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Industrial Assessment of Mineral Deposits of Zurbatiyah Area, Eastern Iraq

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ABSTRACT

The study deals with industrial assessment of deposits in Zurbatiyah area of eastern Iraq. The deposits are represented by limestone, marly limestone, gypsum and clay which belong to the Ibrahim, Serikagni, Dhiban, Jerbie, Fat'ha, Injana and Mukdadiya formations. These deposits are characterized by well extensions and thickness. These deposits were assessed for the cement, clay bricks and gypsum board industries; limestone wea fairly pure composed of calcite and trace amounts of quartz and dolomite. The chemical analyses of limestone showed its suitability for use in the OPC industry, it became more suitable when corrected materials containing alumina were added to be in agreement with the requirements of IQS, No. 5, 1984 for the cement industry. Gypsum has 45% SO_3 and 31% CaO, moreover, gypsum is nearly pure with low impurities. It is considered a good raw material for preparation of panel gypsum boards. the flextural strength of prepared gypsum panels is compatible with the requirements of ASTM C473-2016. Clay deposits are composed of kaolinite (30% - 35%) followed by palygorskite (20% - 28**%)** a minor amount of iIllite and a mixed layer montmorillonite –chlorite. Clay deposits have significant percentages of SiO_2, Al_2O_3, Na_2O, K_2O and moderate percent of CaO and Fe_2O_3 which qualifies them to be used in making clay building bricks of classes A and B according to the Iraqi standard specification No. 25, 1993 and British standard No.3921, 1985.

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التقييم الصناعي للرواسب المعدنية في منطقة زرباطية، شرق العراق

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الملخص

يتناول البحث الحالي تقييم صناعي للرواسب في زرباطية، شرق العراق والمتمثلة الحجر بالجيري والحجر الجيري المارلي والجبس والاطيان ذات الامتدادات والسماكات الجيدة ضمن تكاوين ابراهيم وسركاكني والذبان والجربيي والفتحة وانجانة والمقدادية لصناعة السمنت والطابوف الطيني والواح الجبس اظهرت النتائج ان الحجر الجيري والحجر الجيري المارلي ذات نقاوة جيدة ويتكون بصورة اساسية من الكالسايت مع نسب ضئيلة من الكوارتز والدولومايت. اظهرت التجارب ملائمة الحجر الجيري لصناعة الاسمنت البورتلندي بعد اجراء التعديلات المطلوبة على الخلطات والمعاملات الكيمياوية (عامل الاشباع الكلسي ونسبة السليكا ونسبة الالومينا) وكان أكثر ملائمة بعد اضافة الالومينا كمادة مصححة وكانت النتائج مطابقة لمتطلبات المواصفة العراقية رقم 5 لسنة 1984. صخور الجبس ذا نسبة عالية من SO_3 (45%) وCaO (31%) واعتبرت مادة جيدة لصناعة الواح الجبس. حضرت الواح الجبس وكانت مقاومة الانحناء للألواح الجبسية مطابقة لمتطلبات المواصفة الامريكية ASTM C473-2016. اما رواسب الاطيان فقد تكونت اساسا من الكاؤولينايت (30- 35 %) تلاها الباليكورسكايت (20-28%) مع كل من الالايت والمونتمورلونايت-كلورايت بنسب ضئيلة. شكلت الاكاسيد SiO_2, Al_2O_3, K_2O, Na_2O نسب جيدة من مكونات الرواسب الطينية مع وجود نسب متوسطة من CaO وFe_2O_3 بحيث أمكن تصنيع طابوق صنف A وصنف B من الرواسب الطينية وحسب متطلبات المواصفة العراقية رقم 25 لسنة 1993 والمواصفة البريطانية رقم 3921 لسنة 1985.

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Introduction

Zurbatiyah area is located, south east of Iraq about 80 km east of Wasit governorate and 18 km north-east of Badra city (Fig.1). The study area occupies more than 500 km^2 within latitude 33° 08′ 60″ -33° 23′ 57″ N and longitude 45° 53′ 05″ - 46° 12′ 09″ E.

The study area includes important and economic geological formations; Ibrahim, Serikagni, Dhiban, Jerbie, Fat'ha, Injana, and Mukdadiya which belong to (Oligocene - Miocene- Pliocene.) The formations are considered resources of some industrial rocks (limestone, gypsum, clay, sandstone, and gravel) that are widely exposed in the study area (Al-Khafaji and Al-Hadadi, 2021). There are very few previous studies on the study area because it was the war zone from 1980 until 1988, the first study conducted by Shadher et. al, (2009), about the geology of Wasit governorate including a preliminary study on the investigation of gypsum, field work was carried out by Al-khafaji et al, for the period 2016-2022. Stratigraphic study carried out by Al-luhaibi, (2018), followed by Al-Najjari, (2019), Al-Ali, (2020) and Al-Hadadi, (2021), they carried out their researches on mineralogy and geochemistry of the Zurbatiyah area from 2010 to 2021, as a part of their thesis, the detail geological survey was carried out by the staff of Iraqi GEOSERV for the period 2010-2015 (Mahmoud et al., 2018).

The aim of the present study is to detect the distribution of industrial rocks in the Zurbatityah area and study their suitability for the cement, gypsum panel, and clay building brick industries.

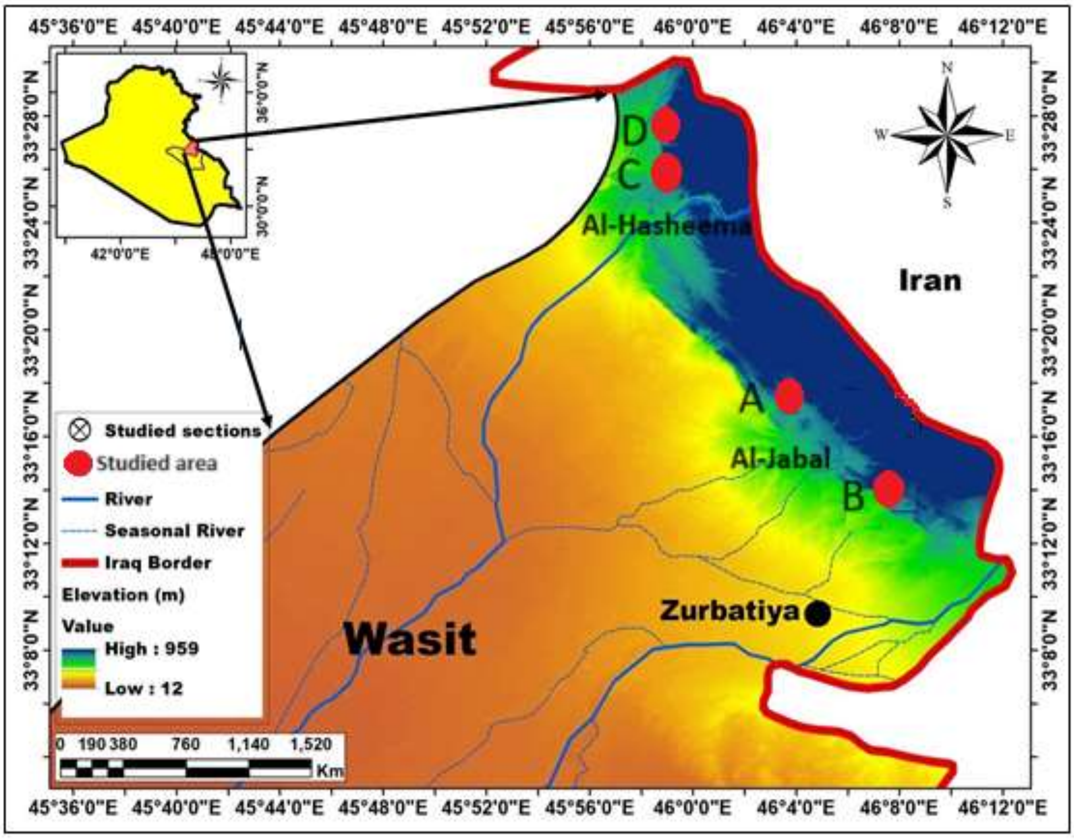

Fig. 1. Map of the studied area after (Al-Ali, 2020)

Structural setting

The study area is a part of Low Folded Zone of Zagros Thrust Belt it is located along the Iraqi-Iranian international borders. The area wsa affected by late regional tectonic movements which caused severe deformation (Fouad, 2012a).

Hemrin anticline: is a major asymmetrical fold in the study area with a trend NE-SE about 30 km in length and 1 to 7 km width, the NE limb of Hemrin anticline was thrust over the SW limb (Al-Shwaily and Al-Obaidi, 2019) (Fig. 2).

The other one is Kani Sakht anticline It is asymmetrical fold extended parallel to the eastern part of Hemrin anticline with a length about 30 km and 1.5 km in width, it has NW-SE trend (Al-Shwaily and Al-Obaidi, 2019). Koolic anticline is also an asymmetrical anticline extended about 20 km parallel to the Iraqi-Iranian international borders.

There is some thrust faults detected by Al-Shwaily and Al-Obaidi,2019, namely Kachaa, Cea koran and Koolic fault extended about 12km along the Iraqi-Iranian borders. (Fig. 2).

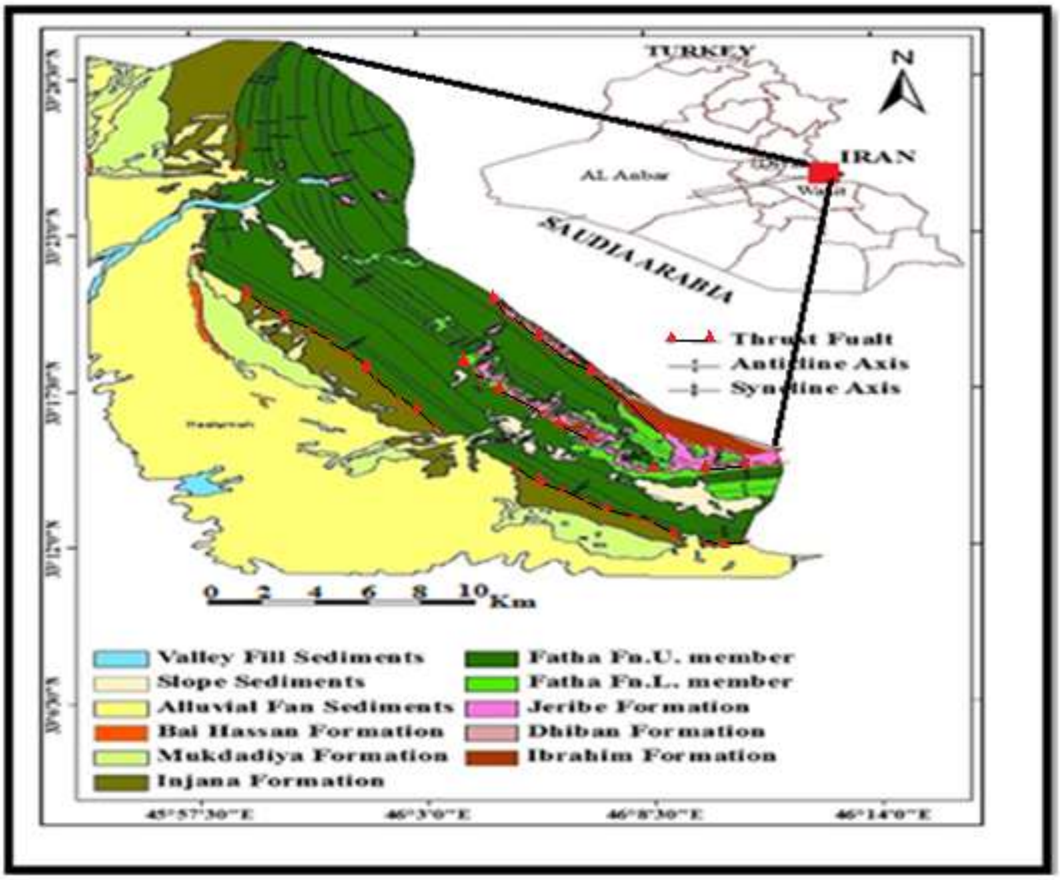

Fig. 2. The geological map of the study area after (Mahmoud et al., 2018)

Geology of study area

The study area is represented by wide range of exposures of some geological formations (Oligocene -Pliocene) described from older to younger, (Al-khafaji, and Al-Hadadi, 2021).

1-Ibrahim Formation (Oligocene)

It is exposed along the deep Sheraw valley in the eastern part of the area, it represents the oldest exposed rocks in the area (Plate 1-a).

The Formation consists of 30-50 m of more than twenty cycles of white to gray thickly bedded limestone alternated with gray marly limestone (plate 1-a). especially at the lower part of the formation.

The formation extended about 4-6km along Sheraw valley and was conformably overlayed by Serikagni Formation.

2-Serikagni Formation (Early Miocene)

It is exposed in some eastern part of the area at the deepest valleys; it consists of 15-20m of grey to white limestone and marly limestone, sometimes chalky and highly fractured, its extension about more than 4km, the formation is intertounged with upper Dhiban Formation in some locations Plate (1-b).

3-Dhiban Formation (Early Miocene)

It is exposed at the eastern part of the area and extended about more than 3km; it is consisting of about 30m of white to gray nodular and blocky gypsum and anhydrite, gray limestone beds are alternated with gypsum in some locations, the formation is overlaying by Jerbie Formation Plate (1-b).

4-Jerbie Formation (Lower-Middle Miocene)

The Formation have wide range of extension and high thickness (about 40m) of blocky tough darkish brown dolomitic limestone the overlaying Fat'ha Formation was detected at the appearance of thickly gypsum beds. (Field observations), whereas the lower contact was distinguished by massive gypsum of Dhiban formation (Al-Mashaikie and Mustafa, 2018) (Plate 1-c).

5- Fat'ha Formation (Middle Miocene)

The most widely exposed formation in the area; it is composed of more than 20 cycle red clay, green marl, limestone and blocky gypsum. Both lower and upper members are well exposed in the area. The upper member is thicker than lower; the total maximum thickness about 300m, gypsum is the thickest unit especially at the upper member. The cyclicity phenomenon of Fat'ha formation may be attributed to glcioeastatic sea- level changes cyclic processes Plate (1-d).

6-Injana Formation (upper-Miocene)

This Formation have widely exposed at the south-western part of Hemrin anticline. It is covered about 150km^2 at the study area, it is consisted of cyclic alternation of red silty clay to brown sandstone, the formation varies in thickness from 100m to 300m. Plate (1-e).

7-Mukdadiya Formation (Upper Miocene- Pliocene)

The Formation formed as a strip along the south –western limb of Hemrin anticline extended from Zurbatiyah to Badra city, it is consisted mainly of pebbly sandstone –brown claystone. The thickness ranges from 70-100m, the lower most part consist of pebbles and pebbly sandstone which represent the lower contact with Injana Formation.

8-Bai Hassan Formation (Pliocene-Pleistocene)

The Formation is exposed at some separated locations at the southern limb of Hemrin anticline, it occupies small areas about 50 km^2, it is consisting of thick conglomerate (2-3m). Followed by interbedding of gray sandstone and brown clay, there is angular unconformity between Bai Hassan and quaternary deposits.

9-Quaternary Deposits

It is composed mainly of alluvial fan deposits (Gravel, sand, and clay), and flood plain deposits.

Plate 1: a-Ibrahim Formation b- Serikagni and Dhiban Formation c-Jerbie Formation d- Fat'ha Formation e-Injana Formation

Methodology

Field work includes the description of lithology, extension and measured the thickness of the exposed formations whereas the laboratory works were conducted to assess the deposits as raw materials in terms of mineralogy, geochemistry and industrial evaluation.

Limestone, gypsum and clay deposits were subjected to test by XRD type broker D2 phaser in the Iraqi German laboratory, University of Baghdad, College of Science, Geology Department, scanning at (2θ) range from (5° - 60°), and chemically analyzed by XRF type Spectro-Xepos of Ametek Company at the same laboratory.

A representative limestone sample (average five samples) was assessed to prepare ordinary Portland cement (clinker) by mixed with clay in different proportions; The mixture was burned using firing program and then assessed mineralogically and chemically in the laboratory of Tehran university.

The pure blocky gypsum samples (average of five samples) of Fat'ha Formation were conducted to prepare gypsum panel composite and flexural tests were carried out at the laboratory of engineering College of Basrah University according to ASTM C473-2016.

A representative clay sample of both Fatha and Injana formations were assessed for brick industry to prepare blocks of clay building bricks by using special firing and cooling program in the laboratory of the Department of Geology, College of science, Basrah University.

The physical properties, water efflorescence, absorption, and compressive strength of the prepared bricks were measured in the laboratories of College of engineering of Basrah University according to the requirement of IQS,No. 25, 1993 and British standard No. 3921, 1985.

Results and discussion

Mineral assessment

The study area includes wide range of industrial deposits o of an economic importance occupied about 300 km^2. It can be easily quarried and transported to factories in future.

-Limestone deposits

A numerous limestone, marl and marly limestone of good reserve in different formations; Ibrahim, Serikagni, Jerbie, and Fat'ha formations were documented.

Calcite is the main mineral in all limestone deposits except for Jerbie Formation which have dolomite beside calcite (Fig. 3 a, b, c and d).

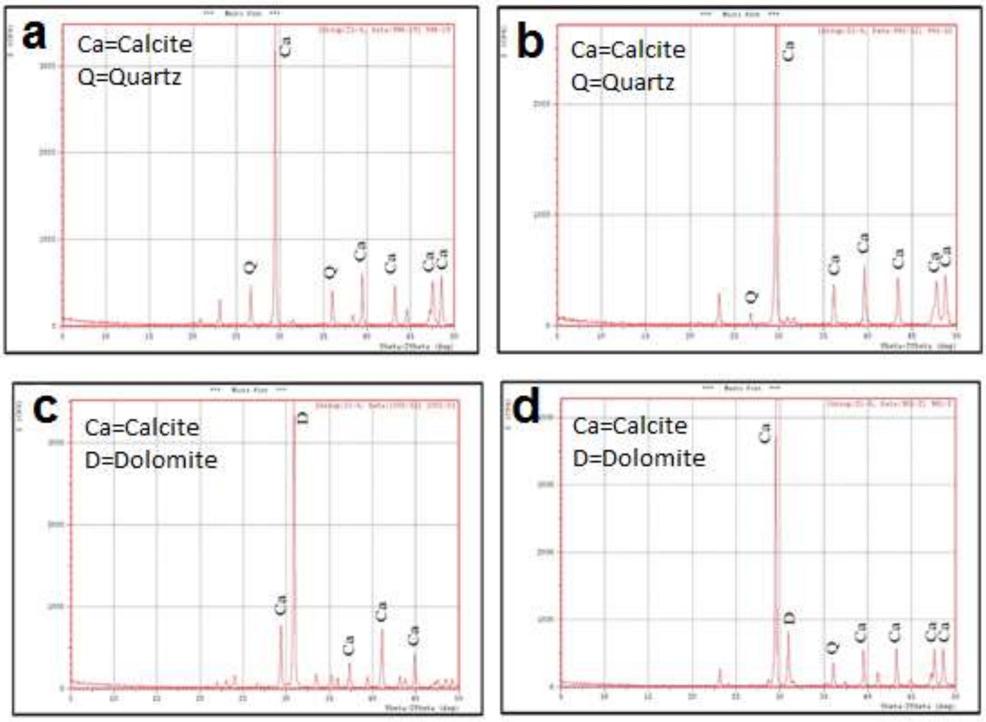

Fig. 3. X-Ray diffraction patterns of limestone

a - Ibrahim Formation, b- Serigakni Formation, c- Jeribe Formation, and d- Fat'ha Formation

-Gypsum deposits

There are a huge gypsum deposits in Fat'ha and Dhiban formations in the area. There are more than 10 thick horizons of nodular and massive gypsum in Fat'ha Formation in different locations alternated with marl, clay and limestone forming multi cyclic deposition. (Plate 1-d). Gypsum composed mainly of gypsum mineral. (Fig. 4a).

-Clay deposits:

Fat'ha and Injana are the main formations bearing reddish - brown clay to silty clay deposits with good thickness and extensions in the studied area (Plate 1-d).

XRD test of two clay samples for each formation shows that kaolinite is the main mineral (30 %-35%) followed by palygorskite (20 %- 28 %), illite (15 %- 20 %) and small amount of mixed layer montmorillonite- chlorite. (Fig 4-b) the percentage of clay minerals was estimated using semiquantitative method (area under the curve) which reported in Al-khafaji and Al-Najari (2023).

The non-clay minerals are represented by quartz, calcite, trace of feldspar and dolomite. (Fig. 4-c).

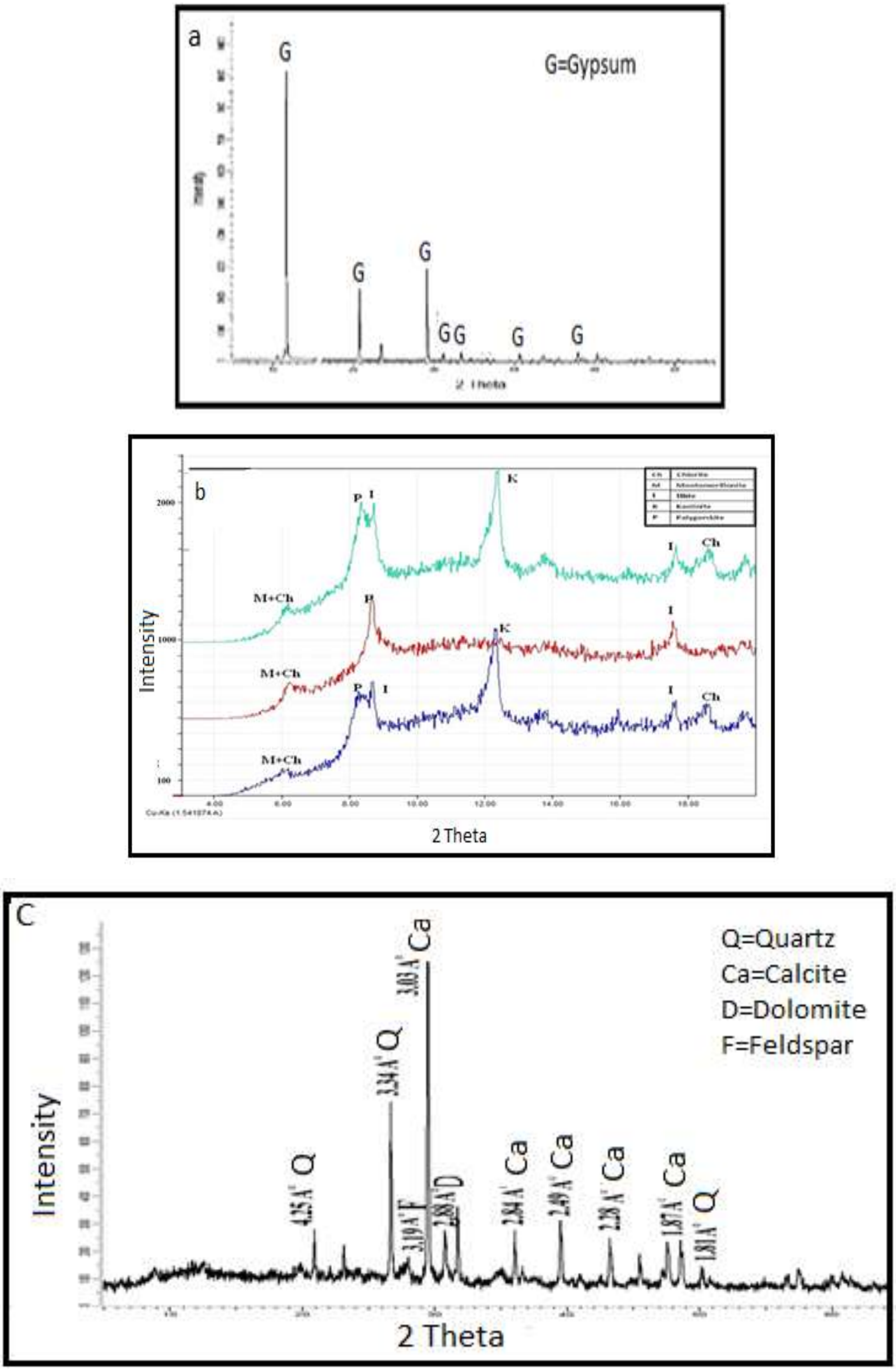

Fig. 4. X-Ray diffraction patterens a- Gypsum of Fat'ha Formation b- Clay minerals of Injana Formation c- Non clay minerals of Fat'ha Formation

Geochemical assessment

Limestone

The average chemical composition of limestone listed in Table (1)

Table 1: The chemical composition (Oxides) of limestone

Formation	Sample	SiO_2	Al_2O_3	FeO_3	Na_2O+K_2O	CaO	MgO	SO_3	LOI	Total
	1	9.64	1.61	1.26	0.49	51.85	1.79	0.20	34.78	101.62
	2	10.31	1.82	0.99	0.61	50.16	2.10	0.30	35.35	101.64
Ibrahim	3	9.50	1.70		0.58	50.93	2.40	0.10	34.80	101.51
	4	10.40	1.60	0.85	0.66	49.90	1.85	0.23	35.80	101.29
	5	10.00	1.85	0.92	0.42	51.94	1.60	0.42	34.70	101.85
	Average	9.97	1.71	1.10	0.55	50.95	1.94	0.25	35.08	101.58
	1	7.67	2.25	1.55	0.578	52.77	1.04	1.01	38.10	104.96
	2	9.16	2.67	2.46	1.42	49.79	1.07	0.37	35.29	102.23
Serikagni	3	9.00	1.99	1.97	0.99	50.90	1.01	0.46	35.70	102.02
	4	7.56	2.49	1.86	0.89	53.60	1.20	0.65	36.90	105.15
	5	8.70	2.48	1.98	0.91	49.80	0.95	0.86	33.90	99.58
	Average	8.41	2.37	1.96	0.96	51.37	1.08	0.67	35.97	102.78
	1	4.60	0.379	0.14	0.77	40.79	12.00	0.291	39.07	98.04
	2	7.57	0.54	0.09	0.33	45.18	8.90	0.191	41.02	103.82
Jerbie	3	9.40	1.40	0.05	0.70	50.10	5.90	0.30	37.20	105.05
	4	7.90	0.90	0.14	0.46	43.00	9.90	0.20	40.50	103.00
	5	6.80	0.59	0.08	0.84	47.10	7.90	0.22	40.60	104.10
	Average	7.60	0.96	0.12	0.62	46.63	8.92	0.24	41.87	102.80
	1	4.27	1.06	1.008	0.88	52.04	2.25	0.55	39.50	102.97
	2	5.43	1.52	0.92	0.75	51.25	1.91	0.62	40.70	103.10
Fat'ha	3	4.40	1.20	0.75	0.72	51.85	1.80	0.48	37.60	98.80
	4	5.30	1.60	0.87	0.98	50.75	2.50	0.57	39.80	102.37
	5	4.80	1.70	0.98	0.75	52.44	2.10	0.68	41.40	104.85
	Average	4.84	1.41	0.905	0.81	51.66	2.11	0.58	39.80	102.41

Limestone dominated by CaO with an average of 50.95% and 51.37%,46.63, 51.66% for Ibrahim, Serikagni, Jerbie and Fat'ha respectively, MgO shows an obvious variation, the lowest value observed in Serikagni and the highest value recorded in Jerbie Formation attributed to dolomitization (Table 1).

The moderate average values of SiO_2 especially in Ibrahim and Serikagni limestone formation is attributed to the silicification processes on the other hand the excess of silica and alumina due to the alteration of limestone to marl and marly limestone especially in the lower parts of all sections. There is low average of Fe_2O_3, SO_3 and alkaline (Na_2O+K_2O) in both limestone and marly limestone lithofacies. Most of oxides are meet with chemical requirements for use limestone in cement industry IQS, No.5 (1984).

Gypsum

The purest gypsum (high SO_3% and CaO %) were recorded in Al-Hasheema location in comparison with Al-Jabal location, the results compared with previous study reported by Shadher et al., 2009). (Table 2).

Table 2: Chemical analyses of Fat'ha gypsum

Location	Sample	CaO	SO_3	MgO	Al_2O_3	Fe_2O_3	LOI	Total
AL-Jabal	1	31	45.2	0.9	0.2	0.1	20	97
AL-Jabal	2	32	44.9	0.92	0.99	0.09	19	97.9
AL-Jabal	3	31	45	1.2	0.9	0.42	20	98.5
AL-Jabal	4	29.3	45.2	0.99	1.02	0.29	21	97.8
AL-Jabal	5	30	44.9	1.3	0.89	0.29	20	97.3
Average		30.66	45.04	1.06	0.8	0.23	20	97.8
AL-Hasheema	1	31.66	45.7	1.2	0.4	0.09	19.5	98.55
AL-Hasheema	2	31.7	45	0.48	0.38	0.14	18.8	96.5
AL-Hasheema	3	32	45.6	0.3	0.49	0.13	19.4	97.92
AL-Hasheema	4	31.6	44.9	0.2	0.5	0.14	20	97.34
AL-Hasheema	5	30.9	44.8	0.2	0.34	0.01	21	97.25
Average		31.57	45.2	0.47	0.42	0.102	19.7	97.4
Shadher et al., 2009)		32.1	44.2	-	-	-	-	

Clay:

Reddish brown clay deposits were analyzed for their major oxides content for Fat'ha and Injana formations respectively (Table 3).

The most abundant oxides are SiO_2 (51.30%, 45.24%), Al_2O_3 (7.93%, 10.27%), CaO (17.92%, 18.45%) and Fe_2O_3 (5.34%, 5.52%). in Fat'ha and Injana respectively. There is high content of CaO and Fe_2O_3 in Fat'ah and Injana clays.The moderate contents of Na_2O and K_2O is related to the presence of illite, k-feldspar and plagioclase, the relatively high MgO content in some samples related to palygorskite, the high L.O.I especially in Injana clay is associated with loss of structural water in clay minerals and the presence of volatile organic compounds. (Table 3).

Table 3: Major oxides % contents of clay deposits

Formation	Sample	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	Na_2O	K_2O	SO_3	MgO	L.O. I	Total
Fat'ha	1	50.28	8.56	4.72	1.05	17.36	0.83	1.26	1.91	2.45	11.5	99.92
	2	49.69	7.09	4.65	1.5	18.73	0.61	1.4	1.99	2.34	11.27	99.27
	3	51.86	9.01	5.09	1.09	19.51	0.71	1.5	2.16	2.16	12.54	105.63
	4	50.34	8.11	4.75	0.83	20.67	0.49	1.27	2.17	2.37	11.99	102.99
	5	51.72	8.04	5.26	0.95	17.86	0.6	1.6	1.88	1.98	11.82	101.71
	Average	50.77	8.16	4.89	1.08	18.83	0.64	1.4	2.02	2.26	11.82	101.90
Injana	1	47.56	9.31	5.19	0.41	16.67	0.65	1.16	0.36	4.31	10.31	95.93
	2	46.4	10.52	6.16	0.69	20.8	1.35	1.7	1.42	4.37	9.2	102.61
	3	46.1	9.55	7.27	0.47	17.8	0.68	1.61	1.53	3.65	9.1	97.76
	4	47.02	10.02	5.39	0.49	19.87	1.23	1.71	1.21	4.05	10.1	101.09
	5	46.2	9.8	5.79	0.58	18.58	1.14	1.47	1.26	5.32	10.05	100.19
	Average	46.65	9.84	5.96	0.52	18.74	1.01	1.53	1.15	4.34	9.75	99.51

Industrial applications

Limestone: -

Limestone is one of the important resources for human beings it used as construction material especially as raw materials for cement industry.

The required CaO content in raw limestone used for cement industry should be between 40-50 % (Schorcht et al., 2013), and 52% according to Peray (1986).

The quality of limestone depends on its chemical composition and the amount and type of impurities (Bouazza et. al, 2016), such as MgO, fluorine, sulphates, phosphates, silicate, evaporites, and feldspar (BGS, 2005).

Limestone of Ibrahim Formation was assessed for Ordinary Portland Cement manufacturing.

Many chemical parameters must be calculated to evaluate and meet the requirement of the standard of cement and clinker

Lime saturation factor (LSF): -

The LSF is the most critical control ratio that used to measure the degree of conversion of silica, alumina, and iron oxides to their basic calcium compounds (Hewlett and liska, 2019), LSF can be determined by the equations 1 and 2 according to MgO content in raw material:

$$LSF\ (MgO \leq 2) = \frac{(CaO\ \% + 0.75\ MgO\ \%)}{2.8\ (SiO_2) + 1.2\ (Al_2O_3) + 0.66\ (Fe_2O_3)} \times 100 \quad (1)$$

$$LSF\ (MgO > 2) = \frac{(CaO\ \% + 1.5\ MgO\ \%)}{2.8\ (SiO_2) + 1.2\ (Al_2O_3) + 0.66\ (Fe_2O_3)} \times 100 \quad (2)$$

Silica ratio (SR): -

It is the measurement of the SiO_2 ratio to the summation of Al_2O_3 and Fe_2O_3 in cement (Peray, 1986) give as equation: -

$$SR = \frac{SiO_2}{(Al_2O_3) + (Fe_2O_3)} \quad \text{------------------------------(3)}$$

Alumina ratio (AR): -

The alumina ratio (AR) is used to calculate the ratio of Al_2O_3) to Fe_2O_3 in cement (Hewlett and liska, 2019), The alumina ratio (AR) is defined as

$$AR = \frac{(Al_2O_3)}{Fe_2O_3} \quad \text{------------------------------(4)}$$

Two suggested theoretical raw mix were designed for prepare OPC from limestone of Ibrahim Formation and clay of Injana Formation (Table 4). The limestone of the Serikagni and Fat'ha formations were excluded in our research due to the very high cost of burning process for new suggested mixtures. On the other hand, the limestone of Jerbie Formation was also skipped in our research because of its higher content of MgO.

The first one mix include 84 % of limestone and 16 % of clay whereas the second one composed of 84 % limestone, 14 % clay and 2 % of bauxite ,bauxite was added as corrected material in order to be the chemical parameters especially for AR to be within the requirement of clinker according to IQS, No. 5, 1984 ,Newman and Choo,2008, for cement taking into consideration the rules of Duda, (1985), Peray, (1986) and Hewelt& liska, (2019), the oxides content of the two raw mix were calculated theoretically (Table 4).

Table 4: Suggest raw mix for preparation of clinker

Chemical composition of cement raw meal according to Schorcht et al. 2013									
	Mix	%	SiO_2 12-16	Al_2O_3 2-5	Fe_2O_3 1.5-2.5	CaO 40-45	MgO 0.3-5	$Na_2O + K_2O$ 0.2-2	SO_3 0-1.5
1	Limestone	84	15.796	2.590	1.877	45.796	2.324	0.25	0.15
	Claystone	16							
2	Limestone	84	15.194	3.609	1.784	45.427	2.237	0.15	0.08
	Claystone	14							
	Bauxite	2							

The two suggested raw mixes were burned by using a special firing and cooling program with soaking time 30 minutes at 1450 C°, the produced hot clinker samples were cooled from 1450 C° to 1200 C° at suitable cooling rate and then the clinker was quickly cooled from 1200 C° to 100 C° by using technological cooling processes which available in University of Tehran.

The produced clinkers were assessed mineralogically and chemically, the identified phases of cement; are Allite (C_2S), Bellite(C_3S), Aluminate (C_3A), Ferrite (C_4AF) were appeared as good crystalline phases. (Fig 5). The results of chemical analysis of clinker listed in (Table 5). The phases values were calculated according to Bogue equations that reported in Chatterjee, 2018.

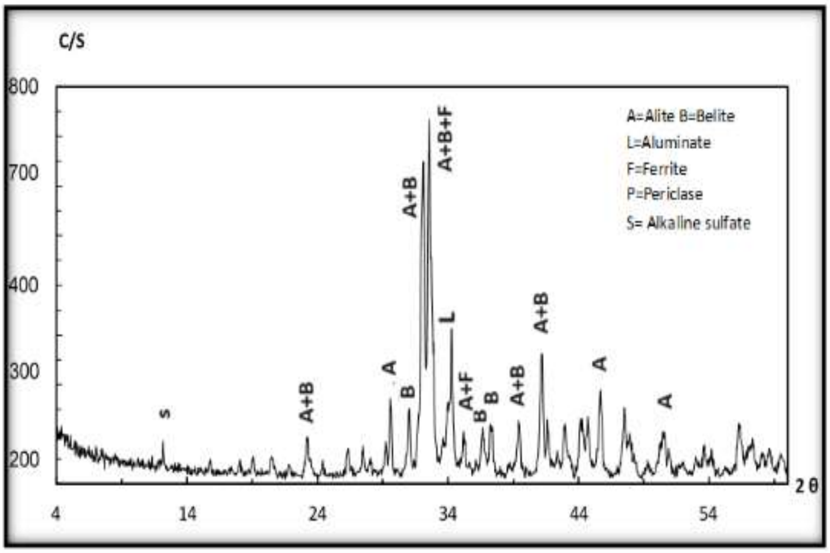

Fig. 5 The XRD patterns for produced clinker

Table 5: Chemical analysis of produced clinker for Ibrahim limestone Formation

Clinker	SiO_2	Al_2O_3	FeO_3	CaO	SO_3	MgO	Na_2O+K_2O	I.R	LSF	SR	AR	C_3S	C_2S	C_3A	C_4AF
1	22.35	4.95	2.11	64.5	0.29	2.98	0.45	1.1	93.08	3.17	2.35	56.37	21.86	9.55	6.41
2	22.86	5.16	2.32	65.2	0.23	2.66	0.38	0.92	91.69	3.06	2.22	53.63	25.38	9.906	7.052
Newman and Choo,2003 standard							<1.6%	-	90-98	2.2-2.3	1.4-2.9	45-65	10-30	5-12	5-12
IQS, No.5, 1984	-	-	-	-	2.8	≤ 5%		≤1.5 %	90-100	1.8-3.4	1.5-2.5	-	-	-	-

Gypsum:

Gypsum has multiple common uses and has been considered a wonder mineral in construction because of its many uses in the industry, it is widely usual for manufacture wall boards that are usual to cover walls and ceiling. Gypsum is good material to make a plaster for decoration at homes as well as mixed into patching compound for wall board repair, moreover it is used as retarder material in Portland cement to prevent the flash setting of concrete (Venta and Venta, 1997).

The purity of gypsum under study were calculated according to their content of sulfur trioxide which is an important parameter to measure the purity of gypsum as recorded by Henkels and Gaynor method (2005), ASTM,5-6,2007. The gypsum samples have no impurities such as carbonate, quartz and iron oxide as shown in Table (2) which consider important factors affect the properties of gypsum (Zaskalicky, 1985). So, all gypsum samples have higher purity (up to 95%) (Table 6). The average purity ranges from 96.344% to 98.279 % (Table 6).

Table 6: Purity values for gypsum raw materials

Studied area	sample	Purity
Al-Jabal	1	97.204
Al-Jabal	2	96.559
Al-Jabal	3	96.774
Al-Jabal	4	97.204
Al-Jabal	5	96.559
Average		96.860
Al-Hasheema	1	98.279
Al-Hasheema	2	96.774
Al-Hasheema	3	98.064
Al-Hasheema	4	96.559
Al-Hasheema	5	96.344
Average		97.204

Gypsum panel composite

Gypsum panel is one types of gypsum board uses for interior wall, shaft wall, and separation walls, fill walls, stair walls and duct enclosures (Hankhuntod et. al., 2021).

The raw gypsum (natural gypsum) was crushed and calcined firstly at 180 C° to dehydrate the feed stock, and then it mixed with 7-15% water to prepare slurry mixture.

Two types of additives (sawdust and date palm fiber powder size of different ratios 1 %, 5 %, and 10 %) were used as a core mat between two layers of gypsum (sandwich), the prismatic type panels were mold and formed according to ASTM C473, 2016, (plate 2-a).

The prepared panels were dried for 28 days (ASTM C 473) to become rigid and strong enough to carry out the laboratory tests. ((Plate 2-b)

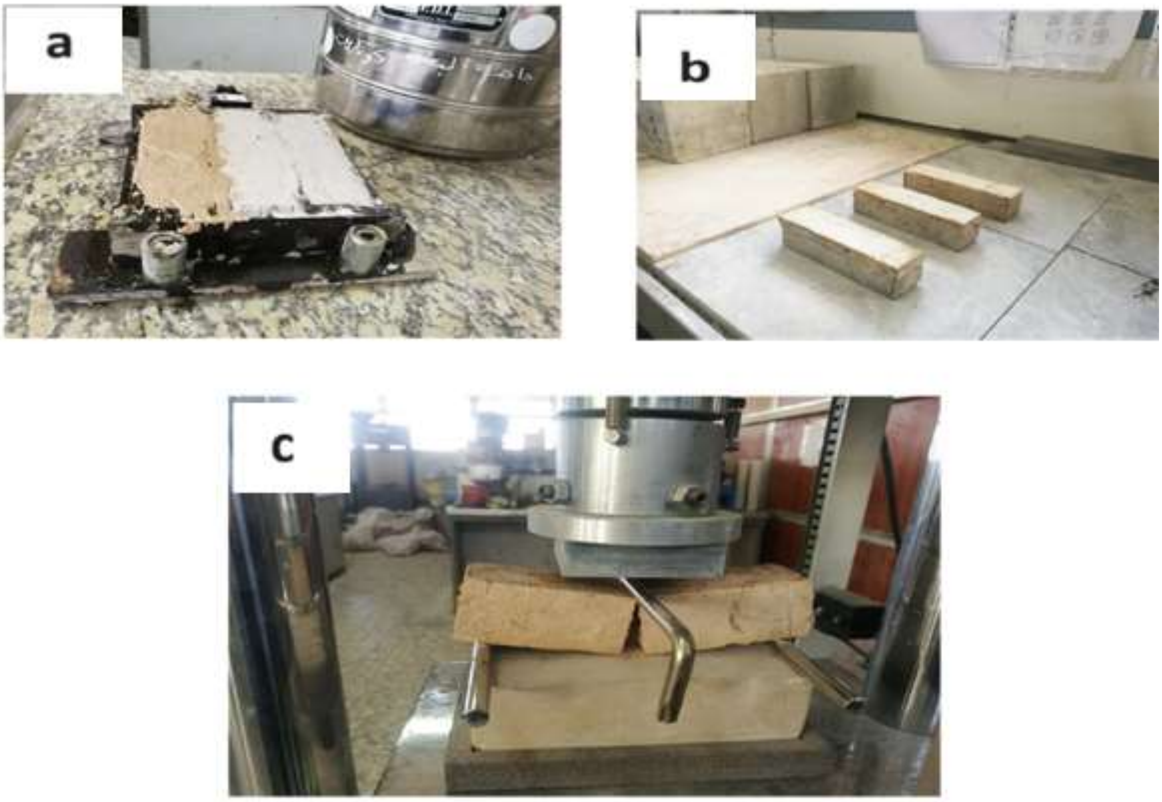

Plate 2: a- Dimension cube for tests, b- Rigid dimension cube for tests, and C- panel composite flexural test

Table 7: Physical properties and Flexural strength for composite panels

PHYSICAL TEST AFTER 28 DAYS				RATIO %	SPECIMEN	ADDITIVE TYPE	PHYSICAL TEST AFTER 28 DAYS				RATIO %	SPECIMEN	ADDITIVE TYPE
FLEXURAL STRENGTH		Setting time (Min.)	Consistency Ml/gm				Flexural strength		Setting time (Min.)	Consistency Ml/gm			
ACROSS PANNEL	A long pannel						Across pannel	A long pannel					
1.3	**2.2**	**9**	**52**	**0**	**40x40x 160 mm**	**Date palm fiber Size 4.75 mm**	**1.3**	**2.2**	**9**	**52**	**0**	**40x40 x160 mm**	**Saw dust Size 4.75 mm**
1.6	**3**	**12**	**57**	**1**			**1.8**	**3.2**	**11**	**55**	**1**		
2.5	**4.5**	**14**	**60**	**5**			**2.5**	**5**	**13**	**58**	**5**		
2.4	**4.4**	**16**	**66**	**10**			**2.3**	**4.4**	**14**	**64**	**10**		
2.1	**4**	**17**	**77**	**15**			**2**	**4**	**16**	**75**	**15**		
1.3	**2.2**	**9**	**52**	**0**	**40x40x 160 mm**	**Date palm fiber Size 5.60 mm**	**1.3**	**2.2**	**9**	**52**	**0**	**40x40 x160 mm**	**Saw dust Size 5.60 mm**
1.8	**3.2**	**13**	**59**	**1**			**1.9**	**3.6**	**12**	**56**	**1**		
2.6	**5**	**15**	**62**	**5**			**2.7**	**5.2**	**14**	**60**	**5**		
2.4	**4.8**	**17**	**70**	**10**			**2.3**	**4.7**	**17**	**65**	**10**		
2.2	**4.2**	**18**	**80**	**15**			**2.2**	**4.4**	**18**	**79**	**15**		
$220X10^{-3}$	**$614x10^{-3}$**	**ASTM C473**					**$200x10^{-3}$**	**$599x10^{-3}$**	**ASTM C473**				

The flexural strength test (three point bending test) was carried out according to ASTM C473-2016. (Plate 2-c)

The results shows that 5% of both additives (sawdust and date palm fiber) can improve the flexural strength value from 2.2 Mpa to 5.2 Mpa (Table 7). Especially when adding 5% of sawdust and date palm fiber.

The results are in agreement with requirements of the ASTM C473-2016 for physical testing of gypsum panels (Table 7).

Clay

Fat'ha and Injana clay formation were subjected to particle size distribution, atterberg limits and chemical analysis to assess their suitability for clay brick manufacturing, (Table 3 and Table 8). Three different mixtures of both types of clay were prepared by using semi dry method (Table 9) under forming pressure 200 kg/cm^2, the physical and mechanical properties of prepared clay bricks were listed in Table 10 and compared with IQS, No. 25, 1993 and British standard No. 3921, 1985, the results shows that the water absorption of Fat'ha clay bricks increase with increasing of sand percentage where as in Injana clay bricks it decrease with increasing of sand percentage due to its primarily high content of clay , it's possible to prepare clay bricks of good compressive strength of classes A and B.

Table 8: Particle size and Atterberg limits of clay samples

samples	Sand	Silt	Clay	samples	Liquid Limit	Plastic limit	Plasticity index	Sticky limit	Reike index
S1	20	44	36	S1	51	40	11	45	4
S2	16	46	38	S2	57	45	12	50	5
S3	24	41	35	S3	55	38	17	47	9
S4	26	42	32	S4	52	46	6	48	2
S5	17	49	34	S5	50	40	10	45	5

Table 9: Suggested raw mix for clay bricks

Fatha clay			Injana clay		
Mix no.	Mud%	Sand%	Mix no.	Mud%	Sand%
1	100	0	1	100	0
2	90	10	2	90	10
3	85	15	3	85	15

Table 10: Physical and mechanical properties of prepared clay bricks (Fat'ha and Injana Formations)

TYPE OF BRICKS	PHYSICAL PROPERTIES			MECHANICAL PROPERTIES	CLASS		
	Mixtures	**Water absorption %**	**Efflorescence**	**Compressive strength**	**A**	**B**	**C**
FATHA CLAY BRICKS	**Mix 1**	**18.7**	**S**	**39.6**	√		
	Mix 2	**21.3**	**N**	**41.3**	√		
	Mix 3	**22.6**	**N**	**42.6**		√	
INJANA CLAY BRICKS	**Mix 1**	**21.7**	**N**	**26.6**	√		
	Mix 2	**20.3**	**S**	**28.3**	√		
	Mix 3	**20.8**	**N**	**29.7**	√		
IQS NO.25 1993		**classes**	**classes**	**classes**			
		A / B / C	**A / B / C**	**A / B / C**			
		22 / 26 / 28	**S / M / H**	**16 / 11 / 7**			
BRITISH ST. NO.3921, 1985		**No limits**	**N-M > 5**				

Conclusion

Zurbatiyah area has good potential and economic reserve of limestone, gypsum and clay deposits distributed as raw materials in Ibrahim, Serikagni, Jerbie, Fat'ha, Dhiban and Injana Formations.

Limestone dominated by CaO with an average of 50.9 % ,51.37%, 46.63%, and 51.66 % for Ibrahim, Serikagni, Jerbie and Fat'ha respectively, the excess of silica in Ibrahim limestone due to silicification process. The limestone is suitable for OPC industry as it is, on the other hand, it became more suitable by adding 2% bauxite to the raw mix in order to be more compatible with requirements of IQS,No. 5,1984 especially for SR and AR.

The important phases of cement OPC; Allite (C_3S), Bellite(C_2S), Aluminate (C_3A), Ferrite (C_4AF) were appeared as good crystalline phases.it is possible to prepare OPC from limestone and clay deposits in the study area by using suitable firing program.

The high purity gypsum (high content of SO_3% and CaO %) was recorded in Al-Hasheema location of Fat'ha Formation.

The addition of 5% of both sawdust and date palm fiber powder can improve the flexural strength of the prepared gypsum panel composite from 2.2 Mpa to 5.2 Mpa.

It is possible to prepare clay building bricks of class A and B from clay deposits of Fat'ha and Injana Formations.

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