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The possibility of Manufacturing Building Bricks from Al-Qend Hills Clays in North Iraq by using the extrusion and pressing methods

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Abstract. This study deals with the properties of Al-Qend Hills clays (Nineveh Governorate, North of Iraq) that effect on the production of building bricks and determines the best method for bricks industry. Two methods used to the manufacturing of clay brick samples, the first is the extrusion with dimensions (2.5×4×7.5) cm and the second is the pressing (cylinder shape) with dimensions (3.5×5.5) cm after that dried at room temperature for 48 hr. and for 24 hr. at 110 °C using the laboratory oven. After the drying process, the samples will burn at different temperatures (750, 800, 850 and 1100) °C according to burning program for 2 hr. in muffle furnace, The results appear that extruded samples at 800 °C is successful because conform to the requirements of Iraqi standards specification No.25, 1993.

1. Introduction

Manufacturing of clay bricks is among the oldest industrial activities in the history of the human civilization. Brick remains one of the most important building materials and continues to be the mainstay of construction activities. Many bricks factories in Iraq using clays as ore materials, these factories used tens of millions of tons from these deposits annually, which is found as a succession from clay and silt [1], studying using the physical and mechanical tests on quaternary deposits in south Iraq and carry out by two methods (extrusion and pressing) of the samples, the produced are valid for the manufacture of the bricks after burning them at (950,1100) C°[2], many studies on locally brick industry that including qualitative and quantitative assessment, area contain isolated hills consist of bedding sequence for clays, silt, sand, claystone, clays layers have contain major clay minerals as montmorillonite and palygorskite also non clay minerals as calcite and quartz [3]. The ratio of these minerals effect of brick and other ceramics industries, another study on presence fine limestone grains in clays and effect on characteristics product bricks [4] which concluded lime not causes the cleavage of sample during bulge in burn (850 ºC). In another study show that addition of calcite with a little ratio for clays will decrease from temperature of maturity and improves the resistance compression to brick [5], another studying [6] appearing the presence of calcite in the ore material leads to increase in porosity when bricks burn between (800 – 1000 ºC), so that in this research will study, the properties of the clays and the optimal conditions of production as volumetric graded and the difference between pressing or extrusion methods and the burning temperatures and their effect on the properties of ceramic products (physical and mechanical).

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2. Location

Studied area located 30 km north of Mosul and 10km south Al-qosh area, Nineveh Governorate in North of Iraq.

3. Methods

3.1 Preparation of samples

(10) samples with a weight of (10) kg for each sample were taken from the location and divided into two groups (fragment and claystone), the fragmented samples divided and squared, sort coarse grains and screening on a sieve size 2mm then took a representative sample for physical tests, chemical and mineralogical analysis carryout in chemical laboratories of Geosurve, the claystone samples were broken by the jaw crusher then divided and quadrature and also took a representative sample for physical tests, chemical and mineralogical analysis.

3.1.1 Physical tests. Physical tests (plasticity, grain size analysis) were carried out for clay minerals, the plasticity test was achieved by calculating the soil texture and the Atterberg limits (ASTM, D4318) [7], the grain size analysis was performed by hydrometer method (ASTM, D422) [8]. The results are shown in (Table 1).

Table 1. Result of physical tests (ASTM, D4318), (ASTM, D422).

Sample No.	Clay	Silt	Sand	*L.L	*P.L	*P.I
K1-1	36	30	34	38.23	25.13	13.11
K3-1	45	28	27	51.75	27.85	23.9
K4-1	33	39	28	39.2	24.82	14.38
K5-1	42.0	52.0	6	35.8	22.52	13.31
K7-1	43	35.2	21.8	36.22	27.07	9.14
K8-2	43	30	27	42.81	23.45	19.37
K3-3	44.3	36.5	19.2	49.93	27.81	22.13
K1-3	40	30	30	36.4	22.16	14.24
K6-1	53	24.7	22.3	35.93	25.5	10.4
K3-4	19.9	36.1	44.0	39.44	25.95	13.52

*** L.L = liquid limit P.L = plastic limit P.I = plasticity Index**

3.1.2 Chemical composition. Chemical analysis of ore materials was carried out by wet analysis and the results are shown in (Table 2).

Table 2. results of chemical analysis of ore materials

Samples	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	L.O.I	Na_2O	K_2O
K1-1	43.45	4.72	9.4	16.24	6.2	0.16	16.97	0.62	1.72
K3-1	44.66	4.2	9.39	15.68	4.1	0.08	16.52	0.19	1.85
K4-1	35.22	3.88	7.69	22.68	3.5	0.11	22.31	0.10	1.82
K5S1	42.04	4.7	10.27	17.36	4.5	0.19	17.65	0.17	1.93
K7S1	37.68	4.5	8.73	21.28	4.1	0.10	20.12	0.12	1.18
K8S2	44.82	4.38	9.61	15.68	3.5	0.09	15.98	0.37	2.22
K3S3	47.70	6.01	14.25	10.08	4.82	0.14	12.37	0.16	2.88
K1S3	43.80	5.3	9.55	16.24	6.53	0.19	15.86	0.66	1.77
K6S1	40.56	4.85	9.01	20.72	4.35	0.10	19.41	0.12	1.82
K3S4	51.30	3.94	9.10	14.56	3.60	0.10	13.68	0.65	2.03

3.1.3 Mineralogical composition. X-ray of ore materials were performed to determine the clay and non-clay mineral compositions by using (7000 Shimadzu) device, as shown in Fig. (1-a&b), (2-a&b), (3-a&b), (4-a&b), (5-a&b), (6-a&b), (7-a&b), (8-a&b), (9-a&b) and (10-a&b).

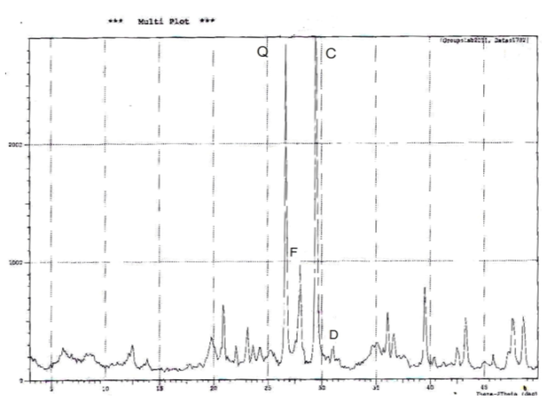


Figure (1-a). Mineralogical analysis of (K1-1) non clay minerals

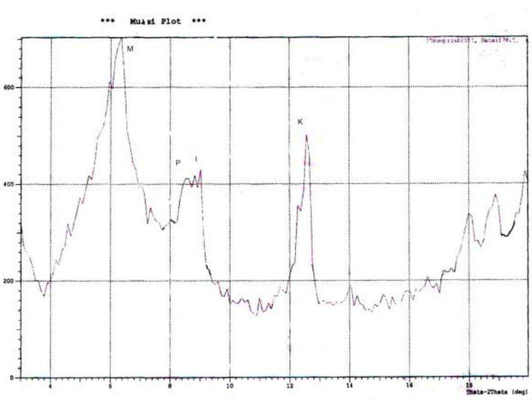
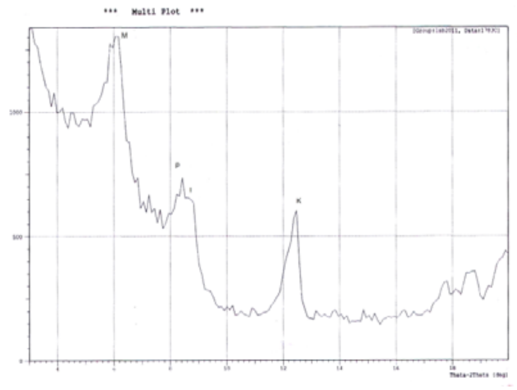


Figure (1-b). Mineralogical analysis of (K1-1) clay minerals



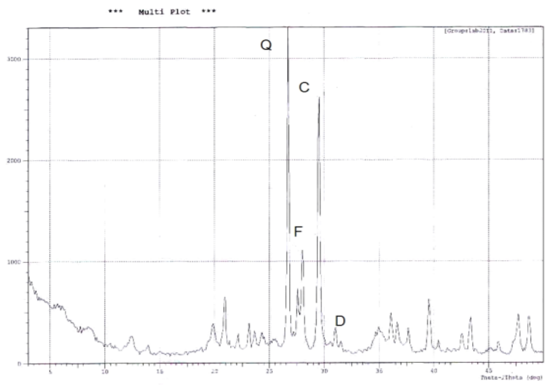
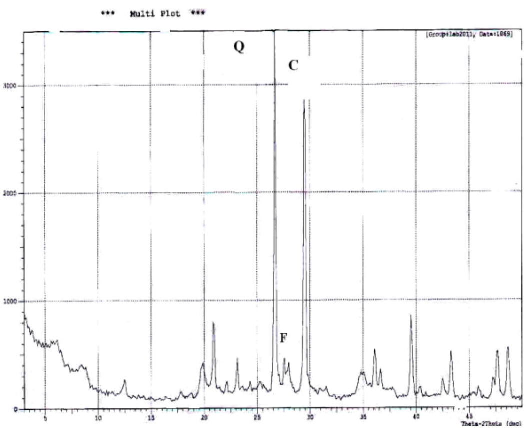


Figure (2-b). Mineralogical analysis of (K1-3) clay minerals **Figure (2-a).** Mineralogical analysis of (K1-3) non clay minerals



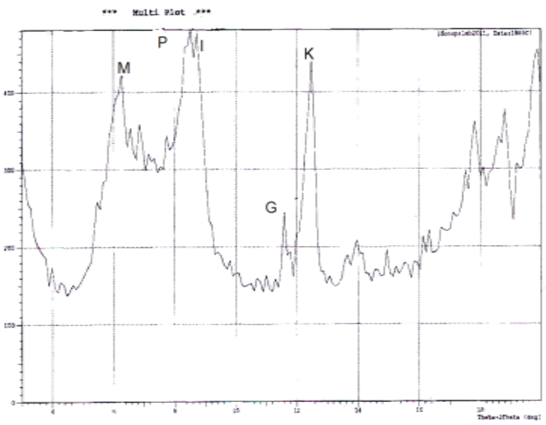


Figure (3-a). Mineralogical analysis of (K3-1) non clay minerals **Figure (3-b).** Mineralogical analysis of (K3-1) clay minerals

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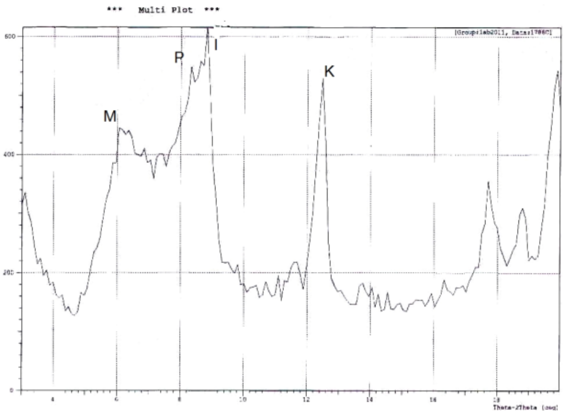


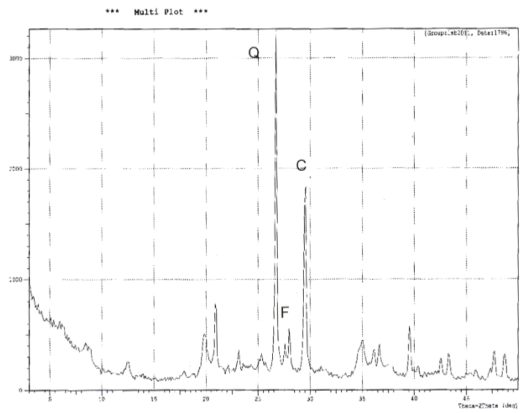
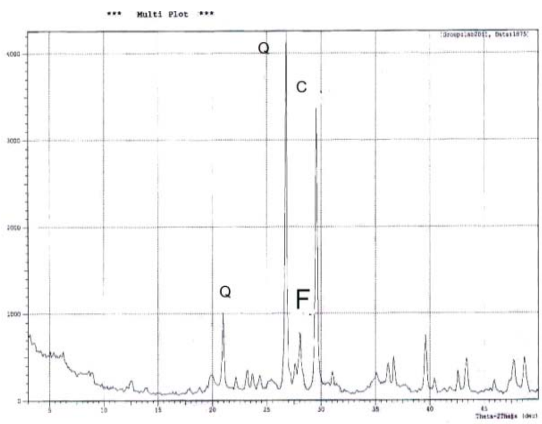


Figure (4-b). Mineralogical analysis of (K3-3) clay minerals **Figure (4-a).** Mineralogical analysis of (K3-3) non clay minerals



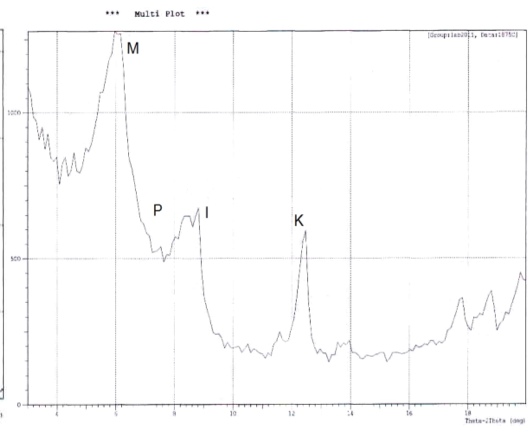
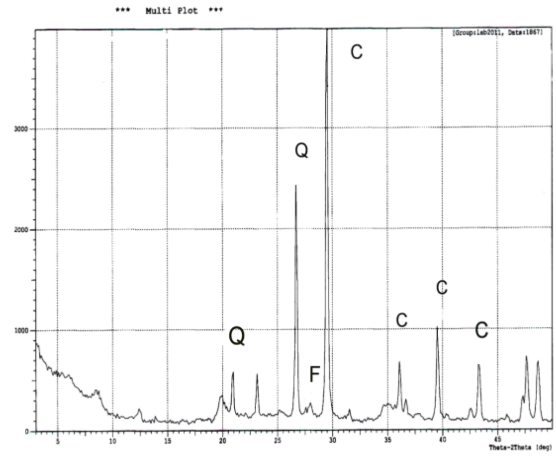


Figure (5-a). Mineralogical analysis of (K3-4) non clay minerals **Figure (5-b).** Mineralogical analysis of (K3-4) clay minerals



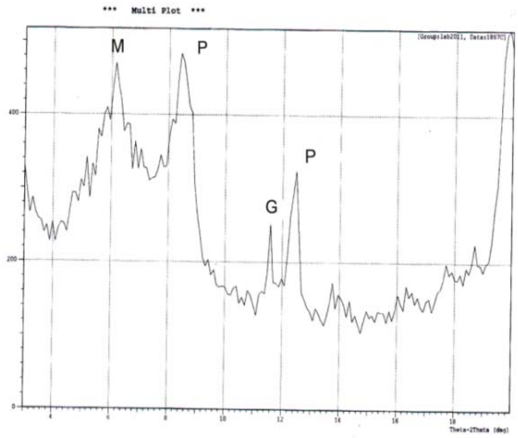
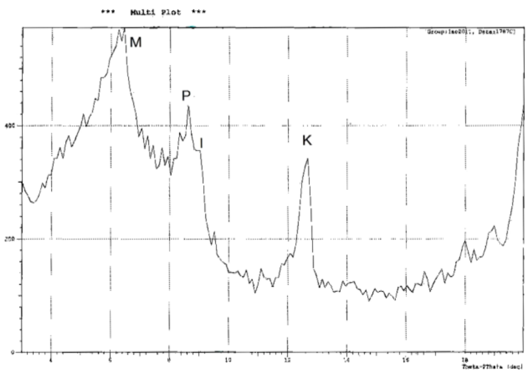


Figure (6-a). Mineralogical analysis of (K4-1) non clay minerals **Figure (6-b).** Mineralogical analysis of (K4-1) clay minerals



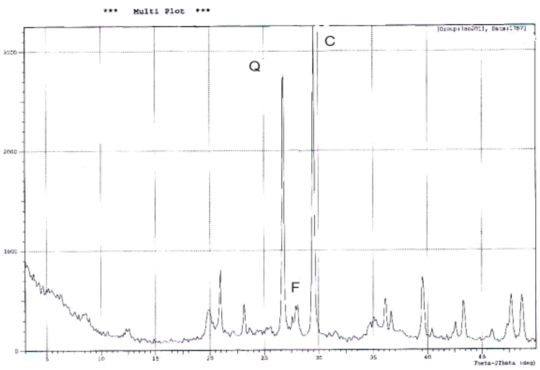
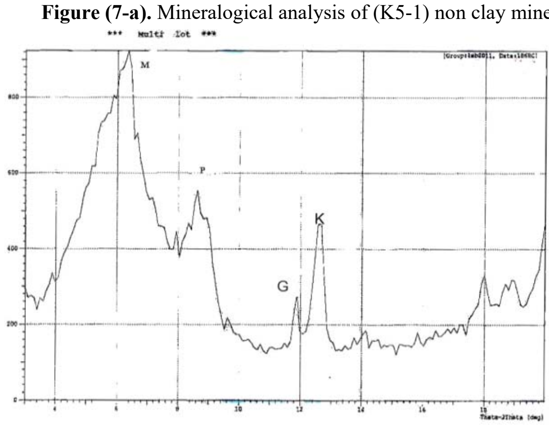


Figure (7-a). Mineralogical analysis of (K5-1) non clay minerals **Figure (7-b).** Mineralogical analysis of (K5-1) clay minerals



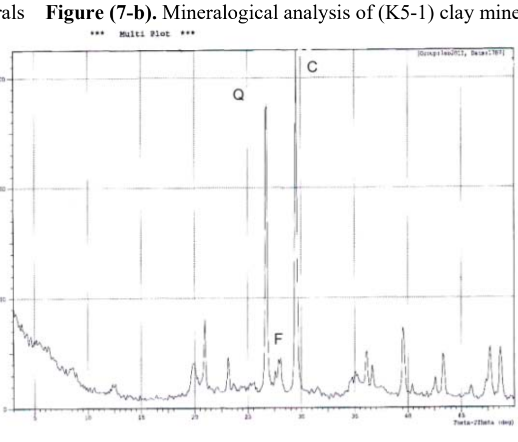


Figure (8-a). Mineralogical analysis of (K6-1) clay minerals **Figure (8-b).** Mineralogical analysis of (K6-1) non clay minerals

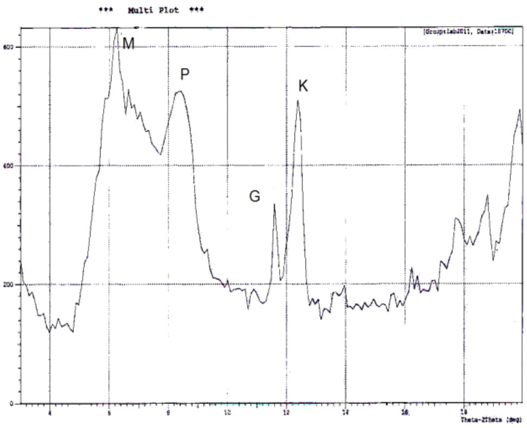


Figure (9-a). Mineralogical analysis of (K7-1) non clay minerals

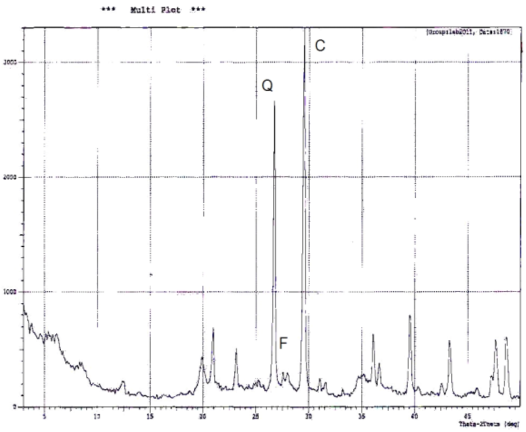


Figure (9-b). Mineralogical analysis of (K7-1) clay minerals

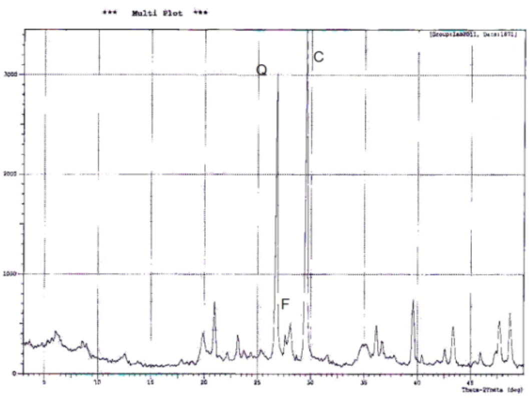


Figure (10-a). Mineralogical analysis of (K7-1) non clay minerals

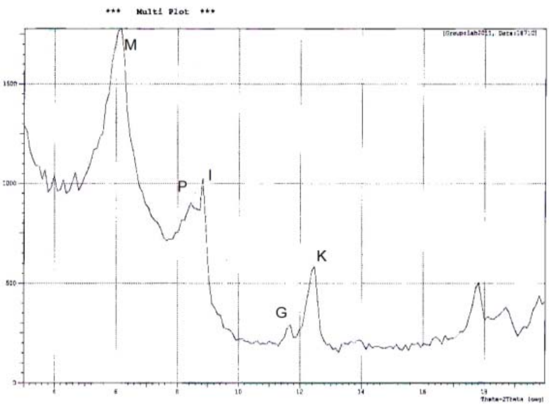


Figure (10-b). Mineralogical analysis of (K7-1) clay minerals

Q: Quartz D: Dolomite C: Calcite G: gypsum I: illite
H: Hematite P: palygorskite K: Kaolinite M: montmorillonite

3.2 Preparations of samples

Two methods (extrusion and pressing) used for prepared the building brick samples:

3.2.1 Extrusion Method. The samples were prepared by extrusion with dimensions (2.5×4×7.5cm), the ore material was screening on sieving (2 mm), water was added to the clay for fermentation to period 3 days to get the homogeneity of moisture because may be disintegration if stay longer period so samples (K1-1 and K4-1) choice to prepare in lab and submerge with water 72 hr. to ensure from disintegration of clays and then sieving to (1 mm), after that deposited clay and remove from existing water and dry the sample with air then by electric oven with temperature (110 ° C), however the sample was broken and sieved (300 μ) to prepare the samples by extrusion.

3.2.2 Pressing Method. Brick samples were prepared in laboratory with using semi-dry press method with moisture content about (6–8%) and pressure to formation sample (250 kg/cm^2) by using a cylindrical template has dimensions (12 ×5 cm), the samples divided into three groups with different grain size, each group was treated differently as in below:

- The samples (K1-3, K3-3, K3-4, and K6-1) that screening previously on a sieve (2 mm) treated by screening again on sieve (300 μ) and crushing the residual until ensure from crossing all the sample which prepared for pressing.
- The samples (K1-1, K3-1, K5-1, K7-1, and K8-2) grinded and screened on sieve (75 μ) and prepared for pressing.
- The samples (¯K1-1, ¯K4-1 and ¯K8-2) submerged with water for (72 hr.) to ensure the disintegration of clays and passed on sieve (1mm) to remove coarse grains from limestone, after that precipitate suspension clay and disposal of excess water and drying the sample in air and oven in a temperature (110 º C), the sample will disintegration after drying and screening at sieve (300 μ) to prepare for pressing.

3.2.3 Drying and burning. The formed samples by (extrusion, pressing) were dried in two stages:

First stage: Room temperature for 48 hr.
Second stage: electric oven with temperature 110 °C ± 5 for 24 hr.
The samples were burned at different temperatures (750, 800, 850 and 1100 °C) according to a 3 °C / min burning program and a 2 hr. retention time.

3.3 Physical and Mechanical Tests

Physical and mechanical tests of the manufactured brick samples were determined according to the requirements of the Iraqi standards specification no. (25) for the year (1993) [9], and the evaluation of the external appearance after burning and physical and mechanical tests of the sample formed by the extrusion and pressing methods shown in Tables (3, 4, 5 and 6), and (Fig.11).

Table 3. Iraqi Standard specification No.25 for the year 1993

Efflorescence	Maximum water absorption%	Minimum compressive strength kg / cm2	Brick class
light	20	180	A
medium	24	130	B
high	26	90	C

Table 4. External appearance of samples before and after burning

Sample No.	Appearance before burning	Appearance after burning for extruded sample after 10 days	Appearance before burning	Appearance after burning for compressed sample after 10 days

		750 °C	**800** °C	**850** °C	**1100** °C		**750** °C	**800** °C	**850** °C	**1100** °C
K1-1	-	-	-	-	-	Free of defects	d. of upper surface	Few d. Surface cleavages	Few d. surface cleavage	-
*K1-1^{-}	Free of defects	s.	s.	s.	-	Free of defects	s.	Circular cleavage Medium d. Surface cleavages	Circular cleavage d. surface cleavage	-
K3-1	Free of defects	Few d.	Much d. much Lime	Much d. much Lime	-	cleavage	Inter cleavage	Inter cleavages Surface cleavages	Inter cleavages Surface cleavages	-
*K4-1^{-}	cleavage	Inter cleavage	Inter cleavages	Inter cleavages	-	Free of defects	Circular cleavage	Inter cleavages Surface cleavages	Inter cleavages Surface cleavages	-
K5-1	Free of defects	Few d.	Much d. much Lime	fragmentation	-	cleavages	Inter cleavage	Sample division	Sample division	-
K7-1	Free of defects	Few d.	Much d. much Lime	fragmentation	-	cleavages	Inter cleavage	Sample division	Sample division	-
K8-2	Free of defects	s.	s.	s.	-	cleavages	Surface cleavage	Inter cleavages Surface cleavages	Inter cleavage d. Surface cleavages	-
*K8-2^{-}	-	-	-	-	-	Free of defects	Circular cleavage d.	Inter cleavages Surface cleavages	Inter cleavage d. Surface cleavages	-
K3-3	Free of defects	s.	s.	s.	Bulges with surface glazes	Free of defects	s.	s.	s.	Intense shrinking
		s.			s.		Crumble	Much d.		s.

K1-3	Free of defects		Few d.Few lime	Few d. Few lime		Free of defects		Surface cleavages	Fragmentation in sides Surface cleavages	
K6-1	Free of defects	Few d. much Lime	Many d. much Lime	Crush	Few d. much Lime	Free of defects	s.	Excessive cracks Surface cleavages	Excessive cracks Surface cleavages	Excessive cracks
K3-4	Free of defects	Few d. much Lime	Medium d. much Lime	Crush	s.	Free of defects	Crumble	Many d. Superficial cracks	Excessive cracks Superficial cracks Crumble	s.

*submerge the ore material with water for three days d. disintegration s. successful

Table 5. Physical and mechanical tests of sample prepared by the extrusion method

Sample no.	750ºC	800ºC			850 ºC			1100ºC		
	Longitudinal contraction %	**Water absorption %**	**Compression resistance kg / cm^{22}**	**Longitudinal contraction %**	**Water absorption %**	**Compression resistance kg / cm^2**	**Longitudinal contraction %**	**Water absorption %**	**Compression resistance kg / cm^2**	**Longitudinal contraction %**
K1-1$^-$	- 0.07	17.37	217.37	1.08	18.64	335.79	1.24	20.97	245.50	-
K3-1	0.12	17.99	203	0.39	18.09	273.9	1.08	15.85	301	-
K3-3	- 0.3	18.1	296.34	1.6	15.49	460.3	2.35	11.85	295.3	4.66
K1-3	0	13.58	210.6	0.25	17.78	256.1	0.07	21.0	166.07	1.67
K5-1	2.04	17.96	106.86	1.07	14.92	307.6	1.4	13.24	342.4	-
K6-1	0.39	14.25	288.6	1.38	13.03	264.6	1.1	14.2	Crush	3.68
K7-1	0.35	16.3	165.55	1.20	14.52	364.3	1.66	13.32	293.2	-
K3-4	- 0.14	18.5	165.7	0.6	20.83	173.8	0.14	24.4	93.4	2.7
K8-2	0.29	24.17	196.46	0.61	19.28	238.56	0.72	17.44	274.3	-
K4-1$^-$	0.29	18.76	265.33	2.75	17.43	403.63	2.94	18.91	311.06	-

Table 6. Physical and mechanical testing of samples prepared by the pressed method

Sample no.	750ºC	800ºC		850 ºC			1100ºC		
	Longitudinal contraction %	Water absorption %	Compression resistance kg / cm²	Longitudinal contraction %	Water absorption %	Compression resistance kg / cm²	Longitudinal contraction %	Water absorption %	Compression resistance kg / cm²
K 1-1	0.28	19.8	193.14	0.46	21.1	266	0.92	24.66	240.8
K 3-1	- 0.36	23.95	123	-	-	Crush	2	24.2	154.6
K3-3	0.09	19.2	358.6	1.5	19.68	536.55	2.88	14.65	581.87
K1-3	- 0.56	15.9	243.5	- 1.8	20.2	Crush	- 2.21	22.4	Crush
K5-1	0.18	24.65	118.8	-	-	Crush	-	-	Crush
K6-1	0.28	17.05	271.95	-	-	Crush	0.37	19.36	Crush
K7-1	0.18	23.2	151.78	-	-	Crush	-	-	-
K3-4	- 0.46	17.05	212.75	- 1.5	21.7	199.4	- 1.29	22.55	125.88
K8-2	0.37	22.45	184.4	0.65	23.3	251	2.02	21.62	302.05
K8-2^{-}	- 0.37	22.68	170.34	0.28	24.9	201	-	-	-
K4-1^{-}	0.09	26.34	152.19	0.64	27.05	143.1	-	-	-
K1-1^{-}	- 0.83	18.78	135.04	- 0.09	21.24	256	-	-	-

Figure 11. Samples burned to 750 ° C

4. Results and Discussion

4.1 Ore materials properties

The properties of ore materials include results of physical tests for grain size analysis and plasticity of samples in (Table 1), most of samples have ratio of clays range (33%-53%) causing plasticity property except (K3-4) which property with be claystone. It is mineralogical grains and solid buried in depths, lime was available in little depth from soil. The temperature and pressure were effect on lime and fragmentation it causing the overlap between clays compounds so ratio of clays reach to (19.9%) sand (44%), while plasticity coefficient will high in montmorillonite and palygorskite and not plasticity in quartz and calcite so moisture limit will be appropriate for brick production it is ranging between PI (10 – 30 %) [10].

4.2 Chemical and mineralogical properties

The mineral analysis (XRD) of ore materials show that samples including in non-clay minerals especially calcite and quartz and minor feldspar and dolomite, gypsum in some samples and contain

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clay minerals in major montmorillonite and palygorskite, kaolinite and illite in smaller quantities. The different in ratio of minerals analysis (XRD) in ore material be the reason in determine the properties of brick manufacturing especially the effect of the existence ore lime (calcite) on brick sample with temperature range (800-1050 º C) [11] because calcium carbonate ($CaCO_3$) disintegration and exit gas (CO_2) and existence (CaO) that lead to weaken of sample because absorption of moisture and converted (CaO) to (CaOH) caused form cleavage in the sample. In another case clays that have high plasticity as montmorillonite and palygorskite that cause cleavage in samples after drying and burn for some samples in (Table 4).

Chemical analysis of ore (Table 2) carryout after screening on 2 mm to sort coarse grains from limestone and after passing samples from sieves used to prepare laboratory brick samples. That presence ratio from (MgO, Fe_2O_3, Na_2O, and K_2O) with contrast of their proportions also different in presence of mineralogical compounds in ore material cause reducing from degree of thermal maturation and decrease the resistance of high temperature [12 and 13].

5. Brick samples property

The samples were left after burn exposed to air for 10 days to ensure that no changes on samples, after that carry out physical and mechanical analysis, (Fig. 12, 13) showed changes occur on it.

Figure 12. Samples burned with (800 ºC)

Figure 13. Samples prepared with extrusion and pressing with (1100 ºC)

5.1 Properties of samples forming with extrusion

- Screening of disintegration samples on scale (2mm) and their fermentation with water consider the method followed in the labs, also carry out the same method in pressing especially samples which less in it the ratio of calcite (K1-3,K3-1,K3-3) these samples not affect (the external appearance) in burn with temperature (750 ºC) (Table 4) comparison with another samples that contain more ratio calcite (K5-1),(K6-1),(K7-1) so showed cleavage in external appearance when temperature is high, so it is better that decrease burn temperature less than (750 ºC) to avoid disintegration of calcite even a little which consider major factor in cleavage of extruded samples [11].
- Disintegration of rigid samples (K3-4,K8-2) and sieving on (300μ) and forming by extrusion , the result is good in external appearance (without cleavages) and physical tests at burn in (850ºC) as show in (Table 5), limestone spreading in rigid samples be less affect during burn compared to friable samples, less in ratio of (CaO) in sample which reach to (15.68%) not effect on extrusion brick properties [11].
- Effect of submerge ore material with water, depend on screening sieve (300μ) to prepare sample after dry process to extrusion, this method carryout in two samples (K1-1¯and K4-1¯) the first sample was better in external appearance from the second sample that appear cleavages on surface because plasticity which increase due to submerge in water addition to the presence of limestone.

5.2 Properties of samples forming with pressing

- The disintegration and screening with (300μ) for samples (K1-3, K3-3, K3-4 and K6-1) notice that the difference is clear between selected samples in external appearance (Table 4) because variation in ore material properties, increasing in clays ratio led to form cleavages in sample as (K6-1) during burn in temperatures (750,800,850 ºC) the clay ratio reach to 53% in this sample (Table 1) while two samples (K1-3,K3-4) notice cleavages in upper surface of sample and disintegration in perimeter of sample result exposed to air after burn and the sample begins to damage as a result of absorbing moisture and convert (CaO) to $Ca(OH)_2$ that be larger this leads to swelling and fragmentation of the edges of the sample, (K3-4) is a perfect sample because given when burning at (800ºC) results (Table 5) compression resistance (536.55 kg/cm^2) and absorption (19.68%) because decreasing in (CaO) to (9.52%) , Fe_2O and K_2O increase to (6.01%,2.88%) [14].
- The samples (K1-1, K3-1, K5-1, K7-1and K8-2) which screening (<75 μ) in (Table 6) appear beginning of cleavage after their dry in the oven as a result of the exit of formation water from the samples and the high smoothness of the clays and the effect of pressing on the convergence of the clay grains which obstruct the exit of crystallization water when burning and creates excessive cracks samples.
- Effect of pressing on clays submerged with water in exterior (K1-1,¯ K8-2,¯ K4-1¯) in (Table 4), cleavages appear and disintegration of samples especially on upper surface when exposure to air for period 10 days, intensity of cleavages graded according to the ratio of calcite in sample, the soaking process leads to the softness of ore material during the pressing process convergence of grains caused obstruct exist of crystallization water in burn and form cleavages on the surface of the sample [15].

6. The effect of increasing the burning temperature to 1100 º C

Carry out the experiments with increased the burning temperature to 1100 º C for samples (K1-3, K3-3, K3-4 and K6-1) in (Tables 5 and 6), the sample (K3- 4) showed the best results (compressive resistance 393.8 kg / cm2 and absorption ratio of 13.21%) and this temperature is not recommended for the industry of bricks but it is used to produce other types of building products such as floor tiles or brick facades and other ceramic products because it contains sand and fusible materials as well as clays with ratio suitable for these products [16].The sample (K3-3) showed a high increase in shrinkage (4.66% by extrusion, 7.75% by pressing) shown in (Tables 5 and 6), as a result of the increase of clay and fusible materials. The sample which formed by extrusion method has deformations (bulges and glazes) so that it is not recommended to use it in high temperatures. The sample (K1-3) has shown success in this temperature by extrusion and pressing methods, while the sample (K6-1) showed a clearly failed in this temperature (for the press and extrusion samples) as shown in (Tables 5 and 6).

7. Comparison between extrusion and pressing methods

The result in (Table 5, 6) for extrusion and pressing methods respectively (Fig.12), extrusion process is more suitable from pressing in brick production from plasticity clay and containing on calcite with different ratio because extrusion method accompanied with air pull of sample (vacuum) means reduce the voids leading to little moisture absorption, this explain a reason of increasing the absorption water for pressing samples compared with extrusion.

in (Table 6) notice cleavages appearance in upper surface confrontation to press as result interfere of clay grains in lower mold more than surface so that samples absorb moisture when exposed to air because partial disintegration of calcite during burn forming (CaO) which consider unstable for moisture in air so that convert to $Ca(OH)_2$ which increases the size and appearance of clavages [17].

8. Conclusion

1- Using extrusion method to form brick have better Continuation properties after burning compared with pressing method in prepare of samples.
2- The samples (K3-3, K8-2, and K1-1) that burned at (800 ° C) and prepared by extrusion was a success.
3- Burning samples prepared by pressing and extrusion by temperatures up to (1100 ° C) suitable for the production of other ceramic materials as in samples (K3-4 and K1-3).

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