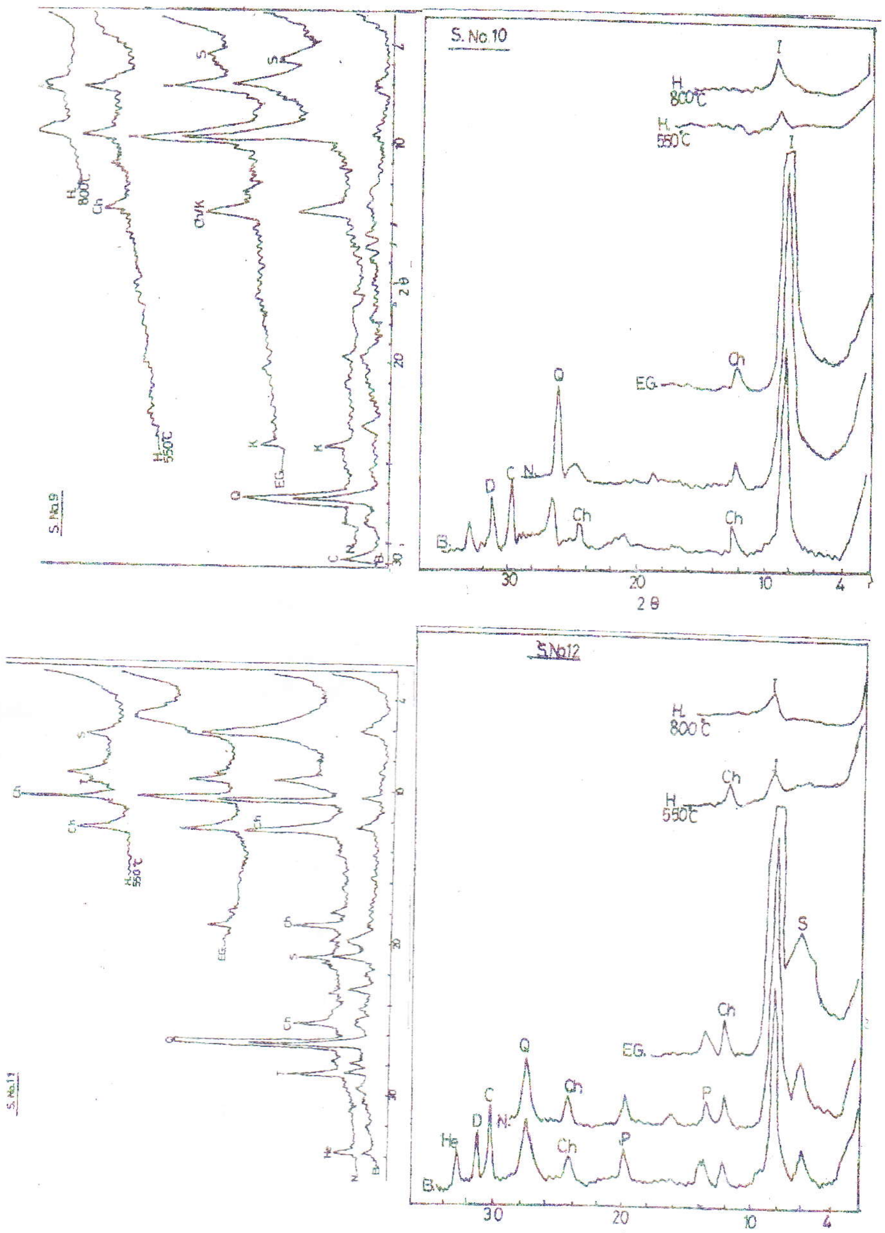

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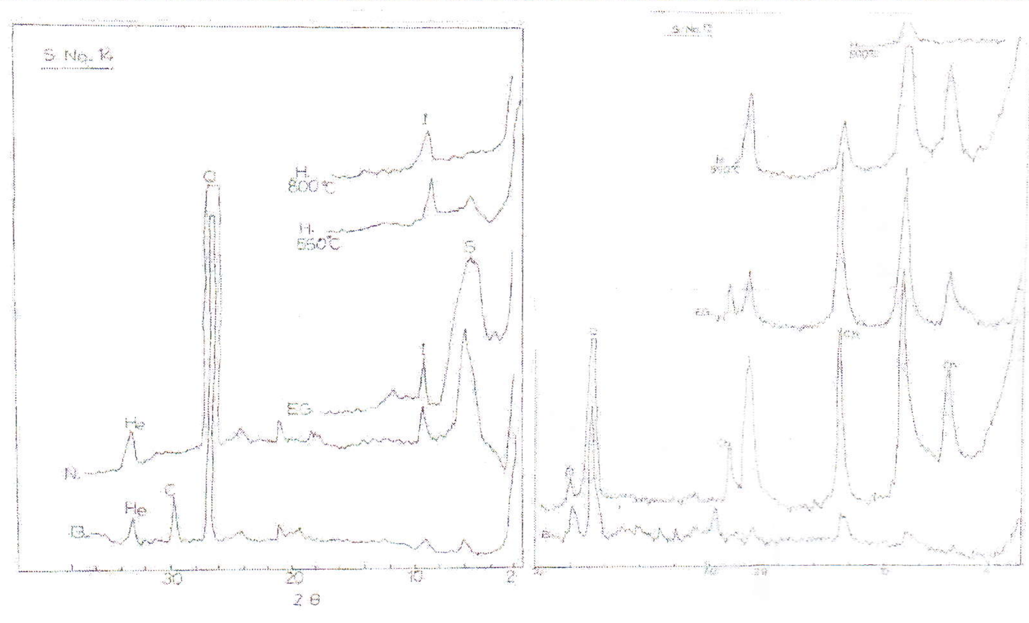


Fig.2 : Continued.

Table 2. Mineralogical composition percentage of the studied samples.

	Whole composition						Clay minerals				
S.No.	Q	Ca	Do	Plag	Talc	Hema	Ilite	Smectite	Kaol.	Paly.	Chlo.
1	10	9	-	-	-	-	70	4	-	3	4
2	15	3	-	-	-	-	70	4	5	-	3
3	3.3	-	27	-	-	1.25	-	59	-	-	9
4	6	35	-	-	-	-	15	-	5	-	39
5	5	71	-	-	-	-	5	18	1	-	3.9
6	5	38	-	-	-	-	17	-	3	-	37
7	5	32	-	-	-	-	19	7	4	-	33
8	6	65	-	-	-	-	4	23	2	-	-
9	20	4	-	-	-	-	65	3	2	-	6
10	14	6	5	-	-	3	67	-	-	-	5
11	12.1	-	-	-	10.3	2	-	49.3	-	-	26.3
12	11	8	3	-	-	2	61	4	-	3	8
13	19	-	-	0.9	-	-	44.5	-	-	-	35.6
14	45	6	-	-	-	6	5	38	-	-	-

Table 3. The particle size distribution for the studied samples(%).

S.No.	<2 µm%	2-20 µm%	>20 µm %
1	60	25	15
2	30	50	20
3	28	60	12
4	35	55	10
5	52	43	5
6	62	34	4
7	32	48	20
8	70	20	10
9	49	33	18
10	42	36	22
11	46	33	21
12	54	40	6
13	37	58	5
14	15	78	7

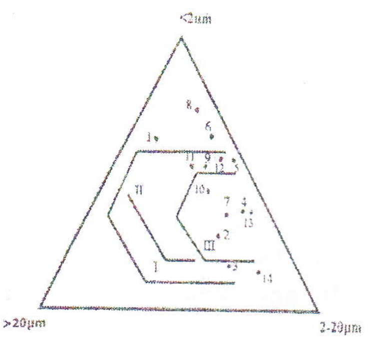
Table 4. The results of Atterberg limits and Rieke index for the studied samples.

S. No.	Plasticity index	Rieke Index
1	10.8	10
2	17.72	28.57
3	14.17	9.52
4	7.81	11.18
5	12	15
6	7.465	10.5
7	25.33	10
8	9.85	13.4
9	8.56	5.2
10	16.75	7.34
11	15.24	13.67
12	12.04	5.36
13	6.33	6.1
14	5	6

In general, a Rieke index less than 10 is desirable for ceramic industries [19]. Hence the samples 3, 9, 10, 12, 13 and 14 may be suitable for this purpose.

The results of linear shrinkage, apparent porosity, water absorption, bulk density and compressive strength are shown in tables 5, 6, 7, 8 and 9. Figures 3, 4, 5, 6 and 7 are show the results as diagrams.

The samples 1, 2, 3, 4, 6, 7, 10, 11 and 12 under went linear shrinkage at temperatures 950 and 1050 °C (Fig.4). This is directly related to water of plastisity and particle size. It increases as the water of plastisity increases, and the paertricle size decrease[3, 5, 19]. The linear shrinkage values (Table 3) for samples 5 and 8 were not recorded because sample 5 broke at temperature 1050 °C and sample 8 broke at temperature 950 and 1050 °C .This is due to high content of calcium carbonate which is begin to decompoced at temperature850°C that increase the cracks and cause



I: Brick for thin wall products.
II: Brick for roofing tiles.
III: Perforate bricks.

Fig. 3. Location of the studied samples on Winkler diagram (1954).

breaking of these samples at temperatures 950 and 1050 °C [16]. While samples 9 and 14 melted at temperature 1050 °C. This is due to high percent of flux material content such as FeO, MgO, CaO, Na_2O, K_2O,.. etc[20, 21]. Minerals illite, smectite, chlorite and hematite are sources of these materials(table 2).

According to Rhoades[22] the linear shrinkage less than 8% may be used in ceramic industries. Hence all fired samples at temperature 950 °C, except samples 8 and 13 may be used for this purpose.

In general, above the temperature 850 °C the water absorption capacity decreased, and the porosity diminshed(Tables 6, 7,Figers 5,6). The bulk density with compressive strength increased abruptly(Tables 8 and 9 , Figures 7 and 8)for all fired samples, except sample 8 which is broke and sample 7 and 10 are increased. This is owing to vertification and decomposition of minerals content of raw materials and the crystallization of new silicate minerals filling the pores presented between the particles or creat during the drying and firing of tiles[2, 5, 21].

According to [23] for the effloresence test of fired briquettes at temperature 850 °C, the samples may be classified as follows; samples 2, 4, 8, 9, 11, 12, 13 and 14 are heavy efflorescence (more than 50% of the area covered by deposits and salt). The samples 1, 7 and 10 are moderately efflorescence (10-50% of the area covered by salt), while samples 3, 6 and 13 are slightly efflorescence because less than 10% of the surface area covered by salt. In general for all fired samples that are remained at temperatures 950 and 1050 °C, the effloresence test shows the decreasing of covered area by deposits and salt. So the samples with heavy effloresence change to moderate and those with moderate change to slightly efflorescence. This is related to escaping of volatiles such as SO_3, Cl,..etc during the increasing of firing tempreature and lowering the percentage of salt content in raw materials[2, 16].

Table 5. The results of linear shrinkage % of fired tiles at temperatures 850, 950 and 1050 °C .

S.No.	Linear shrinkage %			S. No.	Linear shrinkage %		
	850 °C	950 °C	1050 °C		850 °C	950 °C	1050 °C
1	2.92	4.65	17.36	8	0.39	-	-
2	2.12	4.32	7.82	9	1.54	1.55	*
3	4.1	4.50	5.12	10	2.12	2.50	2.80
4	1.89	1.62	17.17	11	0.86	1.80	1.63
5	1.84	0.88	-	12	1.64	2.00	7.33
6	3.19	3.25	4.00	13	10.50	9.7	8.75
7	8.51	7.90	9.00	14	1.37	0.35	*

Note : - Broken tiles * Melted tiles.

Table 6. The results of apparent porosity % for fired tiles at temperatures 850, 950 and 1050 °C .

S.No.	Apparent porosity %			S. No.	Apparent porosity %		
	850 °C	950 °C	1050 °C		850 °C	950 °C	1050 °C
1	38.50	42.80	36.30	8	45.31	-	-
2	50.90	40.10	35.40	9	27.11	27.27	*
3	36.17	35.92	30.91	10	30.90	34.50	37.50
4	42.62	50.90	13.00	11	33.33	31.25	30.00
5	40.90	37.12	-	12	42.11	47.36	36.36
6	36.36	34.54	33.33	13	27.20	37.00	36.95
7	33.33	47.68	46.30	14	27.86	38.59	*

Note : - Broken tiles * Melted tiles.

Table 7. The results of water absorption % of fired tiles at temperatures 850, 950 and 1050 °C .

S.No.	Water absorption %			S. No.	Water absorption %		
	850 °C	950 °C	1050 °C		850 °C	950 °C	1050 °C
1	49.00	54.00	33.30	8	58.00	-	-
2	59.50	40.30	32.70	9	21.33	20.00	*
3	34.00	31.00	30.10	10	25.00	28.50	30.00
4	40.00	52.00	6.55	11	28.57	28.57	26.00
5	40.90	35.40	-	12	42.11	46.15	20.51
6	33.33	33.92	25.00	13	29.50	28.70	28.33
7	25.00	45.60	48.30	14	24.28	33.84	*

Note : - Broken tiles * Melted tiles.

Table 8. The results of bulk density (gm/cm^3) for fired tiles at temperatures 850, 950 and 1050 °C .

S.No.	Bulk density (gm/cm^3)			S. No.	Bulk density (gm/cm^3)		
	850 °C	950 °C	1050 °C		850 °C	950 °C	1050 °C
1	1.02	1.05	1.09	8	1.23	-	-
2	1.59	1.60	1.66	9	1.27	1.36	*
3	1.06	1.10	1.19	10	1.80	1.42	1.25
4	1.07	1.03	1.57	11	1.17	1.29	1.32
5	1.41	1.53	-	12	1.00	1.03	1.77
6	1.10	1.02	1.33	13	1.10	1.25	1.30
7	1.03	1.00	1.04	14	1.15	1.14	*

Note : - Broken tiles * Melted tiles.

Table 9. The results of compressive strength (N/mm^2) for fired tiles at temperatures 850, 950 and 1050 °C .

S.No.	Compressive strength (N/mm^2)			S. No.	Compressive strength (N/mm^2)		
	850 °C	950 °C	1050 °C		850 °C	950 °C	1050 °C
1	7.33	3.91	20.97	8	5.44	-	-
2	3.67	14.2	13.14	9	38.29	76.30	*
3	3.26	8.92	15.87	10	0.05	10.70	16.23
4	8.68	13.12	112.08	11	4.98	24.54	26.66
5	20.43	9.82	-	12	12.80	33.78	57.14
6	26.66	34.18	55.55	13	15.12	20.94	57.14
7	22.72	23.67	13.26	14	33.31	38.27	*

Note : - Broken tiles * Melted tiles.

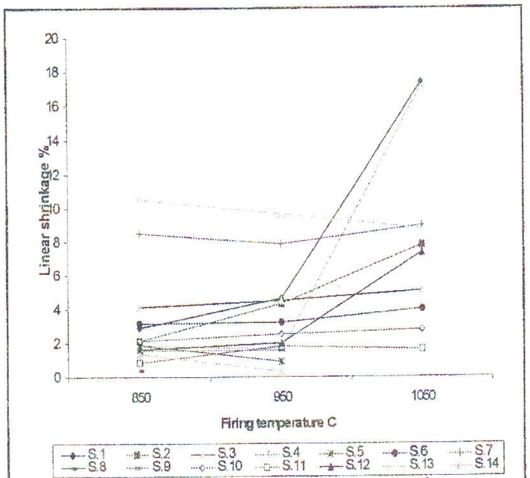


Fig.4. The relationship between firing temperatures and the linear shrinkage % for the studied samples.

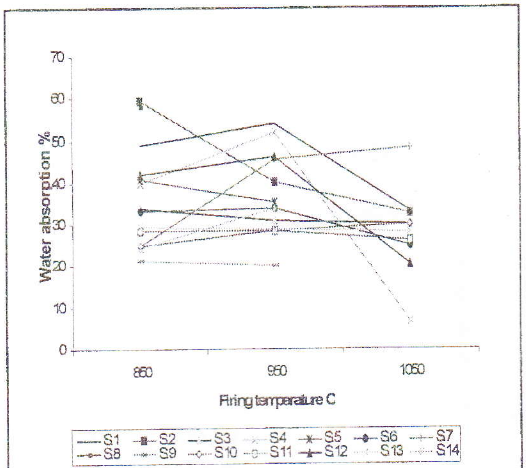


Fig.6. The relationship between firing temperatures and water absorption % for the studied samples.

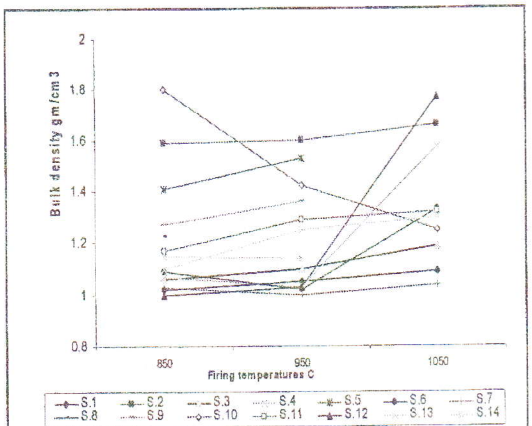


Fig. 7. The relationship between firing temperatures and bulk density for the studied samples.

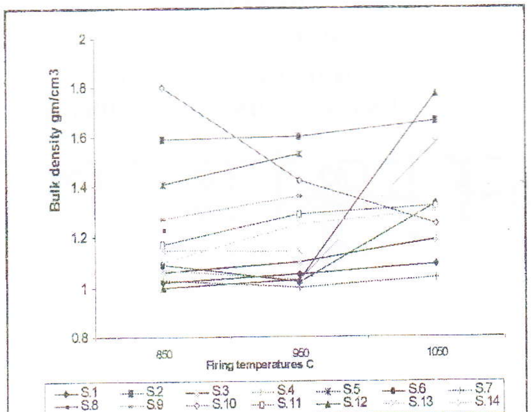


Fig. 7. The relationship between firing temperatures and bulk density for the studied samples.

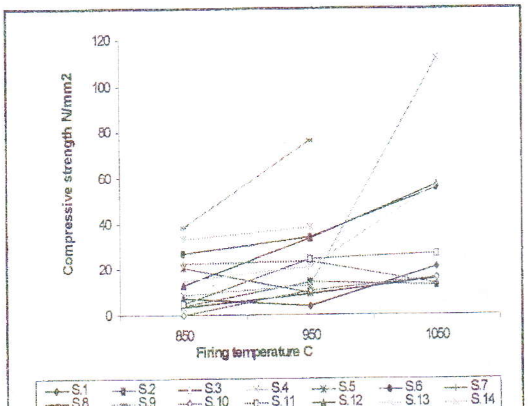


Fig. 8. The relationship between firing temperatures and the compressive strength for the studied samples.

Conclusions

From this study the following points can be concluded:

1. According to the results of particle size analyses and plotting on the Winkler diagram, samples 2, 4, 7, 10 and 13 may be used for manufacturing perforated bricks, the samples 5, 9, 11 and 12 are suitable for manufacture roofing tiles and the samples 3 and 14 could be used for manufacturing thin wall products.
2. The plasticity values show that sample no. 7 is super plastic, samples13 and 14 are poorly plastic while the other samples are moderatly plastic. The Rieke index indicates that samples 3, 9, 10, 12, 13 and 14 are suitable for ceramic industries.
3. X-ray diffractograms show that the samples are consist of clay minerals (i.e. smectite, illite, palygorskite, kaolinite and chlorite) and non-clay minerals; quartz, calcite, dolomite, plagioclase, talc and hematite.
4. The linear shrinkage test shows that all samples fired at 950 °C, except 8 and 13 may be used for ceramic industries.
5. Above temperature 850 °C the water absorption capacity decreased, the porosity diminished and the density increased in all samples, except samples 7, 8 and 10. According to [24] the accepted percent of water absorption ranges between 1 to 37 %, hence all fired samples at temperature 1050 °C, except samples 5, 7, 8, 9 and 14 could be suitable for manufacturing clay building bricks.
6. According to [25] the sample no.9 that is fired at 950 °C may be used for manufacturing of solid bricks which are used in loaded bearing wall not subjected to humidity and change in weather(class B, compressive strength range between 11-16N/mm^2 and water absorption 20-26%), while the samples 10, 11 and 13 may be used for manufacturing of perforated or hollow bricks in partition and not subjected to humidity (class C, compressive strength range between 7-11N/mm^2 and water absorption 26-29%).
7. The efflorescence test indicates presenting of three groups of bricks; heavy moderate and slightly efflorescence.
8. The samples containing high $CaCO_3$ (i.e. samples 5 and 8) and high SiO_2 (sample no. 14) preferred to be fired at low firing temperature before extensive decomposition of $CaCO_3$ and SiO_2, which occurred at about 950 °C.
9-In general, reffering to all properties after firing it can be concluded that the most suitable samples for brick manufacture are samples 9, 10, 11 and 13 and the best firing temperature is 950°C. These samples are returned to Fatha, Gercus and Red beds Formations.

Acknowledgments

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دروست کردنی خشت لە گڵی خۆماڵی ، باکور و باکوری ڕۆژهەلاتی عێراق

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پوختە

لەم توێژینەوەیەدا چواردە جۆر لە گڵی خۆماڵی لە کوردستاندا کۆکراوەتەوە و بە درێژی گشت ڕەوشتە کانیان باسکراوە و دیاری کراوە لە پێناو هەڵسەنگاندنی ئەم جۆرە گلانە کە ئاخۆ شیاون بۆ دروست کردنی خشت . ئەنجامی تاقیکردنەوەکانی سنووری پلاستیکی دەریخست کە پەیوەندییەکی پتەو هەیە لە نێوان ناوبراو وپێکهاتەی خاوی گڵەکەوە . ئەو نموونانەی کە دەوڵەمەندن بە خاوە قوڕییەکانی وەك سمێکتایت و ئیلایت خاوەن سنووری پلاستیکی بەرزن بۆ مام ناوەندی و بە پێچەوانەوە ئەوانەی کە دەوڵەمەندن بە کوارتز ئەوا سنووری پلاستیکیان نزمە.

شیکاریکردنی قەبارەیی دەنکۆڵەکان دەریخست کە دەتوانرێت نموونەکان بە کاربهێنرێن بۆ سێ جۆری جیاواز لە خشت کە ئەوانیش: خشتی کوندار و کاشی و خشتی دیکۆر . لەم نموونانە هەشتاوچوار قاڵب داڕێژراوە لە ژێر پاڵپەستۆی ٧٨کیلۆنیوتن /مم ٢ و پاشان لە ژێر پلەی گەرمای جیا دا ٨٥٠م° و ٩٥٠م° و ١٠٥٠م° دا سوتێنراون .

گشت ڕەوشتە فیزیایی و میکانیکیە کانی وەك Linear shrinkage وwater absorption و bulk density و compressive strengthپێوانە کراوەو لە ئەنجامدا دەرکەوت کە هەندێك لە نموونەکان دەگونجێن بۆ دروست کردنی خشتی پتەو (بێکون) هەروەها خشتی کوندار .

صناعة الطابوق من المواد الأولية المحلية ، شمال و شمال شرق العراق.

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الخلاصة

في هذه الدراسة تم فحص أربعة عشر نوعا من المواد الطينية المحلية فى كردستان من اجل معرفة مدى صلاحيتها لصناعة الطابوق. أظهرت قيم حدود اللدونة لهذه المواد علاقة قوية مع المواد المكونة لها . حيث النماذج الغنية بالمعادن الطينية (سمكتايت و الايت) ذات لدونة عالية الى متوسطة أما النماذج الغنية بالكوارتز كانت ذات لدونة منخفضة.

التحليل الحجمى للنماذج أظهر توزيعها النماذج على ثلاثة أنواع وهى نماذج جيدة لصناعة الطابوق المثقوب و نماذج مناسبة لصناعة طابوق البلاط و البقية مناسبة لصناعة طابوق الديكور. تم صنع أربعة و ثمانين قالبا تحت ضغط ٧٨كيلونيوتن/مم٢ و حرقت تحت درجات حرارة مختلفة ٨٥٠ م° و ٩٥٠ م°و ١٠٥٠ م° . ثم تم فحص كل القوالب من حيث خواصها الفيزيائية الميكانيكية مثل النسبة المئوية للتقلص الطولىو النسبة المئوية لامتصاص الماء و الكثافة الحجمية و المقاومة الانضغاطية و اظهرت النتائج إن قسم من هذه المواد تكون مناسبة لصناعة الطابوق الصلب و قسم اخر لصناعة الطابوق المثقوب .

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