Study of Raw Materials for Manufacturing Perforated Clay Bricks (Chamchamal, and Qaradagh Regions in Sulaimani/ Iraq)

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Abstract

There is no information about the optimum molding moisture content and molding pressure on the physical and mechanical properties of clay bricks. In this paper, the effect of moisture content and applied pressure during molding of brick samples for two selected locations of Sulaimani province in Iraq were studied. After firing the molded brick samples at a temperature of 1000°C, the physical and mechanical properties were studied from the following tests: firing shrinkage, water absorption, dry density and uniaxial compressive strength. The results indicate that the optimum moisture content for molding and manufacturing of clay bricks is within (0.6 to 0.7) of plastic limit of the raw materials. Also, it was found that the sufficient applied pressure during molding of clay bricks is 6 MPa.

Keywords: Perforated clay bricks, Density, Compressive strength, Water absorption, Fired shrinkage, Chamchamal, Qaradagh.

1- Introduction

Clay soils are natural materials abundantly found and largely used by the prehistoric civilization to make household utilities. Presently, they are still used in the manufacturing of clay products such as bricks, porcelain, sanitary ware, floor, wall, and roofing tiles. However, the resulting products show uncontrolled variations of the quality, due to the lack of rational investigations on used raw materials and manufacturing processes.

Over the past three decades, many literatures studied raw materials for manufacturing clay bricks. The study of Dondi et al. (1998), considered the effect of grain-size distribution of Italian raw materials for building clay products: a reappraisal of the Winkler diagram. The grain-size distribution of 350 clays currently used in nearly 240 Italian plants was determined by X-ray monitoring of gravity sedimentation. Raw materials are mostly represented by silty clays and clayey silts. This study showed that most of the bodies tend to fall within the field defined by Winkler for "thin-wall hollow bricks". Merza (2002), investigated 4 clay samples from Kani Shaitan Village, about 40 km form Sulaimani City and studied their evaluation for brick manufactures. Grain size analyses, Atterberge Limits, and chemical analyses of raw materials have been studied. Forty test tiles were prepared from the clay samples by semi-dry pressing (250 kg/cm^2) and fired at 700, 800, 900, 1000, and 1100°C. This study found that the increase of $CaCO_3$ content in the soil will decrease the firing temperature, compressive strength and bulk density, whereas it increases linear shrinkage, apparent porosity and water absorption. Merza (2005), studied the Manufacture of brick tiles from local raw materials, N & NE Iraq. The study was established to investigate the visibility of using many types of local raw materials in Kurdistan for brick manufacture. In his study, fourteen types of clayey soil were selected from different localities in the region. The grain size analysis indicates the suitability of using raw materials from some localities in the studied area for manufacturing the perforated bricks, and others for roofing tiles and some others for thin wall product. Semi-dry method of forming eighty-four tiles under load $78 kN/mm^2$ 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 clay bricks. In general, referring to all properties after firing it can be concluded that the most suitable samples for brick manufacture are samples returned to Fatha, Gercus and Red beds formations and the best firing temperature is 950°C. Mauloud (2006), studied the effect of additives, sand and filler (limestone's powder) in order to improve engineering requirements (strength and durability) of local burned mud bricks in Arbil City. Soil was mixed by weight with additives (0.0, 2.5, 5.0, 7.5, 10.0, 12.5, and 15%). Test results indicated that maximum dry strength was found at 8% additives content, while maximum wet strength and minimum absorption were revealed at 3% additives content. Surface hairline cracks decreased especially at about 12.5% additives content. Mauloud (2007), investigated the engineering behavior of clay bricks stabilized with straw, and checked the visibility of using straw as soil stabilizer for brick fabrication. Soil was mixed with straw additive (0.5, 1.0, 1.5, 2.0, 2.5, 3.0, and 3.5) % by weight. Burned bricks were tested and compared with the local clay brick products in Arbil City. Test results indicated that straw stabilizer could improve soil bricks; maximum dry and wet compressive strength, minimum hairline cracks and minimum water absorption were found at 1% by weight straw content. While maximum modulus of rupture was found at 0.5% straw content.

Johari et al. (2010) investigated the effect of the change of firing temperature on microstructure and physical properties of clay bricks from Beruas (Malaysia). The firing temperatures were set from 800ºC to 1250ºC and soaking time was fixed for an hour. The effects of firing temperature on the phase changes, microstructure, compressive strength, water absorption and porosity of the bricks were investigated. They found that the optimum firing temperature was 1200ºC. Mauloud, et al (2010), attempted to find the best method to control shrinkage cracks for the green (freshly molded) bricks. This study was conducted to evaluate the engineering observation applied to find effects of different sand content (0, 10, 12.5, 15, 17.5) % and different drying methods to control develop of cracks during air drying. Results showed that the best method to control air-drying shrinkage cracks of green brick products was drying in closed room and on the ground surface with prim coating condition, and the optimum sand content for Koritan soil was l5%.

Moutou et al. (2011), studied the effect of the mineralogical and chemical composition and the technological properties of the raw material used by craftsmen of Loutete, locality in the south of Congo republic, for manufacturing fired bricks. X-ray Diffraction, IR spectroscopy, ATD, ATG and AEG were used in this study. Atterberg limits and particle size distribution were measured also. Linear shrinkage, water absorption, porosity, apparent density and flexural strength of different bodies at temperatures from 800 to 1150ºC were calculated. The Winkler diagram and clay workability chart allowed considering this material convenient for roof tiles manufacturing. Firing process in brick manufacturing could affect the physical and mechanical properties of fired clay bricks colors and appearance of the brick.

The main purpose of Kadir and Mohajerani (2013), study was to evaluate the effect of different heating rates on the physical and mechanical properties during the firing of standard bricks and bricks incorporated with cigarette butt (CB). Two different heating rates were used: slow heating rate (2°C min-l) and fast heating rate (5°C min-1).Samples were fired in solid forms from room temperature to 1050°C. All bricks were tested for their physical and mechanical properties including compressive strength, initial rate of absorption and density. Higher heating rates decreased compressive strength value but slightly increased the initial rate of absorption and density properties respectively. Mauloud (2015), investigated the control of cracks in brick manufacturing due to drying shrinkage of an expansive soil using different methods and filler additive. He showed the evaluation of the behavior of Koritan's expansive soil against the effects of various amounts (0, 7.5, 10.0, 12.5, and 15.0%) of limestone powder as filler. Natural and artificial drying methods for manufacturing of bricks were used to eliminate the developing of desiccation cracks during air-drying stage. He found that the limestone powder can successfully be added as a filler additive to Erbil's soil to reduce shrinkage cracks in the manufacture of brick. Also he found that the slow drying is a cautious way to avoid drying shrinkage damage.

The literature review reveals that there is a lack information about the effect of moisture content and molding pressure on the physical and mechanical properties of clay bricks. The main objective of this study is to determine the effect of moisture content and molding pressure on the physical and mechanical properties of clay bricks. In this study, twenty locations of Sulaimani province were selected to study their suitability as raw materials in the manufacturing of perforated clay bricks, that are used in building constructions. Physical tests; Atterberg limits, particle size distribution, linear shrinkage, and some chemical tests were used to check the suitability of these soil samples in manufacturing of clay bricks. Then the fired clay bricks were tested for; fired shrinkage, water absorption, dry density and uniaxial compressive strength so as to evaluate the effect of moisture content and molding pressure on physical and mechanical behavior of brick products.

2- Materials and Methods

2.1 - Sampling and Their Locations

20 soil samples were taken from different locations. The earth Google map in Figure (1) shows the locations of the obtained soil samples. The samples were collected either from a cliff (cutting) or by excavating the soil to a depth of 1.0 m by using hand auger. The geographic coordination of the soil samples were taken by using digital (GPS). Table (1) shows the GPS coordination (i.e. Latitude and Longitude) and the global elevation of the taken soil samples. Table (2) shows the geological description of the obtained samples and also shows the approximate estimated quantity of the borrow materials present in the site.

2.2- Laboratory Tests

Physical and chemical tests were conducted on the soil samples and the procedures of ASTM were followed for conducting physical tests; (a) Sieve analysis, (b) Hydrometer analysis, (c) Liquid Limit (LL), (d) Plastic Limits (PL), (e) Shrinkage Limit (SL), while chemical tests of (TSS %), & ($CaCO_3$%) were done according to British standards.

2.3- Brick Samples

Based on the test results of item 2.2, and using Winkler diagram (Figure 2), it was found that only samples from the locations Chami Hanjeera (C2) and Bakhan Village (Q2) are suitable for manufacturing of the vertically perforated clay bricks. For these two locations, thirty two brick samples of 50*50*25 mm were prepared for studying the following tests, after firing the molded samples at a temperature of 1000°C, linear shrinkage, water absorption, dry density, and compressive strength under the following effects:
The effect of molding water content (i.e. moisture content) of clay soils using the range of moisture contents of (0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.0) of plastic limit (PL) of the clay soils.
The effect of molding pressure of freshly molded clay bricks using the range of pressures (2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, and 10000 kN/m^2).

3- Results and Discussion

From the Winkler diagram (Figure 2), which depends on the texture of the samples only, all samples [except samples from Tasluja Mountain (C6), and Sadoobest Village (Q9)] are suitable for brick manufacture. Samples from Chami Hanjeera (C2), and Bakhan Village (Q2) are appeared in the portion (A), thus both samples are suitable for vertically perforated bricks. Most of other samples are appeared in the portion (D), which are suitable for thin –walled hollow bricks and blocks.
Figures (3 and 4) present the curves of particle size distribution for the investigated samples. Table (3) presents the results of the grain size analysis of the raw materials. The corresponding clay, silt and sand fractions were indicated according to the ASTM. The analyzed samples show a large variation in grain sizes. For example, the sand content ranges from 1.9 to 69.9%, silt content ranges from 22.3 to 59.3 %, and the clay content ranges from 7.8 to 71.5 %.
The Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI) and linear shrinkage were from 24.7 to 55.1, 13.18 to 38.72, 2.0 to 28.43 and 4.3 to 15.7, respectively, as shown in Table (4). From these results, soil samples can be classified between low plasticity to high plasticity. The results of the required chemical tests for soil samples are presented in Table (5). The chemical composition of all the soil samples indicated that the presence of $CaCO_3$, was from 9.32 to 29.6 % and the percentage of the total soluble salts (T.S.S.) is from 0.115% to 0.371%. According to the British Standard Classification, BS.3921:1985, concerning the amount of soluble salts in the clay bricks, from which all the samples can be classified as a low percentage content of the soluble salts.

3.1 Molding Moisture Content

No one of the researchers studied the effect of molding water content. For this purpose seven soil bricks were molded from soils of each location (C2 and Q2) at different moisture contents (0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.0) of their plastic limit. The moist soil samples were molded under a pressure of (4000 kN/m^2) and fired at a temperature of 1000°C. After firing, the tiles were tested for fired shrinkage, water absorption, dry density, and compressive strength, the results are shown in Figures (5 to 8) respectively. Stress –strain curves for the tested samples are shown in Figures (9, and 10). From these figures, it can be noticed that the best moisture content for molding is ranged (0.6 to 0.7) of their plastic limit. Also from the test results, it can be indicated that the density and compressive strength of the tiles are increased with increasing moisture content and the maximum value is within the moisture content of (0.6 to 0.7) of PL. Then increasing moisture content will cause to decrease the density and compressive strength of the tiles. The reason for this is the same as in the compaction test, that moisture content less than (0.6 to 0.7) PL will not be sufficient for lubricating of the particles on each other during molding. In the case of moisture content greater than (0.6 to 0.7) PL, the amount of water will be more than the voids between samples and the water will occupy the location of particles and will cause to decrease dry density and compressive strength of the tiles.

3.2 Molding pressure of the clay brick samples

In order to study the effect of molding pressure on physical and mechanical properties of clay bricks, nine freshly molded clay brick samples were prepared for each soil samples using different pressures (2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, and 10000 kN/m^2). These samples were prepared at the moisture content of 0.6 of their plastic limit and fired at a temperature of 1000°C. After firing, tiles were tested for water absorption, dry density, and dry compressive strength test and the results are shown in Figures (11 to 13), respectively. Stress-strain curves of the tested fired brick samples are shown in Figures (14, and 15). From these Figures, it can be obtained that the sufficient pressure for molding is about 6000 kN/m^2 (61.2 kg/cm^2) and greater than this pressure would not be very effective.

Generally the results of density and compressive strength of the tiles from Chami Hanjeera (C2) are greater than tiles from Bakhan Village (Q2) and vice versa for linear shrinkage and water absorption. This is due to the percentage of ($CaCO_3$) and plasticity of the soil samples. So increasing plasticity and percentage of carbonates decrease density and compressive strength, while increase firing shrinkage and water absorption of the tiles.

4. Conclusions

The effect of moisture content and molding pressure on the physical and mechanical properties of clay bricks were studied. From the study, the following conclusions can be drawn:

According to grain size analysis and by using Winkler Diagram, all samples (except C6 and Q9) are suitable for brick manufacture. Samples from the locations Chami Hanjeera (C2) and Bakhan Village (Q2) are suitable for vertically perforated bricks. Most of the bodies tend to fall within the field defined by Winkler for 'thin-wall hollow bricks'.

The optimum moisture content for molding during manufacturing clay bricks is within (0.6 to 0.7) of plastic limit of the used soils.

The sufficient applied pressure for molding samples during manufacturing of the clay bricks is about 6000 kN/m^2 (61.2 kg/cm^2). More than this pressure would not be effective.

Increasing percentage of Carbonates ($CaCO_3$) and plasticity of the raw decreases density and compressive strength whereas increases water absorption and firing shrinkage of the brick tiles.

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دراسة مواد أولية لتصنيع الطابوق الطيني المثقب
(في مناطق جمجمال وقرداغ في السليمانية / العراق)

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المستخلص :
لا توجد معلومات كافية حول تأثير الرطوبة والضغوط التي تستخدم أثناء الصب على الخصائص الفيزيائية والميكانيكية للطابوق الطيني . تم في هذا البحث دراسة تأثير نسبة الرطوبة والضغوط التي تستخدم أثناء صب عينات الطابوق في موقعين مختارين في محافظة السليمانية . وبعد حرق عينات من الطابوق المصبوب عند درجة حرارة (1000°C) ، تم التعرف على الخواص الفيزيائية والميكانيكية باستخدام الاختبارات التالية : الانكماش الحراري ، امتصاص الماء ، الكثافة الجافة وقوة الضغط ذو محورين . وتشير النتائج أن نسبة الرطوبة المثالية لحد اللدونة للمواد الخام أثناء صب وتصنيع الطابوق الطيني هي (0.6 – 0.7) . اضافة الى ذلك فقد وجد أن الضغط الكافي أثناء صب الطابوق الطيني هو 6 ميجا باسكال .

الكلمات المفتاحية : الطابوق المثقب عموديا ، الكثافة ، مقاومة الانضغاط ، وامتصاص المياه ، انكماش الحرارى ، جمجمال ، قرداغ .

Table (1) : GPS Coordinates of the soil samples.

Name of the Investigated Area	Geographic Name of the Site	Location No.	Elevation (m) A. S. L.	Latitude	Longitude
Chamchamal	Shiwasoory Sangaw	C1	558 m	35° 28' 38.1" N	44° 54' 27.4" E
	Chami Hanjeera	C2	554 m	35° 26' 29.4" N	44° 57 ' 06.8" E
	Qara-tamoor Valley	C3	566 m	35° 28' 21.6" N	44° 55' 29.6" E
	Gurgai Shiwasoor	C4	689 m	35° 33' 29.5" N	44° 51' 16.7" E
	Gurgai Shmmar	C5	745 m	35° 34' 19.7" N	44° 52' 10.0" E
	Tasluja Mountain	C6	946 m	35° 35' 21.1" N	45° 11' 54.8" E
	Gopala Area	C7	850 m	35° 38' 31.6" N	45° 02' 58.4" E
	Takya –I	C8	830 m	35° 36' 35.9" N	44° 56' 37.9" E
	Takya – II	C9	833 m	35° 36' 30.7" N	44° 56' 47.9" E
	Kani Shaitan	C10	876 m	35° 38' 41.0" N	45° 01' 20.3" E
Qaradagh	Qaradagh Town	Q1	873 m	35° 18' 50.1" N	45° 22' 59.6" E
	Bakhan Village	Q2	917 m	35° 21' 49.9" N	45° 25' 07.8" E
	Aliawa Village – I	Q3	901 m	35° 21' 48.7" N	45° 25' 24.0" E
	Aliawa Village– II	Q4	903 m	35° 21' 48.7" N	45° 25' 24.0" E
	Aliawa Village–III	Q5	745 m	35° 33' 29.5" N	44° 51' 16.7" E
	Tlazait Village	Q6	961 m	35° 21' 45.2" N	45° 27' 56.4" E
	Baranan Mountain	Q7	1106 m	35° 21' 43.1" N	45° 29' 12.7" E
	Gleni Village	Q8	875 m	35° 23' 28.3" N	45° 28' 22.1" E
	Sadoobest Village	Q9	817 m	35° 25' 22.1" N	45° 27' 44.2" E
	Tanjero River Valley	Q10	876 m	35° 38' 41.0" N	45° 01' 20.3" E

Table (2) : Approximate estimated volume of the borrow materials and geological visual description.

Name of the Investigated Area	Location No.	Estimated thickness (m)	Estimated covered area (m x m)	Estimated volume (Million m^3)	Geological Visual Description of the Soil Samples
Chamchamal	C1	4 m	600x500	1.2	Red to brown soil, which represents the recent sediments (Loam) of alluvial origin
	C2	20 m	1000x400	8	Recent sediments and forming a mixture of clay and silt (Loam)
	C3	4 m	1000x500	2	Brown soil
	C4	30 m	600x500	9	Recent sediments and forming a mixture of clay and silt (Loam)
	C5	10 m	300x400	1.2	Brown soil with white spots
	C6	15 m	200x500	1.5	Yellow soil composed of silt, clay, and fine sand, mostly friable. It is belong to Kolosh Formation (Paleocene)
	C7	2.5 m	1000x250	0.625	Brown soil with white spots
	C8	4 m	200x400	0.32	Clay and clay stone of Injana Formation, Which composed of the alternations of clay stones (red) and sand stones
	C9	4 m	250x500	0.5	Red clay layers of Injana Formation, sometimes sand stone beds (10cm thick) can be seen.
	C10	15 m	700x400	4.2	Yellow recent alluvial deposits with white spots
Qaradagh	Q1	5 m	100 x 300	0.15	Recent sediments (1 km west of the Qaradagh Town)
	Q2	10 m	300 x 100	0.3	Red clay stone with pebbles (Muqdadiya formation)
	Q3	30 m	800 x 500	12	Red clay stones with fine to medium sands (Injana Formation) / Quarry of Sirwan Factory for bricks
	Q4	20 m	1000 x 500	10	Mixture of Clay, silt, and sand (loam deposits)
	Q5	5 m	300 x 200	0.3	Recent alluvium deposits of sandy clay
	Q6	3 m	100 x 250	0.075	Red clay stone with fine sand (Fatha Formation)
	Q7	5 m	300 x 400	0.6	Red Clay stone with alteration of sandstone beds. (Gercus Formation)
	Q8	3 m	100 x 150	0.045	Yellowish gray Clay with silt and medium sands (Kolosh Formation)
	Q9	2 m	500 x 100	0.10	Recent soil of brown silty clay with organic materials
	Q10	3 m	500 x 200	0.3	Recent sediments with organic materials

Table (3) : Texture of the soil samples.

Name of the investigated Area	Geographic Name of the Site	Location Designation	Clay %	Silt %	Sand %	Gravel %
Chamchamal	Shiwasoory Sangaw	C1	42.8	43.2	14.0	0.0
	Chami Hanjeera	C2	30.8	49.3	19.9	0.0
	Qara-tamoor Valley	C3	38.5	42.8	18.7	0.0
	Gurgai Shiwasoor	C4	36.8	57.5	5.7	0.0
	Gurgai Shmmar	C5	38.8	59.3	1.9	0.0
	Tasluja Mountain	C6	7.8	22.3	69.9	0.0
	Gopala Area	C7	49.5	38.0	12.5	0.0
	Takya Valley –I	C8	38.0	51.1	10.9	0.0
	Takya Vallay – II	C9	45.0	40.5	14.5	0.0
	Kani Shaitan	C10	38.0	56.7	5.3	0.0
Qaradagh	Qaradagh Town	Q1	45.8	29.4	20.1	4.7
	Bakhan Village	Q2	31.5	50.8	10.7	7.0
	Aliawa Village – I	Q3	58.6	34.0	7.4	0.0
	Aliawa Village – II	Q4	61.0	32.7	6.3	0.0
	Aliawa Village – III	Q5	58.3	31.3	7.6	2.8
	Tlazait Village	Q6	51.7	45.6	2.7	0.0
	Baranan Mountain	Q7	39.5	46.7	13.8	0.0
	Gleni Village	Q8	21.5	33.2	40.5	4.8
	Sadoobest Village	Q9	71.5	23.6	4.9	0.0
	Tanjero River Valley	Q10	68.9	25.9	5.2	0.0

Table (4) Atterberg limits test results.

Name of the investigated Area	Location No.	Liquid Limit (LL) %	Plastic Limit (PL) %	Plasticity Index (PI) %	Shrinkage Limit (SL) %
Chamchamal	C1	29.5	16.75	12.75	7.2
	C2	24.7	18.93	5.77	4.3
	C3	26.85	13.18	13.67	6.7
	C4	25.35	15.74	9.61	5.4
	C5	38.65	19.53	19.12	8.18
	C6	39.6	35.72	3.88	7.06
	C7	38.2	20.49	17.71	10.87
	C8	35.75	26.18	9.57	7.77
	C9	31.0	20.99	10.01	6.79
	C10	52.0	27.38	24.62	14.28
Qaradagh	Q1	41.85	23.59	18.26	12.1
	Q2	44.2	29.0	15.2	10.3
	Q3	33.5	22.51	10.99	8.7
	Q4	42.65	18.92	23.73	12.5
	Q5	38.6	22.96	15.64	11.1
	Q6	29.8	19.73	10.07	7.2
	Q7	55.1	38.72	16.38	7.7
	Q8	38.8	36.80	2.0	7.4
	Q9	52.7	24.27	28.43	15.7
	Q10	43.2	30.09	13.11	12.5

Table (5) : Chemical tests for the soil samples.

Location No.	$CaCO_3$ %	Total Soluble Salts (TSS) (%)	Location No.	$CaCO_3$ %	Total Soluble Salts (TSS) (%)
C1	18.25	0.115	Q1	10.3	0.326
C2	12.2	0.135	Q2	29.6	0.34
C3	22.8	0.154	Q3	19.05	0.365
C4	26.3	0.205	Q4	21.6	0.332
C5	23.24	0.141	Q5	27.3	0.16
C6	16.76	0.16	Q6	19.05	0.179
C7	25.68	0.332	Q7	9.32	0.34
C8	10.6	0.192	Q8	19.01	0.371
C9	18.0	0.307	Q9	22.45	0.345
C10	25.5	0.122	Q10	11.67	0.352

Figure (1) : Earth Google map showing locations of the obtained samples.

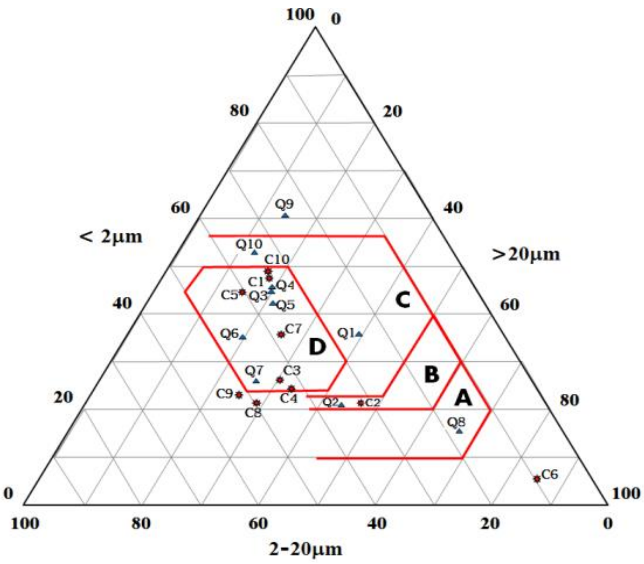

Figure (2) : Grain size classification of clay raw materials in Winkler's diagram.

Zone A "Common bricks (i.e. solid bricks)"
Zone B "Vertically perforated bricks"
Zone C "Roofing tiles and light blocks"
Zone D "Thin –Walled hollow bricks and blocks"

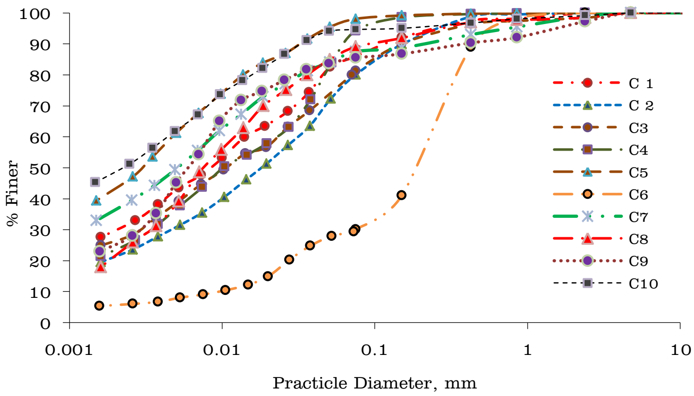

Figure (3) : Grain size distribution curves for soil samples from Chamchamal Area.

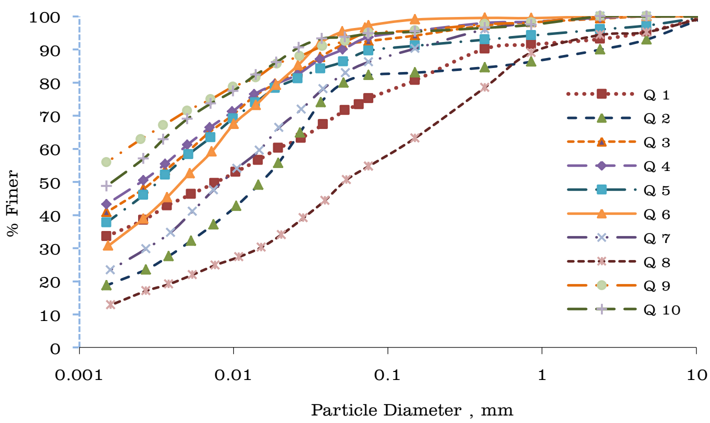

Figure (4) : Grain size distribution curves for soil samples from Qaradagh Area.

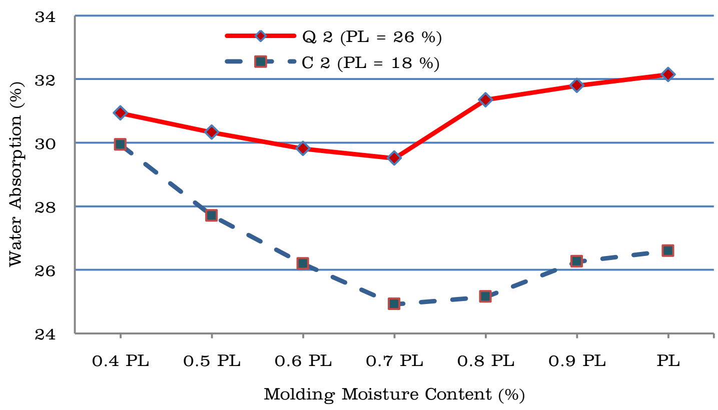

Figure (5) : Water absorption of the fired brick samples versus different molding moisture content.

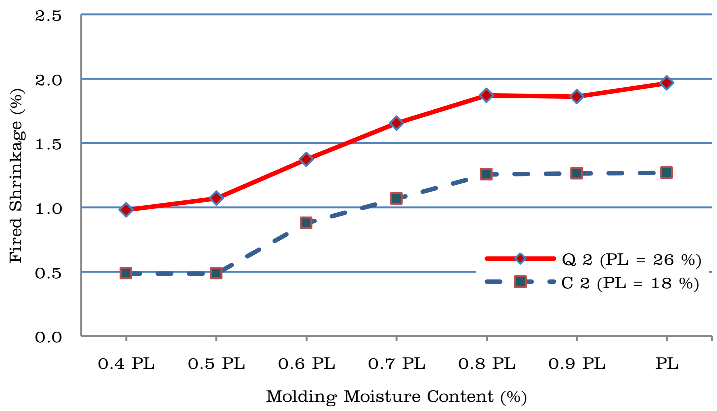

Figure (6) : Shrinkage of the fired brick samples versus different molding moisture content.

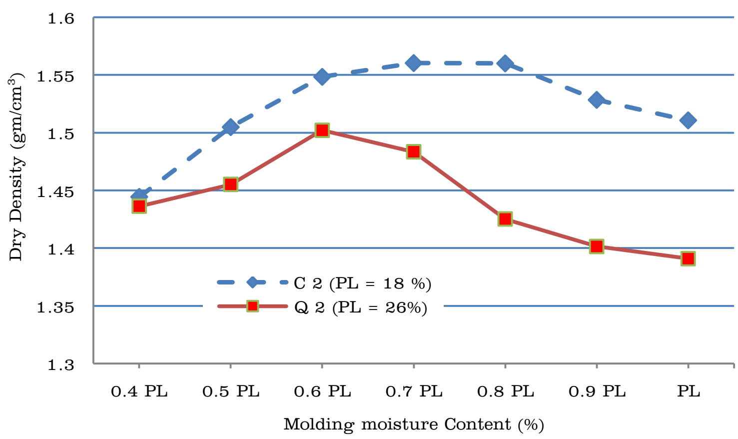

Figure (7) : Dry density of the fired brick samples versus molding moisture content.

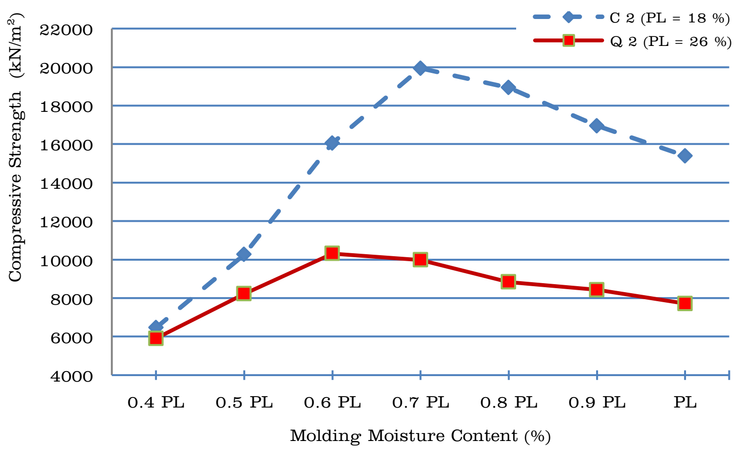

Figure (8) : Compressive strength of fired brick samples versus molding moisture content.

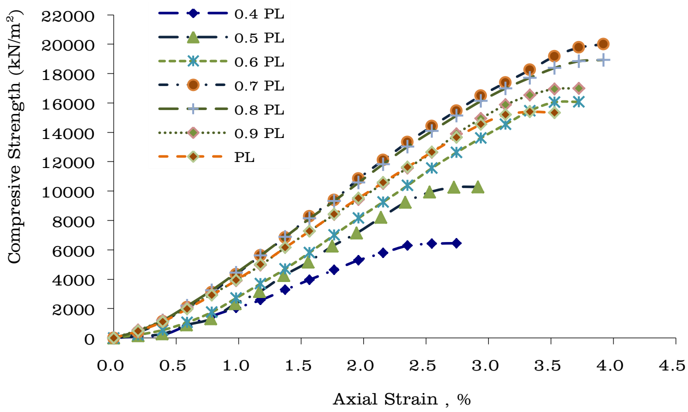

Figure (9) : Stress –strain relationship for fired brick samples (C2) molded at different moisture contents.

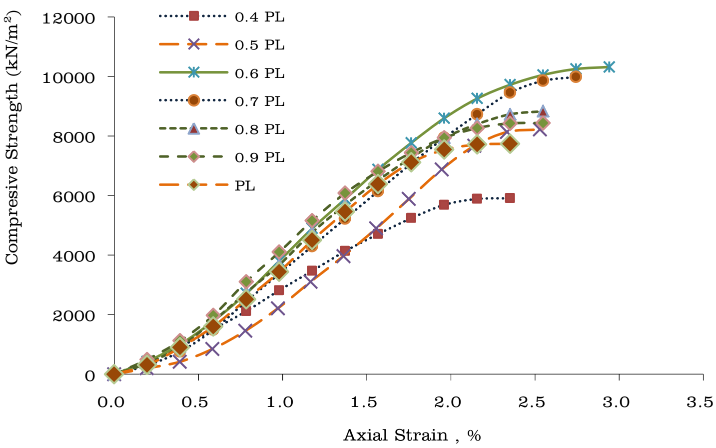

Figure (10) : Stress – strain relationship for fired brick samples (Q2) molded at different moisture contents.

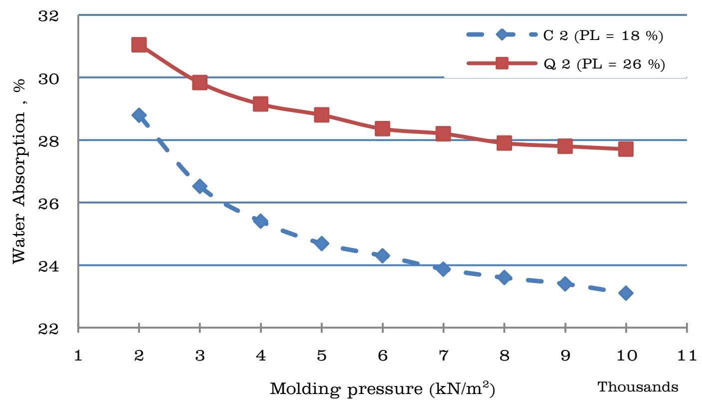

Figure (11) : Water absorption of the fired brick samples versus different molding pressures.

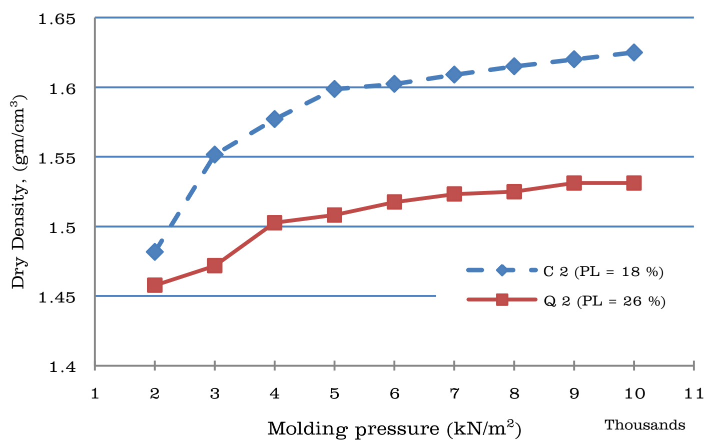

Figure (12) : Dry density of the fired brick samples versus different molding pressures.

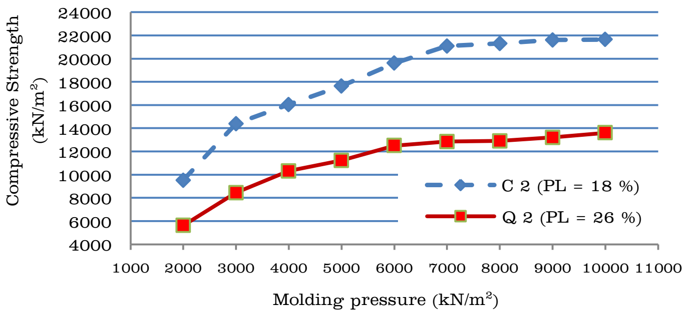

Figure (13) : Compressive strength of brick samples molding under different pressures.

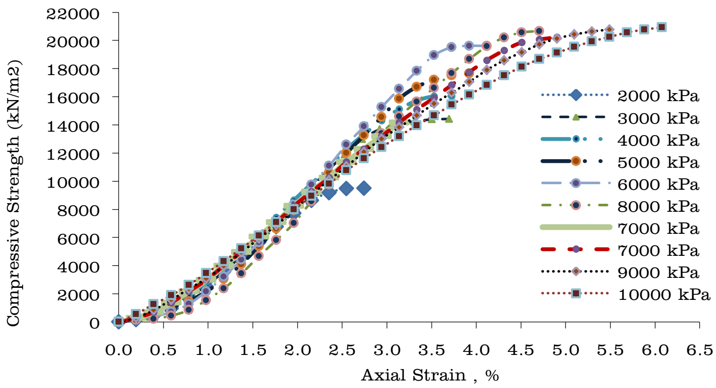

Figure (14) : Stress –strain relationship for fired bricks (C 2) molded under different pressures.

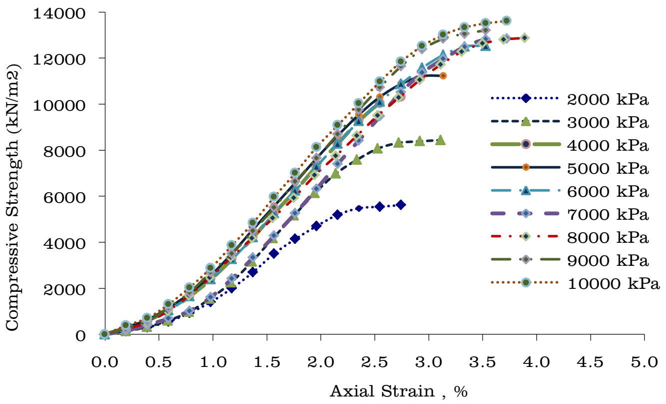

Figure (15) : Stress –strain relationship for fired bricks (Q 2) versus different molding pressures.