Journal of Geology and Mining Research Vol. 1(5) pp. 118-125 July, 2009
Available online http://www.academicjournals.org/jgmr

Full Length Research Paper

Mineralogical, geochemical and geotechnical evaluation of Al-Sowera soil for building bricks industry in Iraq

Salih Muhammad Awadh* and Hamed Hasan Abdallah

Earth Sciences Department, College of Science, University of Baghdad, Iraq.

Accepted 17 July, 2009

The raw material soil of Al-Swera factory quarry (quarry soil and mixture) which is used in the building brick industry were tested mineralogically, geochemically and geotechnically. Mineral components of soil are characterized by clay (Palygoriskite and chlorite) and non-clay minerals such as calcite, quratz, feldspar, gypsum and halite. The raw material was deficient in SiO_2, Al_2O_3, K_2O, Fe_2O_3 and MgO but rich in CaO. Loss on ignition (L.O.I.) and Na_2O are in suitable level and appear to be concordant with the standard. The quarry soil was characterized by high plasticity clayey soil of 30.49 plastic index; whereas, the mixture considered a clayey soil had a low plasticity of 7.7 plastic index. For improving the chemical and physical properties of the raw material, alumina-silicate minerals rich in K_2O, Fe_2O_3 and MgO are recommended as additive materials to the main mixture. Also grain size analyses showed that decreasing sand and clay and increasing the silt ratio in both quarry soil and mixture caused decreased strength of brick during molding and after firing. Plasticity index (P.I) value of quarry soil was 30.49 indicating high plastic clayey soil, whereas the plasticity index (P.I) value of the mixture was 7.7 indicating a clayey soil having low plasticity.

Key words: Geochemistry, liquid limit, plastic limit, raw materials, building bricks.

INTRODUCTION

Humans have been using bricks since thousand years for building houses. The quality of bricks depends on the materials they are made from. Specific soils have a distinct geo-chemical property which makes them suitable as raw materials for industrial bricks. Clay burnt with fire to make mud bricks is the best for dry and wet climates. The unflamable material and relative low cost of mud bricks make them preferable.

Many authors have studied soils that may be used in mud brick industry in different localities of Iraq. Some of these authors are Al-Helali (1980) who studied some geo-chemical and physical properties of clay in Diala area and found high concentration of some heavy elements. Al-Nuaaimy (1982) pointed to the suitability of Al-Nahrawan soil in the mud brick industry. The important study in this topic was done later by Al-Bassam (2004), who classified the physical and chemical properties of raw materials in the bricks industry and this has resulted to a whole review of the brick topic. Al- Qazaz et al. (2005) re-evaluated the Al- Sowera soil reserve and estimated a 3.6 million m^3 of soil suitable for the manufacture of bricks; also they mentioned that the soil was formed mineralogically from carbonates, quarts, feldspar, montmorillonite, palygorskite and kaolinite.

Brick clays and loams can be formed either autochthonously or (more frequently) allochthonously. Autochthonous clays are residual or *in-situ* deposits. The residual type forms by weathering, hydrothermal decomposition, soil formation or alteration and the dissolution or selective removal of the original coarse components while the *in-situ* type is clay formed by weathering or hydrothermal decomposition, soil formation or alteration or growth in salt and fresh water. Allochthonous is a sedimentary clay and loam (lacustrine, fluviatile, brackish, marine, aeolian and glacial) (Lorens and Gwosdz, 2003).

This work was carried out on allochthonous soil of Al-Sowera brick factory which is located at about 17 km southwest of Al-Sowera city (Figure 1). The study area is part of the Mesopotamian plain which comprises of fluviatile flood and erolain silts as unconsolidated sediments.

*Corresponding author. E-mail: Salihauad2000@yahoo.com.

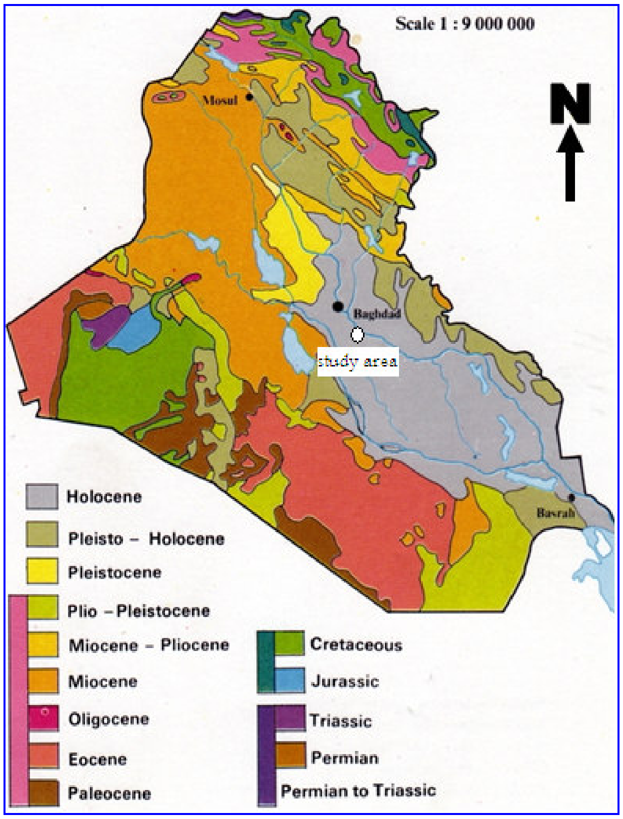

Figure 1. The geological map of Iraq shows location of the study area. (After The State Company of Geological Survey and Mining).

The natural processes forming the Mesopotamian plain have been modified by human activities for several thousand years. Many artificial irrigation cannels have behaved as rivers eroding the original sedimentary cover of the plain. (Jassim and Goff, 2006). Loam, a mixture of clayey silts and silty clays are dominant. Generally, alluvial sediments of quaternary cover the study area. These deposits formed from a mixture of sand, silt and clay as sequence beds have varieties of thickness. The upper part of these sediments is mostly silt. The water table level appears at 4 m depth. Because of increasing population and the high demand for and in the building materials industry especially in the last decade, the authors were encouraged hence the achievement of this work.

The objectives of this work are to evaluate the mineralogical, geochemical and geotechnical properties of soil that was collected from the quarry which was previously and recently still used in the brick industry; also this work seeks to further contribute to the construction materials subject.

MATERIALS AND METHODS

The field work was done with the purpose of collecting samples and investigating the exposures of industrial clay. Samples of three selected sites of the quarry and mixture (that had been prepared for use in bricks industry in the Al-Sowara factory) were collected. Mineral content was calculated as shown in Table 1 based on the chemical composition as well as the molecular proportion of each mineral. Clay minerals were separated from samples. Clay minerals separation procedures of Carver (1970) and Folk (1974) were applied in the geochemical laboratory of the University of Baghdad: whereas the non-clay minerals were identified under a polarized microscope. The X.R.D technique was used for identifying clay minerals in whole samples (Figure 2). Also clay minerals were quantitatively computed as shown in Table 2. The chemical analyses of SiO_2, Al_2O_3, CaO, MgO, K_2O, Na_2O, SO_3 and L.O.I. (Table 3) were done in the Ministry of Science and Technology, Center of Chemical Research. SO_3 is part lost on ignition, but it was calculated separately in order to correlate with Gypsum.

The geotechnical tests (liquid and plastic limits) and hydrometer analyses (Table 4) were done at the Civil Engineering Department, College of Engineering, University of Baghdad.

RESULTS

Mineralogy

The mineral content of the soil collected from the quarry appear to be formed from calcite and clay minerals with little quantities of quartz and traces of feldspar (Figure 2); gypsum was also identified by polarized microscope, but it was not detected by XRD due to its low concentration in sample 1S (Table 1). Chlorite and palygorskite are the main dominated clay minerals. The ratio of chlorite/palygorskite was approximately 4:1. The clay minerals content are summarized in Table 2

Geochemistry

The results of average chemical analyses of the soil were compared with the results of Qaduri (1999) and Al-Bassam (2004) (Table 3). Silica, MgO and Fe_2O_3 concentrations of the mixture appear to be less than those of Qaduri (1999) and Al-Bassam (2004). The amount of alumina is also less and out of range with Al-Bassam (2004), but within range in comparison with Qaduri (1999). All these variations may be attributed to a relation in decreasing clay minerals that involves SiO_2, Al_2O_3, MgO, Fe_2O_3, K_2O and CaO.

Calcium oxide appears to be of higher range in both Qaduri (1990) and Al-Bassam (2004). This is attributed to the presence of calcite as well as palygorskite which have CaO in their structure as a major component; also SO_3 seems to be less than the minimum limit because of the decreasing gypsum content in the quarry soil. Loss on ignition (CO_2 and H_2O) appears to be within range (Table 3).

The differences in chemical results between quarry sites and mixture were attributed to heterogeneity of on-site mixing.

Geotechnical properties

The geotechnical properties of soil in the study area (The

Table 1. Mineral content (%) of quarry soil.

Sample	Halite%	Calcite%	Clay minerals%	Quartz%	Gypsum%	Feldspar%
1S	1.2	19.6	66	7.5	0.3	2
2S	2.0	17.3	72	6.5	0.5	1.5
3S	0.9	20	75	4.1	0.6	3
Average	1.4	19	71	6	0.46	2.2
1H	1.9	16.9	67.5	9.5	1.1	2.7
2H	2.0	17.5	69	8.0	0.6	2.9
3H	3.7	20.5	61	12.2	0.8	1.1
Average	2.5	18.3	65.8	10	0.83	2.2
1R	2.3	11.4	79	4.1	1.9	0.8
2R	1.5	16.7	64	12.5	1.5	3.3
3R	0.5	17.0	65	13.0	1.0	2.7
Average	1.4	15	69	9.9	1.5	2.3

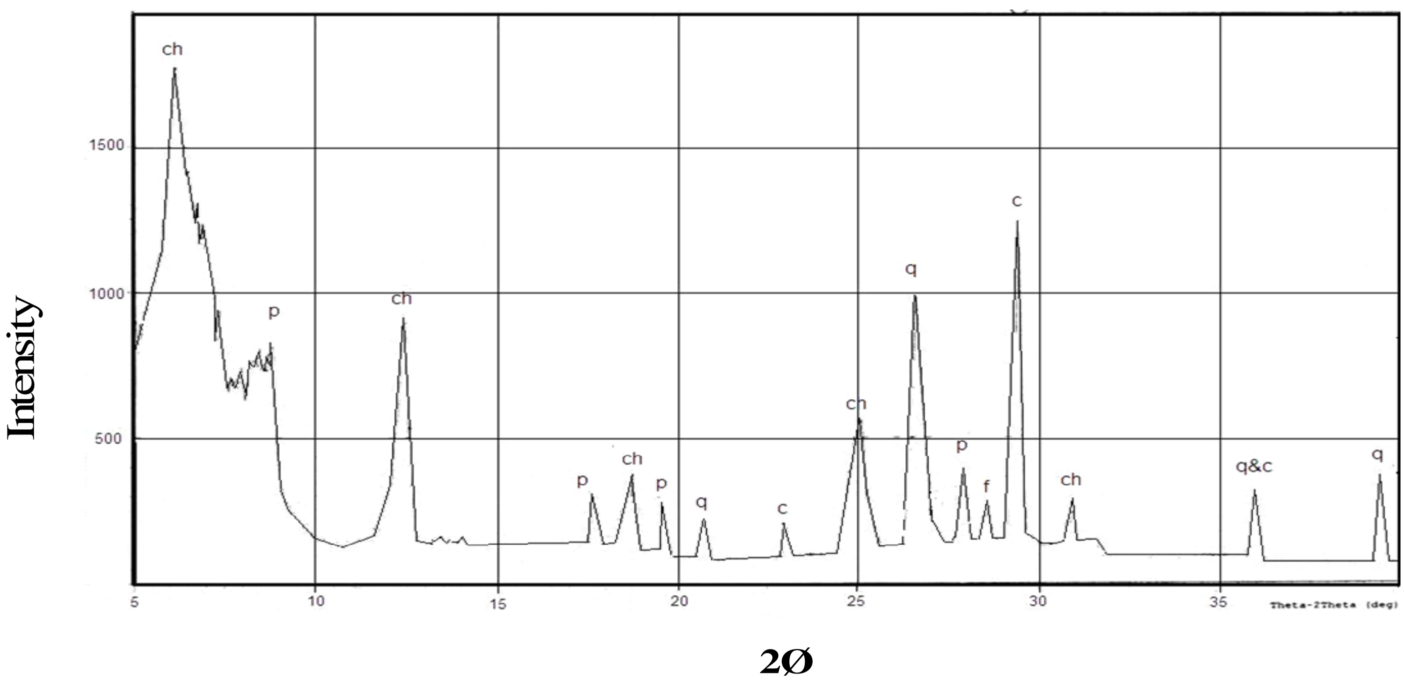

Figure 2. XRD difractograph shows the mineral content in sample 1S. Measure condition is: target Cu kα; Wave 1.5406 A; voltage 40 kv; current 30 A; speed 5°/min. ch = chlorite, p = palygorskite; q = quartz, f = feldspar, c = calcite.

Table 2. Clay minerals content (%) of the quarry soil.

Sample	Chlorite (%)	Palygorskite (%)
1S	16.5	48.5
2S	18	54
3S	18.75	56.25
1H	16.8	50.6
2H	17.25	51.75
3H	15.25	45.75
1R	19.75	59.25
2R	16	48
3R	16.25	48.75

quarry and the mixture soils) were tested; thereafter, they were evaluated for suitability in the building brick industry. This evaluation normally requires many laboratory tests such as, as follows:

Grain size analyses: Sieve analyses of soil were not used because this method is much suitable for engineering purposes (Bowles, 1984). In addition, this method is not effective enough in recognizing soil components especially those that can pass through a 200 mesh-sized sieve (less than 75 micron of grain size). This is due to two reasons; first is the difficult process; and the second is the

Table 3. Results of chemical analyses of both quarry soil and mixture compared with the results of authors. Note: SO_3 had been calculated separately, then it has been subtracted from total loss on ignition.

Oxides	Razuqi (1980) (%)	Qaduri (1999) (%)	Al-Bassam (2004) (%) (at 950℃)	Al-Qazaz et al. (2005) %	The quarry (%)				Mixture (%)
					Site-1	Site-2	Site-3	Av.	
SiO_2	40.14 - 48.34	35 - 45	38 - 40	40.4	26.6	24.9	28	26.5	27
Al_2O_3	10.9 - 20.4	5-12	10.5 - 11	10.38	8.2	7.2	7.1	7.5	6.9
CaO	11.29 - 23.99	Max 20	15 - 16	17.08	11.55	25.14	25.0	20.6	21.25
MgO	0.20 - 5.7	Max 10	4 - 6	6.0	5.3	3.6	6.7	5.1	3.18
K_2O		1 - 6		1.27	0.57	0.58	0.54	0.57	1.0
Fe_2O_3	2.08 - 8.6	4 - 8	3-4	6.08	3.9	3.5	3.2	3.4	3.3
SO_3	0.06 - 3.4	1.0		0.65	0.8	1.3	0.9	1.0	0.7
Na_2O		1.2		1.54	0.29	0.62	0.56	0.52	0.42
L.O.I	16.2 - 18.24 at 1000℃		16 - 18	17	20.8	16.5	21.0	19.8	17.9

Table 4. Grain size analyses of quarry and mixture soil.

Quarry		Mixture	
Diameter (mm)	Cumulative ratio	Diameter (mm)	Cumulative ratio
0.297	100	0.297	100
0.149	99.69	0.149	99.1
0.075	96.426	0.075	93.7
0.05887	93.16533333	0.061113143	91.752676
0.041628	93.16533333	0.044342068	75.9332491
0.029435	91.4	0.032286157	56.9499368
0.020925	90.05982222	0.023364518	41.1305099
0.013183	84.62517778	0.016632972	34.0594414
0.007821	76.08502222	0.008722411	25.311083
0.001217	26.39684444	0.001296563	14.6

Table 5. Percentage of grain size for quarry and mixture samples compared with Al-Hamadani (2002).

Soil component	Size (micron)	(%) Ratio in quarry samples	(%) Ratio in mixture samples	Al-Hamdani (2002)
Sand	>20	3.5	6.5	25
Silt	2 - 20	70	68	35
Clay	<20	26.5	25.5	40

cohesive soil. Hydrometer analyses were carried out on both quarry and mixture soils. a perfect description of the hydrometer analyses is shown in Table 4.

The detailed grain size distribution illustrated in Figure 3 shows that the quarry soil has sand not exceeding 3.5%, while silt and clay are 70 and 26.5% respectively (Table 5). Percentage sand in the mixture sample appears to be 6.5; silt, 68%; while the clay is 25.5% (Table 5).

However, increased silt content causes decreasing brick strength before and after firing (Hussain and Zinal, 1985).

Consistency limit: Generally, water content (moisture) affects soil especially clayey soil. Two characteristics were tested in order to understand the consistency limit; these are liquid limit and plastic limit:

a.) Liquid limit: It is the moisture content expressed as a percentage by weight of the oven dried soil at which the soil just begins to flow when jarred slightly (Grim, 1962). The liquid limit is that water content which can easily be read from the x axis against 25 below on the axis. Therefore, the flow curve of the liquid limit is illustrated in Figure 4. This curve shows the liquid limit of quarry sam-

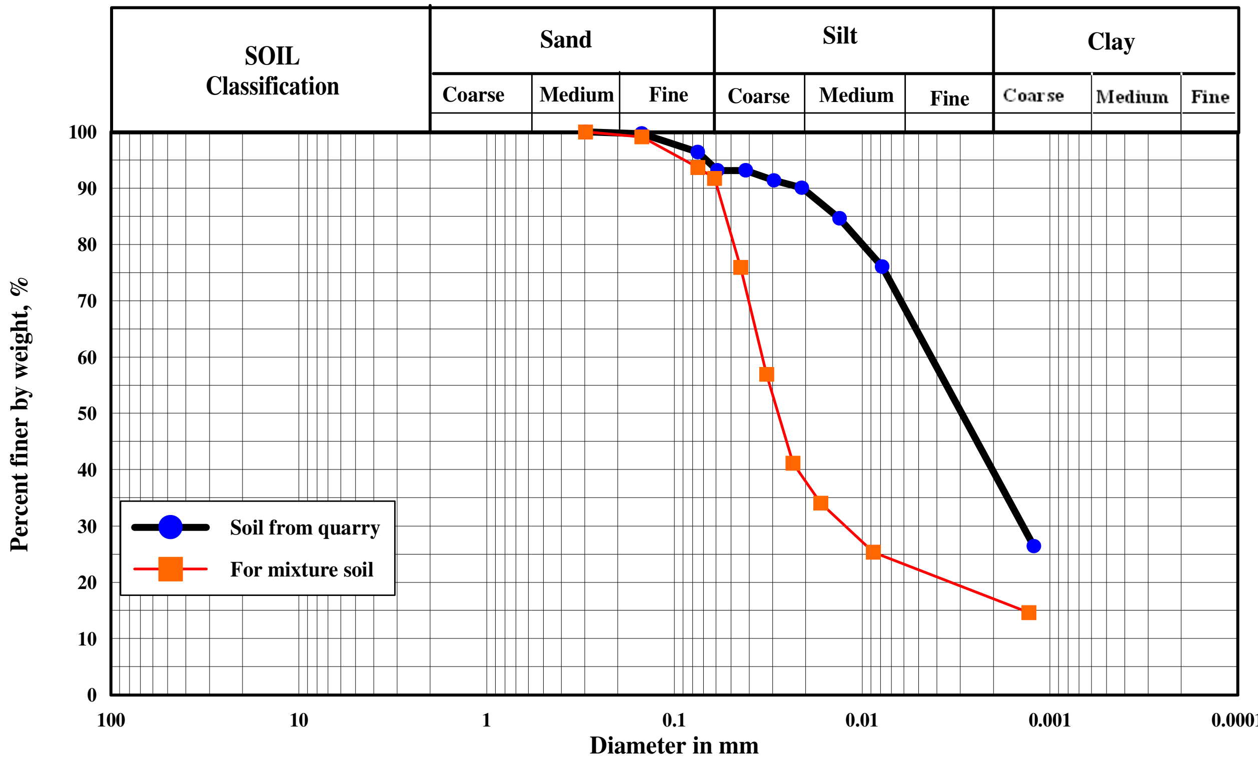

Figure 3. Grain size distribution for quarry and mixture samples.

ple and mixture as 56.5 and 27.4% respectively (Figures 4a and b).

b.) Plastic limit: It is the lowest moisture content expressed as a percentage by weight of the oven dried soil at which the soil can be rolled into threads of 3 mm in diameter without breaking into pieces. This test can be done via rolling the spherical piece of soil on a glassy plate (Ali et al., 1990). The laboratory tests determined the plastic limit of the quarry soil as 26.01and 19.7 for the mixture.

Soil classification

Plasticity index (P.I) was used to classify both soils taken from the quarry and mixture whether they were suitable for the bricks industry or not. Plasticity index (P.I) is the difference between liquid and plastic limits (Grim, 1962). Also it is the range of moisture content at which a soil becomes plastic. When the plastic limit is equal to or greater than the liquid limit, the plasticity index will be recorded as zero. Accordingly, the plastic index is described by the following equation:

P.I = L.L - P.L

Where: P.I = Plasticity index; L.L= liquid limit; P.L= plastic limit.

$P.I_{(quarry)}$ = 56.5 - 26.01
$P.I_{(quarry)}$ = 30.49
$P.I_{(mixture)}$ = 27.4 - 19.7
$P.I_{(mixture)}$ = 7.7

Plasticity index (P.I) values were plotted on the plasticity discriminative curve (Figure 5). The results showed that the quarry soil appears to be a high plastic clayey soil; whereas the mixture is a clayey soil having low plasticity.

Specific gravity

It is the ratio between density of the soil and density of water at 4℃ (Poland, 1984). By the laboratory test, the specific gravity of the quarry soil was found to be 2.82 and 2.7 for the mixture. These values tend to be fit with standard values as shown in Table 6.

DISCUSSION AND CONCLUSION

The quality of bricks depends on the constituents of the raw materials and the technique used for manufacturing. On this basis, mineralogical content and chemical composition play essential roles in determining the quality of brick. The high amount of gypsum in mixture soil causes hydration under wet conditions. Also, the high amount of gypsum during the firing process will lose the SO_3 and H_2O

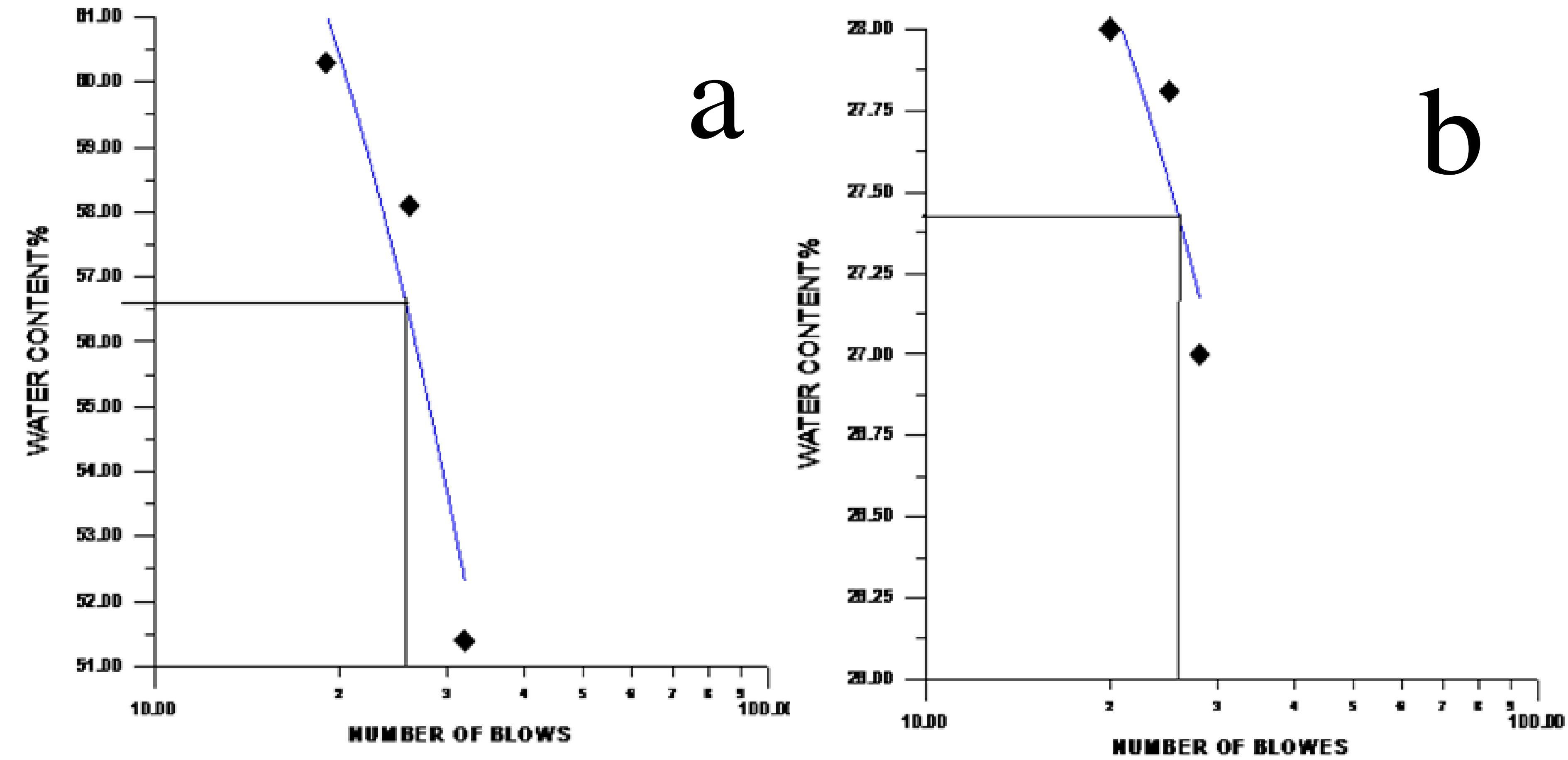

Figure 4. The flow curve of liquid limit for the quarry samples (a); and the mixture (b).

leaving bubbles which will surely generate stress thus making the bricks weak. Gypsum content in the study area is not high (Table 1); therefore, the released SO_3 is lower than the standard. On this basis, gypsum content appears to be suitable for the building bricks industry. The presence of feldspar is very useful, because it is a fusion material, so it helps in decreasing the needed temperature. The fluctuated low percentage of feldspar in Al-Sowera soil (Table 1) makes bricks less durable and less strengthened and is thus considered a negative agent for the bricks industry; therefore a high temperature, in this case will be needed. The presence of quartz in the soil used in the bricks industry participates in decreasing the weight (Al-Bassam, 2004). In the study area, the amount of quartz appears to be slightly effective. At high temperatures, quartz reacts with CaO and Al_2O_3 form-

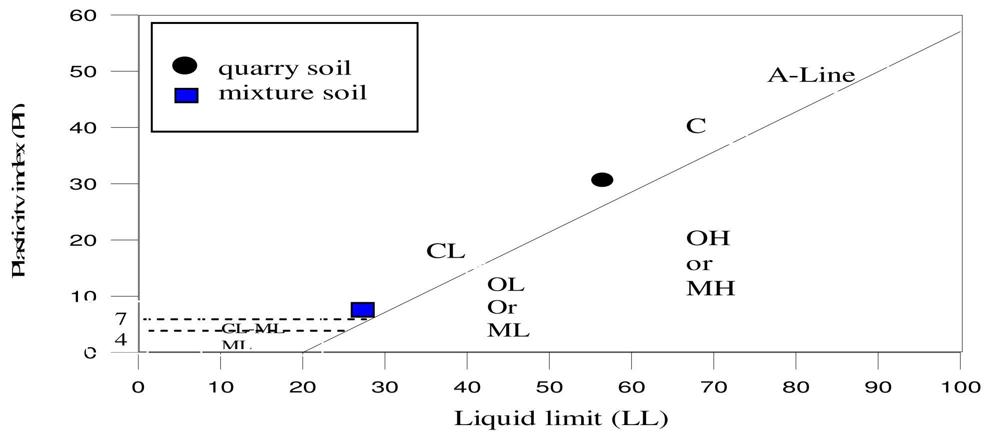

Figure 5. Plasticity discriminative curve shows the nature of plasticity index nature of the quarry and mixture soils. C: clay, M: silt, O: organic, H: high plasticity, L: low plasticity (According to Unified Soil Classification System).

Table 6. Standard specific gravity values of different type of soil (after Wilun and Starzewski (1975) in Djoenaidi (1985)).

Type of soil			Specific gravity
Cohesionless		Coarse and medium sand	2.65
	Inorganic	Fine sand	2.65
	Organic	Sand	2.64
Cohesive		Sandy silt	2.66
		Silt	2.67
		Silt	2.70
		Clayey sand	2.67
		Clayey sandy silt	2.67
	Inorganic	Clayey silt	2.68
		Sand - clay	2.68
		Sand - silt - clay	2.69
		Silt - clay	2.71
		Sandy - clay	2.70
		Silt clay	2.75
		Lean clay	2.75
		Clay	2.80

ing Ca, Al, Silicates; in such a case, the free CaO will be reduced thus avoiding cracks. Carbonates content in the raw materials is a very essential component to form bricks, but in a limited percentage not exceeding 40% (Al-Qazaz, 2005). If the amount of $CaCO_3$ is increased over 40%, the bricks will swell because of the effect of CO_2. During the firing processes, of course, CO_2 is released leaving CaO which has a high ability of absorbing atmospheric moisture, especially during rainfall. This mechanism eventually causes swelling (Grim, 1962). The soil of Al-Sowera quarry appears to have a slightly high content of CaO coming from calcite, clay minerals and gypsum.

The high content of calcite enlarges the brick volume causing troubles during firing process. Lorenz and Gwosdz (2003) mentioned that the 20% calcite in marly clay is suitable for manufacturing bricks. The average calcite in the studied soil is lower than 20%; therefore calcite content seems within standard. Polygorskite and spiolite did not swell because of their fibrous shape. Eventually, the concentration of SiO_2, Al_2O_3, K_2O, Fe_2O_3 and MgO appear to be less than that of required optimal limit. Silt ratio in both quarry and mixture appear to be high, whereas sand and clay is low (Table 5). Increasing silt causes Decreased brick strength before and after firing (Hussain and Zinal, 1985). The results show that the quarry soil appears to be a high plastic clayey soil; whereas the mixture is a clayey soil having low plasticity. Based on the results of evaluation, the soil of Al-sowera quarry should be mixed as possible as with soil from other places rich in fibrous clay minerals to substitute for its deficiency in SiO_2, Al_2O_3, K_2O, Fe_2O_3 and MgO.

Accordingly, future studies of the fluviatile facies surrounding the Al-Sowera area within the Mesopotamia plain is recommended to find an integral raw material that will act as a standby additive material which will add to the main mixture known ratios when necessary.

REFERENCES

Al-Bassam KS (2004). Division of the physical and chemical properties of the raw materials used in building brick industry. The state of geological survey and mining. Internal report. Iraq. Baghdad (Arabic).

Al-Hamadani FF (2002). The problem of mud brick industry and the proposal treatment to prevent this problem, ministry of industry and minerals, Building Research center (Arabic), p17.

Al-Helali MA (1980). Study of some geochemical and physical properties of Baladrose clay-Diala area. Unpublished M.Sc. Baghdad University. 151 p (Arabic).

Ali MH, Hijab BR, AL-Jahsar SH (1990).Engineering geology ,Dar Al-kutb for publication, Al-mousel university(Arabic), p 576 .

Al-Nuaaimy MM (1982). Suitability for brick industry In Al-Nahrawan area. The state of geological survey and mining. Internal report. Iraq. Baghdad (Arabic). p19.

Al-Qazaz D, Boles QM, Jabori WM, Noor ASh, (2005). Re-evaluation of the reserve soil that suitable for clay industry, Al-Sowera brick factory. The state company of geological survey and mining. Internal report (Arabic). p18.

Bowles JE, (1984). Physical and geotechnical properties of soil , second edition, McGraw- Hill international Book Company. p 578.

Carver RE (1971). Procedures in sedimentary petrology, Wiley – Inter Science, NY, p 653.

Djoenaidi WJ (1985). A compendium of soil properties and correlations, M.sc.Thesis, school of civil and mining engineering, university of Sydney, p 307.

Folk RL (1974). Petrology of Sedimentary Rocks, Hemphill Texas, p 182.

Grim RE (1962). Applied Clay Mineralogy. International series in the earth planetary sciences. McGraw-Hill Book Company, Inc. London. p 422.

Hussain TK, Zinal YM (1985). Primary raw materials requirement for building, Ministry of planning and Development Corporation, the central organization for standardization and quality control (Arabic), p 27.

Jassim SZ, Goff JC (2006). Geology of Iraq. Dolin. Praque and Moravian Meseum, Prno, Czech Repblic. p 241.

Lorenz W, Gwosdz W (2003). Manual on the Geological-technical Assessment of Mineral Construction Materials. Manual, mineral resources, construction materials, assessment, technological properties, industrial minerals and rocks, classification, application. Schweizerbart-Germany. p 501

Poland JF (1984). Guidebook to Studies of Land Subsidence due to Groundwater withdrawal , v. 40 of UNESCO studies and Reports in Hydrology, Paris , France , United Nations Educational Scientific and cultural Organization , p 305.

Qaduri A, Razuqi H, Sultan A (1999).The brick industry, The need and its future in Iraq. The State of Geological Survey and Mining. Internal report. Baghdad (Arabic).

Razuqi WH (1980). Properties of construction materials. The State of Geological Survey and Mining. Internal report. Baghdad (Arabic).