Suitability of Recent Clays for Clay Bricks manufacturing within Nineveh Governorate

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Abstract
Field surveying, engineering tests and laboratory test analysis have shown that some of the local soils available in Nineveh governorate are suitable for production of clay bricks satisfying class A, class B and class C according to Iraqi standard No.25 1988.These soils include recent floodplains belongs to Al-Gayyara (GA) and recent sediments belongs to Al- Rashidia (RA) location. GA soil used directly and without treatment by sand, while RA soil was treated with different percentages of sand (10%, 30% and 50%) in order to improve their physical, chemical and engineering properties.

The engineering tests have shown that the properties of the fired samples are affected directly by both the firing temperature and sand percentage. It is noted that increasing the firing temperature from 1100 ºC to 1150 ºC increases the compressive strength of GA samples from 22.50 MPa to 61.59 MPa (about 3 times) while the compressive strength of RA samples treated with 10% of sand is increased from 34.73 MPa to 56.80 MPa. The water absorption of GA samples reduced from 17.05% to 13.05% when the firing temperature increased from 1100 ºC to 1150 ºC while the water absorption of RA samples treated by 10% sand reduced from 13.33% to 3.48% when the temperature increased from 1100 ºC to 1150 ºC. The optimum firing temperature and optimum sand content which give the highest compressive strength, lowest water absorption and minimum amount of cracks were 1100 ºC and 10% respectively for RA location, while the optimum firing temperature which give the highest compressive strength and lowest water absorption for GA location was 1150 ºC without any addition of sand.

Introduction
Mosul city is the second in Iraq by population which needs large quantities of construction materials, particularly building units. The main building units for all the projects are solid and hollow ordinary concrete blocks, because the raw materials of these units (cement, sand and gravel) are widely available and relatively cheap. Unfortunately, concrete blocks possess low thermal insulation; therefore they are not comforted during the whole year. Clay bricks are used rarely in conventional buildings of Mosul city and used only for special purposes because of their relatively high cost if compared with concrete blocks. **It is known that Nineveh governorate doesn't contain any factory for manufacture of clay brick and all the available units are delivered from other cities such as Kirkuk, Baghdad and recently these products are imported from other countries such as Iran, Turkey… etc**. Therefore, it is not economic to use clay brick in construction of buildings in Mosul. Today, the cost of one cubic meter of concrete block delivered to the project is about **(50000) ID**, while the price of one cubic meter of clay brick delivered to the project is about **(150000) ID**, this high difference in prices makes the concrete blocks to be the first choice for most costumers, and if this variation is reduced by neglecting the delivering cost, clay brick will become the material number one in all construction projects in Mosul city.

Many researchers such as [1-7] have tried to produce clay brick from the geological formations instead of flood plains. [8, 9] founded that Injana formation can be considered as an important resource of raw materials for producing of clay brick. [9] Studied the probability of manufacturing clay brick from recent sediments in Mosul Dam. He concluded they must be treated with sand to improve clay properties. [10] Studied the effect of firing temperature on the microstructure and physical properties of clay brick.

They used the local clays in Beruas/ Malaysia as raw materials. They founded that the quality of samples is increased by increasing firing temperature and concluded that the optimum temperature which gives the largest compressive strength is 1200 ºC. They also noted that the compressive strength increases from 25MPa at 1000 ºC to 75MPa at 1100 ºC, i.e. about three times.

Experimental work and site investigation
Nineveh governorate lies on different geological formations such as Injana, Fatha and Bai Hassan as well as floodplains and recent sediments. Five different locations in Nineveh governorate are investigated (Al-Hamdania, Al-Shlalat, Tamoze, Al - Gayyara (GA) and Al - Rashidia (RA)) (Figure 1). Both Al-Hamdania and Al-Shlalat locations contain huge quantities of clay but they are belong to Fatha Formation, Which has been studied by [4] who found that it contains high percentage of calcite and gypsum fragments which cause defects of fired samples. Therefore, the both locations were neglected. Tamoze location was neglected because it has relatively lower quantities of clay than the other location and it contains high population; therefore it cannot be considered as a source of raw materials for brick industry. Both GA and RA locations are selected for this study because these locations quite far from Mosul city have low population and no one has studied the probability of production of clay brick from their soil.

The experimental work is divided into two branches, first deals with raw materials. Each type of soil is tested in order to determine its physical properties and chemical composition. Grain size distribution for each kind of soil is determined according to ASTM D422. Chemical compositions for each type of soil as well as sand are determined by using X-Ray Fluorescence, in Singar cement Plant Company. The second branch of experimental work is forming cubes of clay with dimension (50*50*50) mm by Dry-Press Process. The prepared soil (**RA location**) is mixed with different percentages of sand (10, 30, and 50) %. Then the soil of the both locations blended with 7% water and pressed by hydraulic press in steel molds with pressure of about 10 MPa [11]. The samples then dried at a temperature of (110 °C) for 24h by using oven type (UTest) until the weight of the samples become constant. The dried samples were fired at temperatures (1050, 1100 and 1150) °C for 10 hours (7 hours at maximum temperature) by electrical oven type (MTI) and then cooled by natural convection. The physical and engineering properties of the fired samples are determined according to Iraqi standard No.25, 1986.

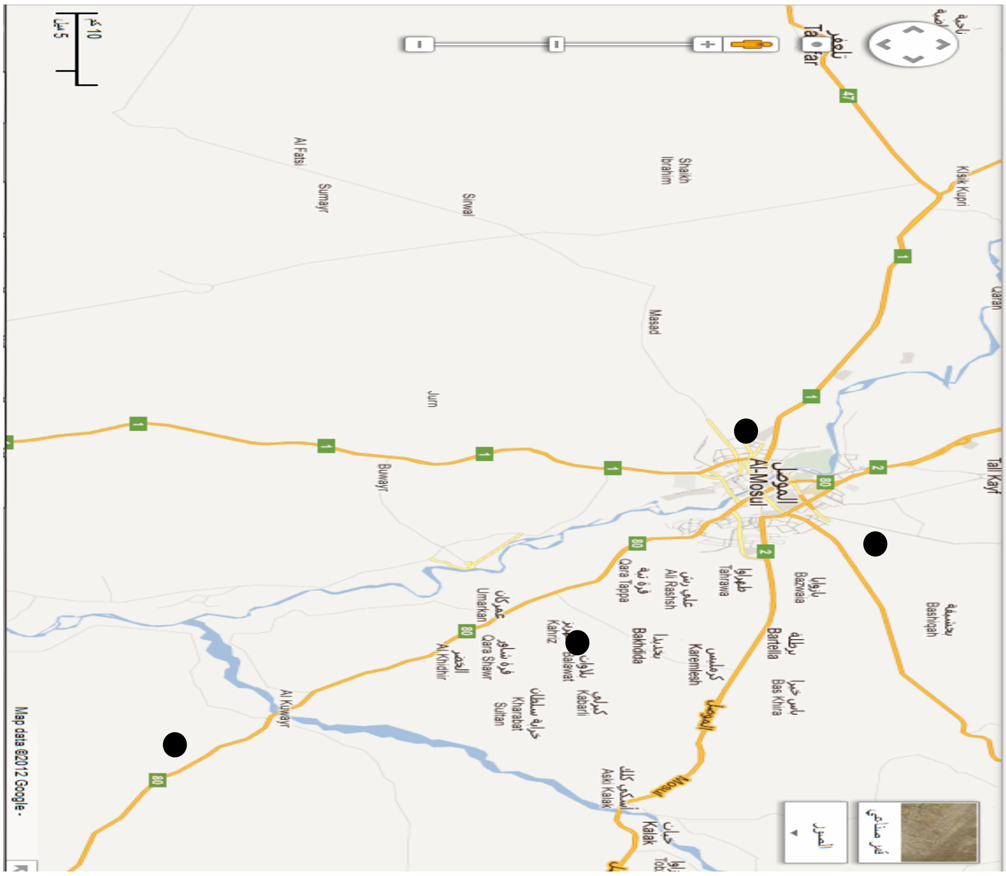

Figure 1: Location of the studied localities

Results and discussion

The chemical analysis of the studied soil is shown in Table 1. Some of the chemical compounds in the raw materials are not satisfying the limits of Iraqi standards for raw materials of clay bricks. Silica percentage in both GA and RA location were less than the minimum limit, Iron oxide in both RA and sand also was lower than the minimum limit while the percentage of sodum oxid in the sand was higher than the maximum limit. Calcium oxide in both locations as well as the sand was within the possible range; therefore lime blowing has not happened. Iron oxide is less than calcium oxide; therefore, the color of all the samples is white yellow instead of reddish color [12].The fluxes contents such as (Na_2O) are relatively high and therefore the clays are classified as low melting clay [13]; that it will start to fuse at a temperature 1150 °C.

Table 1: X−Ray Fluorescence Analyses of Raw Materials (clay and sand)

Oxides	Iraqi Standards Wt%	Weight (%)		
		Sand	GA Location	RA Location
SiO_2	35-42	41.386	28.226	29.891
Al_2O_3	5-14	9.04	9.629	10.019
$Fe2O_3$	4-8	1.852	4.987	3.811
MgO	<10	3.440	4.664	3.787
CaO	<20	9.793	13.913	18.785
Na_2O	<1.2	1.463	0.876	0.197
K_2O	1-6	1.189	1.191	1.276
SO_3	<1	0.238	0.239	0.237

The grain size distribution of natural soil for RA and GA location is shown in Table 2 and Figures 2 and 3 for RA and GA Locations respectively. The natural soil consists mainly of three sizes clay, silt and fine sand as shown in Table 3.

Table 2: Grain Size Distribution of RA and GA Locations

Sieve No.	RA Locations		GA Locations	
	Diameter (mm)	Percentage Passing (%)	Diameter (mm)	Percentage Passing (%)
40	0.425000	100.0000	0.425000	100.000
50	0.300000	90.00000	0.300000	95.125
100	0.150000	72.58000	0.150000	85.000
200	0.075000	56.94000	0.075000	47.000
hydrometer	0.028754	47.13754	0.034451	18.800
hydrometer	0.020883	43.92361	0.024455	17.860
hydrometer	0.015146	40.70969	0.017425	16.920
hydrometer	0.013614	39.63838	0.012916	14.570
hydrometer	0.009951	53.35315	0.011227	14.100
hydrometer	0.008236	33.21054	0.009200	13.395
hydrometer	0.005953	29.99661	0.006553	12.220
hydrometer	0.003902	25.71138	0.004499	10.340
hydrometer	0.001279	21.42615	0.003523	9.400
hydrometer	-	-	0.001339	8.460

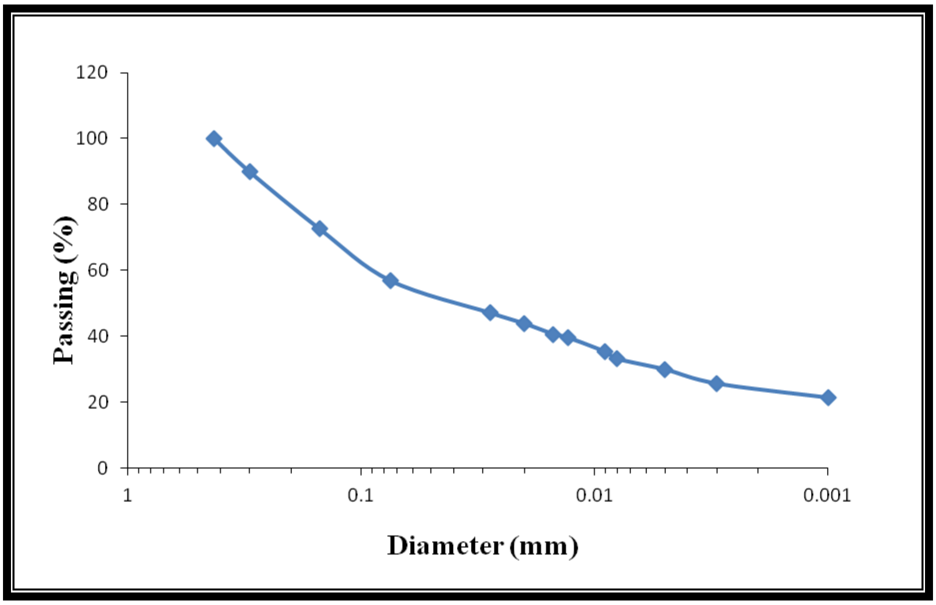

Figure 2: Grain size distribution of RA location

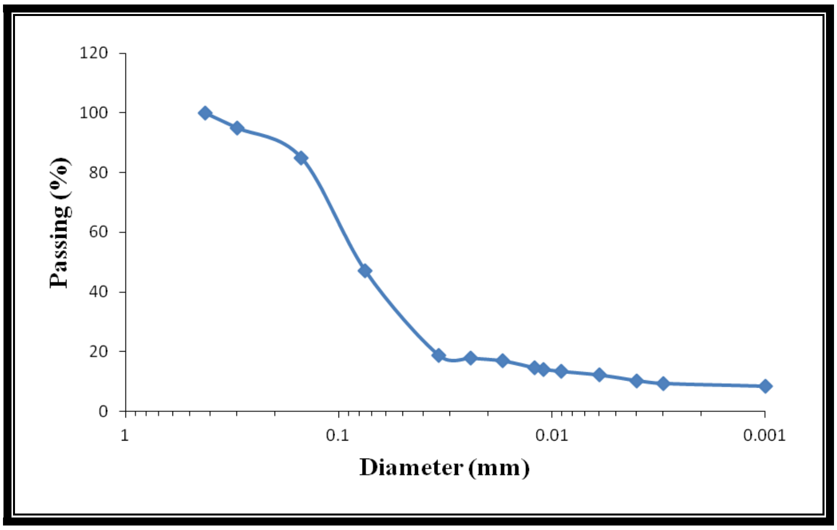

Figure 3: Grain size distribution of GA location

Table 3: Percentage of Clay, Silt and Sand in the natural soils

Location	Clay%	Silt%	Sand%
RA	24	33	43
GA	8	39	53

From Table 3**,** the natural content of sand in the soil of GA location is higher than the natural content of sand in the soil of RA location and this is the main reason that makes the samples which made from GA location shrinks less than the samples which made from the soil of RA location as shown in Figure 4, [13,14] also reported that the samples which contain high sand content shrink less than the others which contain lower content of sand during drying and during firing . It is also observed that clay content(particles less than 0.002mm) in the soil of GA location is very low about 8 % and this may explain the reason that makes the samples which fired at a temperature less than 1150ºC possesses low abrasion resistance.

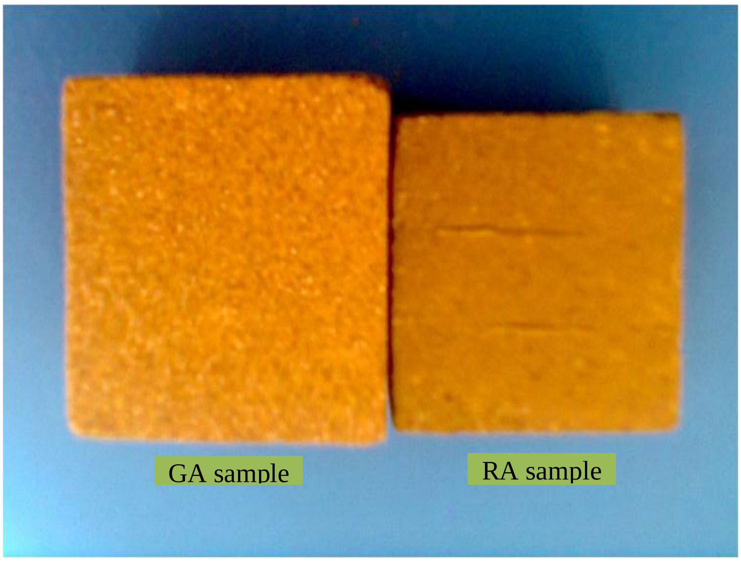

Figure 4: GA samples shrinks less than RA samples after firing at temperature 1150 C°

The relation between desnity of samples, sand content and firing temperature is shown in Figure 5**.** For both locations the maximum density is obtained at temperature1150 °C. It is also observed that there is a sharp increment in the density of of RA samples whean the temperature increased from 1100 °C to 1150 °C while only small incrament occure in the samples of GA location whean the temperature rised from 1100 °C to 1150 °C. The sharp increament in the density of RA samples related to the high shrinkage of these samples.

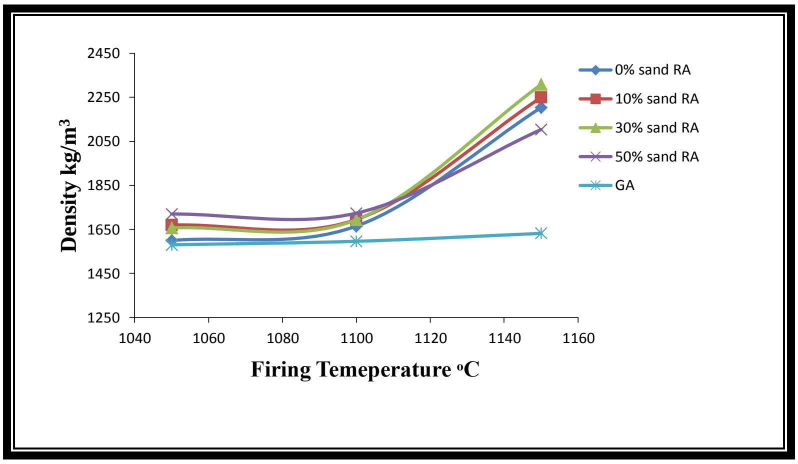

Figure 5: Effect of firing temperature on the density of samples.

The compressive strength of clay bricks(Figure 6, Figure 9) is affected by both firing temperatures and sand percentage directly. Each type of soil shows a different behavior by changing firing temprature as explained.

- **<u>Rashidia Location</u>**:

As shown in Figure 6 the maximum compressive strength for this type of soil is about 76 MPa, it obtained at 1150 °C when sand percentage is 30%. The compressive strength decreases by increasing sand percentag (at both 1050 °C and 1100 °C) because the incomplete vetrification of clay minerals that the bond between particles will become weak [10]. The samples that fired at 1050 ºC have lower persentage of cracks and lower strength than those fired at 1100 ºC. Although the sand reduces the compressive strength but it improves the quality of the samples because it minimize the cracks that occur during firing as shown in Figure 7. The samples with out sand have many defects ranging from thin and short cracks to wide and continuous groves. It is also noted that by increasing sand content, the cracks reduce and become short and thin, but at 30% a wide and continuous cracks are noted. The additional sand minimized the absorbed water during molding and modified the thermal behaivior of the soil during firing because it provided the soil with higher corase grains and silica that increas the melting tempertaure of soil[6, 13, 14] reported that sand provide voids permits the bonded water as well as generated gases to escap during firing. The mensiond resons make the sand minimize and reduce the cracks which accore during firing.

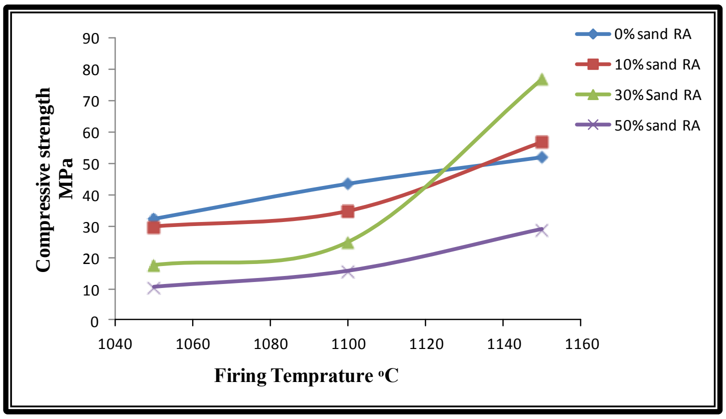

Figure 6: Effect of firing temperature on the compressive strength of RA samples

Figure 7: Effect of sand addition on the shape and cracks development of samples fired at 1100 °C

Although the maximum compressive strength was at 1150 °C but this temperataure can not be used for clay brick manufacture because the samples which fired at this temperature were partaily melted and deformed as shown in Figure 8.

Figure 8: Partial melting of the samples made from RA location which fired at temperature 1150 °C

The optimum firing temperature and optimum sand percentage which give the highest compressive strength and lowest percentage of cracks are **1100** °C and **10**% respectively. The average compressive strength for this mixture is 34 MPa. Firing the samples of RA location at temperature higher than 1100 °C will cause partial melting as shown in Figure 8, while firing them at temperature less than 1100 °C will produce samples have low strength and abrasion resistance that can be scratched easily, on the other hand reducing the percentage of additional sand less than 10% will produce cracked samples as shown in Figure 7 while increasing the percentage of additional sand more than 10% will produce sample have low abrasion resistance that can be scratched easily. [9] noted that the resent clays sediments within the floor and banks of Mosul Dam can be used for manufacture of clay brick after treating it with 25% of sand and firing them at a temperature 900 °C while [6] founded that the best ratio of sand and the best firing temperature which can be used to modify the properties of clays belongs to Gercus Formation was 10 % and 1100 °C respectively. [8] Advised to treat the clay by 50 % of fine sand to modify its thermal behavior.

- **Gayyara Location**

The compressive strength is related directly with firing temperature as shown in Figure 9. [5, 6, 9, 10, 12] obtained the same relationship between compressive strength and firing temperature. It is noted that the samples that fired at a temperature of 1100 °C and 1050 °C appear to be not well verified that can be scratched easily i.e. have low abrasion resistance, while those which fired at 1150 °C appear to be very hard and have good soundness. The compressive strength increased from 22.5 MPa to 61.59 MPa when the temperature rises from 1100 °C to 1150 °C. This development in strength is due to the recrystallization of mulite and vetrification of clay minerals that the particles will be bonded together and the particles will transform into compact mass when will be cooled [10,14]. Unlike RA Location, the samples of GA that fired at 1150 °C remain stable without cracks and other form of defects because they contain only 8% of clay.

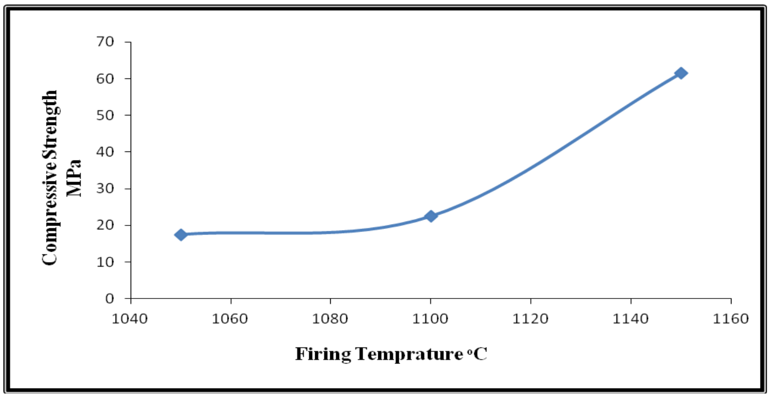

Figure 9: Effect of firing temperature on the compressive strength of GA samples

The relation between water absorption and firing temperature for both GA and RA is shown in Figure 10. The water absorption is related inversely with firing temperature and this is observed by [5, 6, 13], while its relation with sand content is not constant. Generally, the maximum water absorption for the two locations is at 1050 °C. This is expected because the poor vetrification and high porosity of samples. On the other hand, the samples that fired at 1150 °C possess lower water absorption due to very low porosity as well as transform the clay particles to glass-like material [6, 13, 15]. It is also shown that the reduction in water absorption for the samples fired at1100 °C is gradual and small, while the reduction at 1150 °C is sharp.

As shown in Figure 11, the efflorences that occurred in the samples of both locations doesn’t form a problem because it is low and within the limit of Iraqi standard.

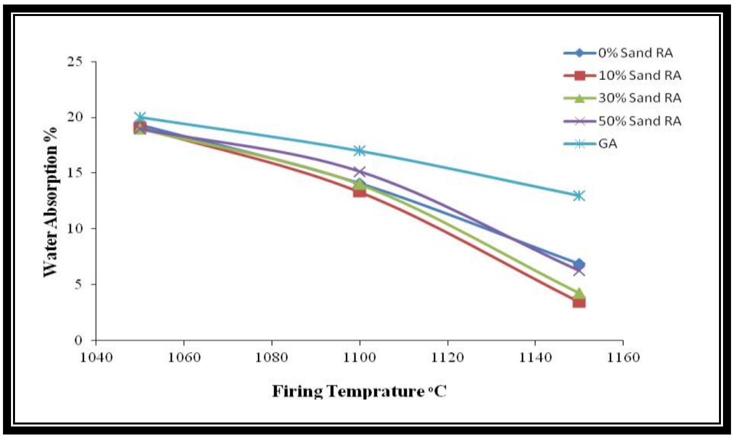

Figure 10: Effect of firing temperature on the water absorption of samples

Figure 11: Low efflorences in the samples of both locations

The Iraqi standard classifies clay brick in to three classes (A, B and C) depending on compressive strength and water absorption as well as efflorences as shown in Table 4.

Table 4: Major grades of clay bricks according to Iraqi standard No.25, 1986

Class	Minimum Compressive Strength (MPa)	Maximum Water Absorption (%)	Efflorences
A	18	17	low
B	13	22	low
C	11	25	**-**

The classification of the samples according to Iraqi standard No.25, 1986 for Rashidia and Gayyara locations are shown in Tables 5 and 6 respectively.

Table 5: Classification of the Rashidia samples according to Iraq standard No.25, 1986

Temperature (C□)	Sand (%)	Al- Rashidia			
		Absorption (%)	Density (Kg/m^3)	Compressive Strength (MPa)	IS.
1050	0	19.34	1600	32.38	B
1050	10	19.11	1670	29.8	B
1050	30	18.95	1657	17.16	B
1050	50	18.96	1720	10.43	C
1100	0	14.11	1665	43.55	A
1100	10	13.33	1695	34.73	A
1100	30	16.86	1694	25.0	A
1100	50	15.15	1724	15.57	B
1150	0	6.89	2204	52.0	A
1150	10	3.48	2250	56.8	A
1150	30	4.29	2309	76.8	A
1150	50	6.25	2104	29.0	**A**

Table 6: Classification of the Gayyara samples according to Iraq standard No.25, 1986

Temperature (C□)	Sand (%)	Al-Gayyara			
		Absorption (%)	Density (Kg/m^3)	Compressive Strength (MPa)	IS
1050	0	20.025	1580	17.5	B
1100	0	17.05	1596	22.5	A
1150	0	13.05	1632	61.59	A

Conclusions

The engineering tests have shown that some of the local soils available in Nineveh governorate are suitable for production of clay bricks satisfying class A, class B and class C according to Iraqi standard No.25 1988. The optimum firing temperature and optimum sand content which give the highest compressive strength and minimum amount of cracks were 1100 ºC and 10% respectively for Rashidia location, while the optimum firing temperature for Gayyara location which give the highest compressive strength was 1150 ºC without any addition of sand.

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امكانية استخدام الاطيان الحديثة لصناعة الطابوق في محافظة نينوى

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الملخص

اضهرت المسوحات الحقلية و الفحوصات المختبرية و الهندسية بان هناك منطقتان في محافظة نينوى تحتوي على ترب مناسبة لصناعة الطابوق و يمكن استخدامها لانتاج طابوق طيني مطابق للاصناف A, B, C حسب المواصفة العراقية رقم 25 لسنة 1988. تتضمن هذه المناطق السهول الفيضية الحديثة في منطقة القيارة(GA) والرواسب الحديثة في منطقة الرشيدية (RA). اضهرت النتائج المختبرية بان نماذج منطقة القيارة (GA) يمكن استخدامها دون أي معالجة بينما نماذج منطقة الرشيدية (RA) تم معالجتها بنسب مختلفة من الرمل (10,30,50%) لتعديل خواصها الكيميائية و الفيزيائية و الهندسية.

اظهرت النتائج المختبرية ان خواص الطابوق الطيني تتأثر تئثر مباشر بدرجة الحرارة و نسبة الرمل (بالنسبة لنماذج منطقة الرشيدية). ان ارتفاع درجة الحرارة من ($1100\ ^oC$) الى ($1150\ ^oC$) ادى الى ارتفاع مقاومة الانضغاط لنماذج منطقة القيارة من (22.5 MPa) الى (61.59 MPa)(حوالي ثلاثة اضعاف) بينما مقاومة الانضغاط للنماذج المصنعة من منطقة الرشيدية والمعالجة بنسبة 10% من الرمل ازدادت من (34.73 MPa) الى (56.8 MPa) كما لحض انخفاض نسبة امتصاص الماء لنماذج منطقة القيارة من 17.05% الى 13.05% في حين ان امتصاص الماء للنماذج المصنعة من منطقة الرشيدية انخفض من 13.33% الى 3.48 % . بعد اجراء الاختبارات الهندسية وجد بان افضل درجة حرارة و افضل نسبة رمل يمكن اضافتها للنماذج المصنعة من منطقة الرشيدية (RA)والتي توفر اعلى مقاومة انضغاط و اقل نسبة من امتصاص الماء و الشقوق هي($1100\ ^oC$) ، 10% على التوالي بينما افضل درجة حرارة يمكن استخدامها لصناعة الطابوق الطيني من منطقة القيارة (GA) هي ($1150\ ^oC$) و بدون أي معالجة بالرمل.