



Mineralogical and Chemical Assessment of Serikagni Limestone Formation in Zurbatiyah Area, Eastern Iraq for Ordinary Portland Cement Industry

Ahmad O. Al-Hadithi ¹ , Sattar J. Al-Khafaji ^{2*}

^{1,2}Department of Geology, College of Science, University of Basrah, Basrah, Iraq.

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Correspondence:

Name: Sattar J. Al-Khafaji

Email: Khafaji52000@gmail.com

ABSTRACT

Limestone deposits of the Serikagni Formation in Zurbatiyah area, eastern Iraq, were evaluated as raw materials for the manufacturing of Ordinary Portland Cement (OPC). X-ray diffraction (XRD) results showed that calcite is the dominant mineral followed by quartz and traces of dolomite appearing in limited limestone samples. X-ray fluorescence results showed that the oxides (CaO, SiO₂, Al₂O₃, Fe₂O₃, MgO, Na₂O, K₂O, TiO₂, SO₃, and P₂O₅) are within the acceptable limits required for the cement industry. Based on the chemical parameters of cement (LSF, SR and AR) two mixtures was designed for cement industry, The first one composed of limestone of Serikagni formation and clay of Injana formation, whereas the second one was composed limestone of Serikagni formation and clay of Injana formation, in addition Bauxite and Sand as corrected materials. The proportions of the mineral phases of clinker were calculated after burning at 1450 °C from the XRF results of the oxides of the produced clinker, the results showed the phases (Alite C₃S, Belite C₂S, aluminate C₃A and ferrite C₄AF) within acceptable limits of international standards.

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التقييم المعدني والكيميائي للحجر الجيري لتكوين سريكانتي في منطقة زرباطية، شرق العراق لصناعة الأسمنت البورتلاندي الاعتيادي

احمد اسامة الحديثي¹، سطار جبار الخفاجي²

^{1,2} قسم علوم الارض، كلية العلوم، جامعة البصرة، البصرة، العراق.

المخلص	معلومات الارشفة
تم تقييم رواسب الحجر الجيري لتكوين سريكانتي في منطقة زرباطية شرق العراق كمواد خام لصناعة الأسمنت البورتلاندي الاعتيادي (OPC). بينت نتائج حيود الأشعة السينية (XRD) أن معدن الكالسيت هو المعدن السائد يليه معدن الكوارتز، كما ظهرت آثار من الدولومايت في عينات محدودة من الحجر الجيري. أظهرت نتائج الأشعة السينية الويضية أن الأكاسيد (Al_2O_3 , SiO_2 , CaO)، P_2O_5 , SO_3 , TiO_2 , K_2O , Na_2O , MgO , Fe_2O_3 المطلوبة لصناعة الأسمنت. بناءً على المعايير الكيميائية للأسمنت (SR, LSF, AR) تم تصميم خلطتين لصناعة الاسمنت، الأولى مكونة من الحجر الجيري من تكوين سريكانتي وأطيان من تكوين إنجانا، بينما الثانية مكونة من الحجر الجيري من تكوين سريكانتي والأطيان من تكوين انجانا، بالإضافة إلى البوكسايت والرمال كمواضع. حساب نسب الأطوار المعدنية للكلنكر بعد الحرق عند درجة حرارة 1450°م من نتائج XRF لأكاسيد الكلنكر المنتج، وأظهرت النتائج أن الأطوار (الاليت C3S والبليت C2S والألومينايت C3A والفرايت C4AF) ضمن الحدود المقبولة للمعايير الدولية.	تاريخ الاستلام: 20- ابريل -2024 تاريخ المراجعة: 21- مايو -2024 تاريخ القبول: 30- يونيو -2024 تاريخ النشر الالكتروني: 01- اكتوبر -2025 الكلمات المفتاحية: تكوين سريكانتي زرباطية كلنكر اسمنت بورتلاندي اعتيادي حيود الاشعة السينية المراسلة: الاسم: سطار جبار الخفاجي Email: Khafaji52000@gmail.com

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Introduction

The cement industry is one of the most significant manufacturing sectors and one of the most pillars of economic development (John, 2020). Cement is an indispensable component in the building and civil engineering construction industries (Schorcht *et al.*, 2013). In approaching years, Iraq will require more cement. Due to Iraq reconstruction plan projects. In addition to population growth and the requirement to create housing units to meet domestic demand, Iraq's future cement consumption is predicted at 30–25 million tons per year assuming the state implements its development initiatives (Mahmood, 2019). To establish a cement factory, it is necessary to have sufficient raw materials to meet the need and ensure economic feasibility. Geologists have carried out a lot of fieldwork, rock surveys, and research to explore industrial minerals in the study area, the most prominent of which are, for example, gypsum rocks (AL-Hadadi and AL-Khafaji, 2020). In addition, raw materials for brick and OPC industry from clay of Fatha formation (Al-Fraji, and Al-Khafaji, 2023). Meanwhile, (Al-Najjari and Al-Khafaji 2019) studied the petrographical of sandstone in Zurbatiyah area for Injana Formation. (Khalaf and Al-Khafaji 2021) used clay deposits in the area to manufacture low-cost and environmentally friendly bricks. The common raw materials used for manufacturing of cement include limestone, shale, and chalk or marl combined with shale, clay, slate, blast furnace slag, silica sand, and iron ore (Sengupta, 2020). A corrective substance that contains one of the combination's primary components is used to change the makeup of the mixture. A knowledge of the chemical composition of the raw materials used in the production of Portland cement provides information on the acceptability of such materials for the cement industry. The chemical composition of Portland cement is primarily dependent on the chemical composition

of each raw material. LSF, SR, and AR are the three chemical parameters on raw materials that are utilized in the cement industry, these parameters play a significant part in determining the viability of the raw materials. A corrective substance that contains one of the combination's primary components is used to change the makeup of the mixture. For the purposes of this study, samples of limestone from the Serigakni Formation and samples of claystone from Injana formation in Zurbatiyah area, eastern Iraq were assessed. The limestone has widely extensions and thickness in the area near the Iraqi-Iranian border, making them appropriate for exploitation in multiple fields via open pit mining. The current study aims to undertake the mineralogical and chemical study on Serikagni limestone deposits in the Zurbatiyah area by using XRD and XRF techniques to determine their potential as raw materials for OPC industry.

Geology and location of the study area

The study area is located in district of Zurbatiyah in eastern Iraq within the Wasit governorate, which is 80 km west of the governorate center (Al-Kut) (Fig. 1).

In the study area, many geological formations are widely exposed noticed. They range from Oligocene to Pliocene – Pleistocene covered by recent sediments. These formations are (AL-Hadadi, 2021):

Ibrahim Formation: This formation can be distinguished in the study area from successions of white to gray limestone, which are interbedded with gray to black limestone, as well as marly limestone. The Ibrahim Formation is exposed at a thickness of up to 20 meters (Al-Ali, and Al-Khafaji, 2020). In the study area, underline of Ibrahim formation is not exposed while the Serikagni Formation is unconformable upper formation.

Serikagni Formation: The present study focuses on its limestone beds, where it consists of a good succession of gray, white marl to marly limestone (Fig. 2), with thickness about 23 m, which overlies the Ibrahim Formation and is covered by the Dhiban Anhydrite Formation (Al-Khafaji and Al-Hadadi, 2024). The formation is exposed in deep valleys in some eastern parts of the study area.

Dhiban Formation: Gypsum is the most important feature of this formation, consisting of recrystallized limestone in addition to thin layers of marl. It is exposed in the study area in its eastern part and extends to more than 3 km (Al-Khafaji and Al-Hadadi, 2024).

Jeribe Formation: In the study area, the Formation exposed thickly darkish brown dolomitic limestone. The upper contact with Fatha Formation can be recognized by conglomerate beds indicating an important unconformity surface, while in the lower contact is distinguished by the massive gypsum of Dhiban Formation.

Fatha Formation: The lower contact of this Formation is unconformable with Jeribe Formation while the upper contact is gradational and diachronous with Injana Formation. It is characterized by containing more than 20 cycles, represented by mudstone, marl, limestone, and blocky gypsum (AL-Hadadi, 2021).

Injana Formation: The lower contact of this Formation is conformable and gradational with the underlying Fatha Formation while overlain by Mukdadiya Formation, it is conformable and gradational, based on the first appearance of pebbly sandstone.

Mukdadiya Formation: The formation is composed almost of gravelly to pebbly sandstone with brown silty clay. Pebbly Sandstone is the contact below Mukdadiya formation underlying with upper part of Injana formation.

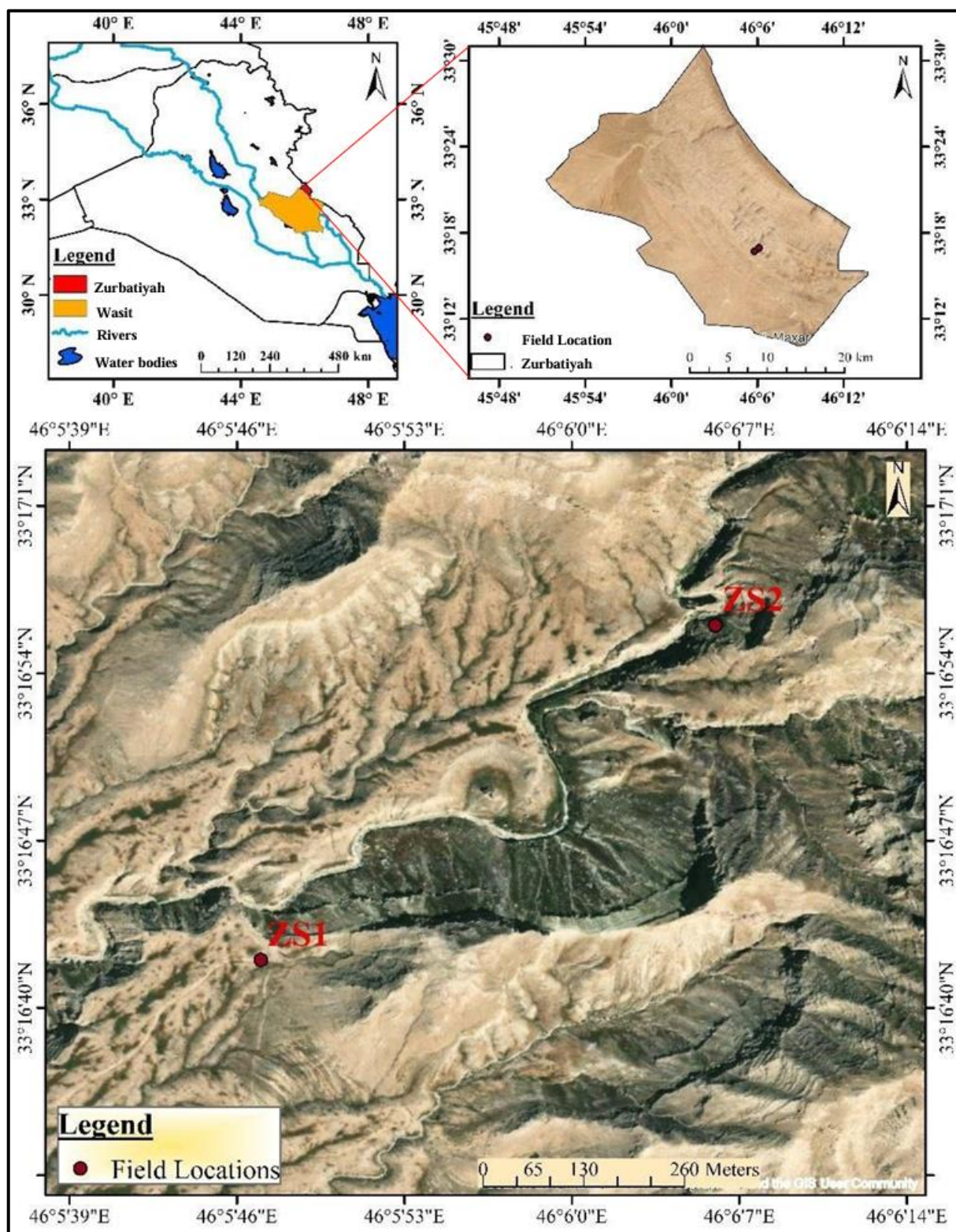


Fig. 1. The location map of the study area



Fig. 2. Serikagni Formation at Zurbatiyah area.

Methodology

The fieldwork was carried out in Zurbatiyah area, near Badra city in Wasit Governorate, eastern Iraq. Five samples were collected limestone samples from a two sections of good exposures of wide thickness and lateral extension in the sections located at ZS1(N 33° 16' 42" / E 46° 05' 47") and ZS2 (N 33° 16' 56" / E 46° 06' 06").

The samples were stored in nylon bags and subjected to cleaning, crushing, grinding, and sieving. Passing the five limestone and two claystone samples from the sieve size (75 μ m) to be ready for various mineralogical and chemical analysis.

Mineralogical and Chemical analysis

X-ray diffraction is widely regarded as the primary method employed for the characterization of the elemental composition of cement, clinker, and raw materials. This technique enables the determination of their compound or phase composition (Chatterjee, 2018). Five limestone samples were selected to test by XRD analysis and scanned at (2 θ) range from (5°-65°). X-ray diffraction (XRD) is performed with a Broker D2 phaser in (Iraqi German laboratory), which is located in the Geology Department of the College of Science at the University of Baghdad. In addition to two samples selected to separate and detect the insoluble residues from limestone according to (ASTM D3042-3, 2004). The clinker produced was analyzed by the XRD, with the scanning range of (2 θ) ranging from 4° to 60°. In the Karsarn Binalond Company, Tehran, Iran, to determine the minerals of the produced clinker. At the AL-Razi Center in Tehran, Iran, the scanning electron microscopy (SEM) technique was utilized to identify the type of clinker phases, as well as their crystal form and microstructure.

The major element compositions of five limestone samples were examined using XRF techniques. The analysis was conducted using the Ed-XRF Instrument Spectro-Xepos of Ametek Company in the Iraqi German Laboratory at the University of Baghdad, in the College of Science, Department of Geology after pulverizing and grinding 200g of limestone by use of

agate mortar, followed by sieving to 75 μ m. The clinker was analyzed for its major elements composition using XRF technology at the (Karsarn Binalond Company) in Tehran, Iran. The analysis was conducted under conditions a current of 30 mA and a voltage of 60 kV.

Cement Chemical Parameters:

Several chemical parameters are calculated, when designing the raw mix materials and assessing the chemical composition of raw materials, this parameters control of clinker composition and optimization of plant performance is greatly. It is feasible to forecast the amount of raw mix and additional corrected materials that will need to be added in order to meet the requirements of the international standards for raw materials used in cement (Ahmed *et al.*, 2022).

Lime saturation factor (LSF)

LSF is the molar ratio of CaO to the other three major oxides, it is typically in the range 92–98 for clinker (Rao *et al.*, 2011). (LSF) has significant significance in the process of feedstock preparation, as it serves as a preventive measure against the use of compositions that exceed the capacity for lime to interact with silica, alumina, and ferric oxide constituents (Hewlett, 2006). According to (Janamian and Aguiar 2023) LSF can be determined by the equation:

$$\text{If (MgO} < 2) \quad \text{LSF} = \frac{\text{CaO} + 0.75 \text{ MgO}}{2.85 \text{ SiO}_2 + 1.18 \text{ Al}_2\text{O}_3 + 0.65 \text{ Fe}_2\text{O}_3} 100$$

$$\text{If (MgO} > 2) \quad \text{LSF} = \frac{\text{CaO} + 1.5}{2.85 \text{ SiO}_2 + 1.18 \text{ Al}_2\text{O}_3 + 0.65 \text{ Fe}_2\text{O}_3} 100$$

Silica ratio (SR)

The SR of clinker often within the range of 1.9 to 3.2 (Duda, 1985) and it is in rang 2 – 3 (Rao *et al.*, 2011). According to (Hewlett, and Liska, 2019) SR can be determine by the equation:

$$\text{SR} = \frac{\text{SiO}_2}{\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3}$$

Aluminum Ratio (AR)

The range of AR recommended values for clinker is 1.3 to 2.5. (Taylor, 1997) and between 1- 4 (Rao *et al.*, 2011). According to (Hewlett, and Liska, 2019) AR can be determine by the equation:

$$\text{AR} = \frac{\text{Al}_2\text{O}_3}{\text{Fe}_2\text{O}_3}$$

Results and discussion

Mineralogical analysis:

XRD results showed that calcite is the main mineral for all samples, and is exists in significant amount. Associated with low content of quartz and trace of dolomite in limited samples, this indicates that limestone of Serikagni formation is a good raw material for the manufacture of ordinary Portland cement (Fig. 3 and 4).

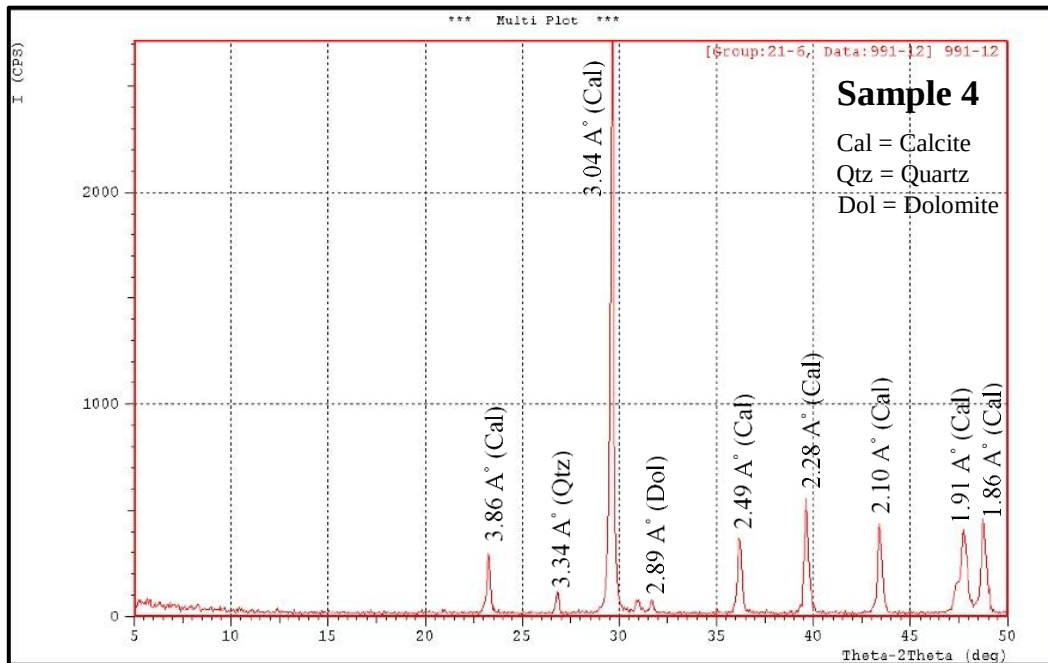


Fig. 3. XRD patterns of limestone (Se4)

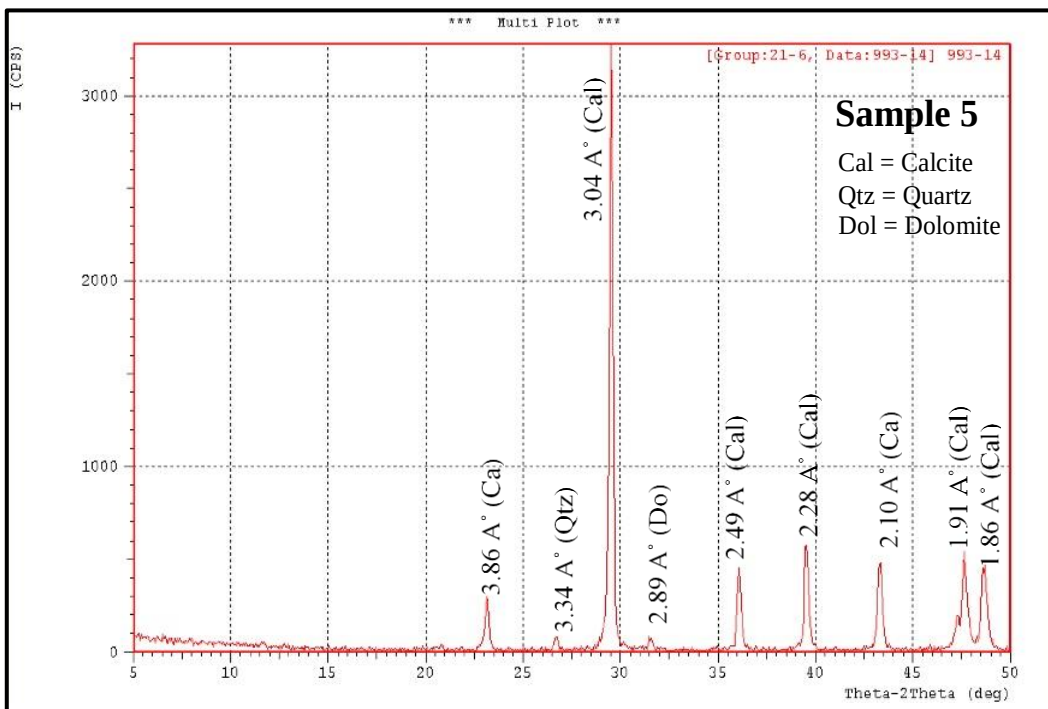


Fig. 4. XRD patterns of limestone (Se5)

Chemical Analysis:

(Table1) indicated that CaO is the prevailing oxide having a range of values ranging from 47.53% to 53.96%, with a mean of 51.43%. SiO₂ range of values from 4.11% to 8.81% with a mean of 6.58%. Al₂O₃ range of values from 0.94% to 3.65% with a mean of 1.75%. Fe₂O₃ range of values from 0.49% to 2.36% with a mean of 1.40%. MgO range of values from 0.65% to 1.22% with a mean of 1.04%, this low value of MgO is because the effect dolomitization process. The percentage of MgO that is present in OPC does not increase above 5%, It is agree with requirement of IQS No.5 (1984), 6%, as specified by ASTM C150-85 (1986), and 4%, as specified by BS12 (1989). Limestone has low content of sulfate ranges from 0.16% to 0.46% with a mean of 0.30%. Although the early strength of cement is improved by the presence of alkaline sulfates, excessive amounts of them can cause accumulations and cover the kiln's interior walls, which may affect the burning conditions (Duda, 1985). According to IQS No.5

(1984), the maximum percentage of sulfate that can be found in OPC is 2.5%, while 3% is the maximum percentage can be found in OPC according to BS12 (1989) and ASTM C150-85 (1986). Alkalies content (Na_2O and K_2O) have a range between 0.84% and 1.41% with an average of 1.09%. The quality of the cement is negatively impacted by percentages that are higher than these acceptable ranges. The reaction of alkalis with silica results tend to increase the volume that is detrimental to the concrete (Schafer, 1987), accordance with the requirements of ASTM C150-85 (1986), which stipulate that the cement must contain maximum 1.6% of alkalis. Based on the results of the chemical analyses conducted on the clays that were selected from the Injana deposits, it was determined that the clays possessed high concentrations of silica and alumina, while having low concentrations of magnesium oxide (Table 2). This suggested that the clays would be suitable for use as auxiliary raw materials in Ordinary Portland cement production. According (Schorcht *et al.*, 2013), the oxides percentages in this study are within the range of acceptable of raw materials for cement manufacturing.

Table 1: Chemical analysis of limestone samples.

Oxides%	SiO_2	Al_2O_3	Fe_2O_3	K_2O	Na_2O	CaO	MgO	SO_3	L.O.I	Total
Schorcht et al. (2013)	0.5-50	0.1-20	0.2-5.9	0-3.5	0-1.5	20-55	0.2-6	0-0.7	2.44	-
samples	Se1	8.12	3.65	2.27	0.81	0.60	47.53	1.05	34.52	98.96
	Se2	4.70	1.10	1.03	0.22	0.76	53.44	1.20	37.26	99.88
	Se3	7.16	2.49	2.36	0.56	0.77	49.97	1.07	35.07	99.75
	Se4	4.11	0.94	0.87	0.15	0.76	53.96	1.22	37.79	100.16
	Se5	8.81	0.59	0.49	0.09	0.75	52.27	0.65	35.79	99.90
	average	6.58	1.75	1.40	0.37	0.73	51.43	1.04	36.19	99.73

Table 2: Chemical analysis of claystone (after Al-Najjari, 2019).

Oxides%	SiO_2	Al_2O_3	Fe_2O_3	K_2O	Na_2O	CaO	MgO	SO_3	L.O.I	Total
Schorcht et al. (2013)	33-78	7-30	4-15	0.4-5	0.1-1.5	0.2-25	0.3-5	0-4	1-20	-
samples	In1	37.40	11.13	5.63	1.80	0.67	11.97	5.55	1.20	99.52
	In2	35.40	9.77	5.02	1.59	2.34	11.64	5.19	1.97	100.41
	average	36.40	10.45	5.33	1.70	1.5	11.81	5.37	1.59	99.96

Raw mix designing

Preparation and design of two theoretical mixtures were prepare according to (Schorcht et al. 2013) (Table 3). Taking into account the observations made by Duda (1985), Peray (1986), and Hewlett (2006) regarding the design of the raw mix, as well as the chemical composition of the raw materials, and determining whether to need corrected materials or not.

The first mixture (without additives) conforms to (Schorcht et al. 2013) with LSF 96.04%, but another mixture was designed by adding (sand and bauxite) from (Iraqi Geological Survey) to obtain more suitable LSF value while keeping the raw meal oxide values within the limits of the mentioned specification, the value of LSF after additive were 97.96%. (Table 4) shows the chemical composition of sand and bauxite used as corrective materials.

Table 3: Chemical composition of designed raw cement meal

	Oxides%	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	SO ₃	LOI	Total	
	Schorcht et al. (2013)%	12-16	2-5	1.5-2.5	40-45	0.3-5	0.1-1.5	0.1-0.5	0-1.5	32-36	-	
Mix1%	Limestone	76	5.00	1.33	1.06	39.09	0.79	0.28	0.55	0.23	27.50	-
	Claystone	24	8.74	2.51	1.28	2.83	1.29	0.41	0.36	0.38	6.20	-
	Total	100	13.74	3.84	2.34	41.92	2.08	0.69	0.91	0.61	33.70	99.83
Mix2%	Limestone	81	5.33	1.42	1.13	41.66	0.84	0.30	0.59	0.24	29.31	-
	Claystone	14	5.09	1.45	0.75	1.65	0.75	0.24	0.21	0.23	3.62	-
	Bauxite	1	0.17	0.61	0.01	0.003	0	0	0.092	0.004	0.20	-
	Sand	4	3.47	0.03	0.03	0.03	0	0	0	0.006	0.43	-
	Total	100	14.06	3.51	1.92	43.34	1.59	0.54	0.80	0.48	33.56	99.80

Table 4: Chemical composition of correction materials

Oxides% Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	LOI	Total
Sand	86.75	0.80	0.66	0.76	0.003	0.0012	0.00001	0.15	10.65	99.77
Bauxite	16.55	60.78	1.31	0.28	0.004	0.01	0.19	0.38	19.66	99.16

Cement clinker manufacturing

Burning and cooling

The two raw mix materials were burned clinker preparation in furnace by utilizing a specific burning and cooling program with a soaking period of thirty minutes at a temperature of 1450°C. Hot clinker samples were fast cooled to 1200°C and then fast cooling from 1200 to 60 by using special technological technique at Materials and Energy Research Center (MERC), Tehran, Iran.

Rapid cooling leads to an increase in the content of Alite at the expense of other phases and therefore increases the compressive strength within 28 days (Kohl, 1979). The crystal form and structure of the clinker become simpler and clearer as the cooling rate increases (Bullard, 2015). The clinker cooling process has a direct impact on the final cement's quality, influencing the mineral composition, grinding capacity, and physical attributes (Duda, 1985). Slow cooling is to be avoided as it increases the Belite content and decreases the Alite content, produces relatively large C3A crystals, and ultimately produces concrete with poor rheology (Newman and Choo, 2003). It is possible that the crystallization of large Periclase grains will occur if the clinker contains a high magnesia content. This will adversely affect the quality of the cement. (Chatterjee, 2018).

Mineralogical analyses of clinker

The X-ray diffraction technique XRD was used to test the clinker in order to identify its mineral phases. The main mineralogical phases of clinker observed during the mineralogical analysis are description below:

The Tricalcium silicate phase, also known as Alite, exhibits multiple reflections that indicate a raised percentage in the cement. Its highest reflection occurs at $2.77\text{\AA}$, with weak reflections at $1.48\text{\AA}$ (Fig. 6). The majority of the reflections that are helpful in detecting Dicalcium silicate phase (Belite) are $2.448\text{\AA}$ and $2.403\text{\AA}$. It is possible that the reflection $2.448\text{\AA}$ may occasionally overlap with the weak reflection of Alite, which is located at $2.17\text{\AA}$ (Fig. 5 and 6). Typically, Tricalcium aluminate phase (Celite) can be identified by its strong reflection at ($2.70\text{\AA}$) (Fig. 8), but diagnosing it becomes challenging when this reflection partially or completely overlaps with the ferrite phase. Calcium Aluminoferrite phase (Ferrite) shows strong reflection at 2.68 and $2.63\text{\AA}$, but these values are close to the reflection value of $2.70\text{\AA}$ for aluminate and the reflection value of $2.608\text{\AA}$ for the Alite phase (Fig. 5).

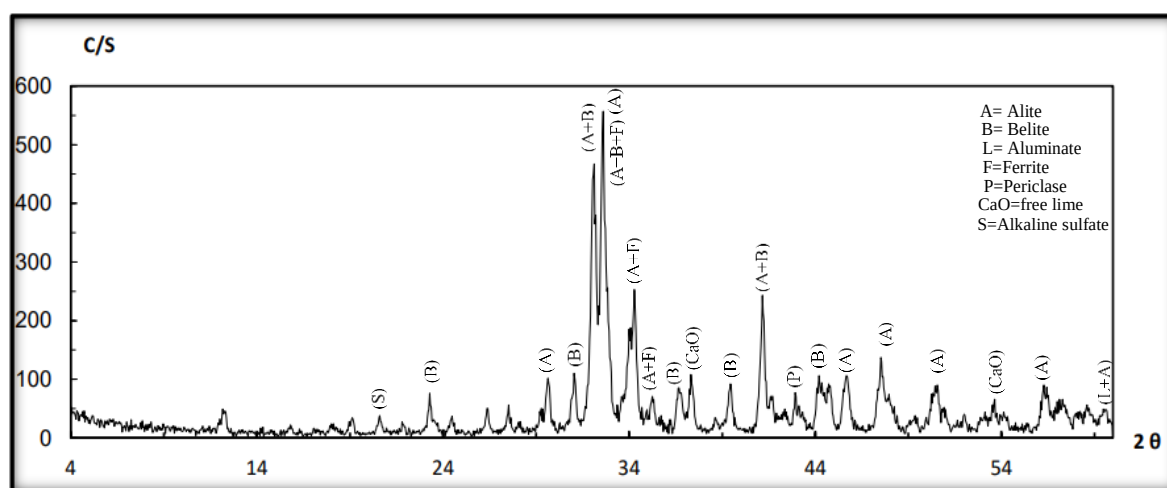


Fig. 5. The XRD patterns for produced clinker of Mix1

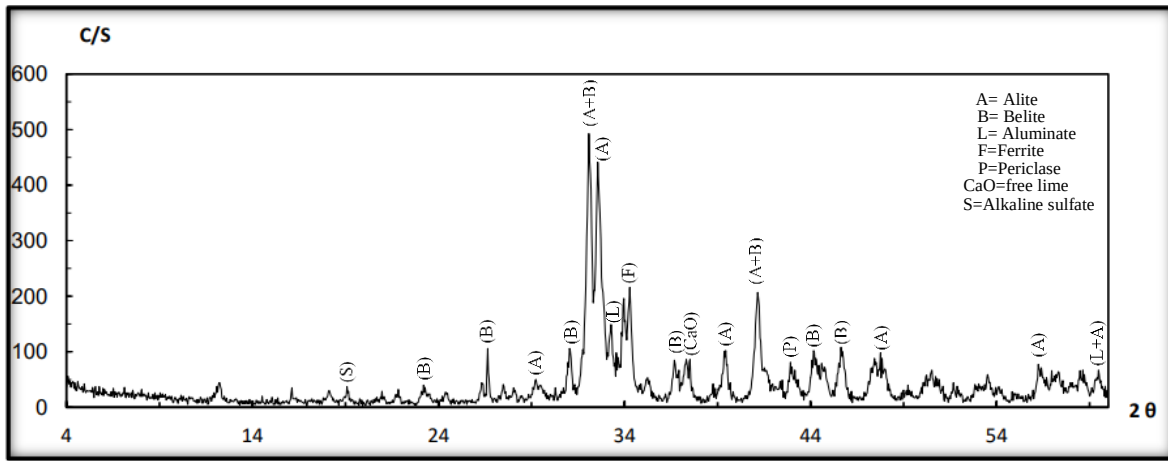


Fig. 6. XRD patterns for product clinker Mix2

Scanning electron microscopy (SEM)

In Portland cement clinker, the Alite crystals is the best clinker phase (Ahmadi 2017). Alite can only form when there is too much CaO, or when $\text{CaO}/\text{SiO}_2 > 1$. It stays stable above 1250°C thermodynamically (De la Torre, 2007). Depending on the angle of cut, typically have six sides in their cross section. They are also frequently perfect hexagons, Alite crystals are idiomorphous, vitreous, compact. (Pritula, *et al.*, 2004). Alite crystals typically range in size from 25 to $65\ \mu\text{m}$ in dimension. (Campbell, 1999). All of the samples contain these crystals in a distinctive crystalline shape the SEM inspection of the clinker samples revealed that the Alite phase crystals appeared in hexagonal configuration (Plate 1).

The grains of Belite are idiomorphous, vitreous, and often round in shape. Additionally, they have a distinct multidirectional lamellar structure. Below 1300°C , the size of Belite ranges from 1 to $4\ \mu\text{m}$, but it recrystallizes 20 to $40\ \mu\text{m}$ whenever it is subjected to treatment at high temperatures, which is around 1500°C (Campbell, 1999). In a microscopically examination, Belite phase crystals appear as round, euhedral crystals with smooth surfaces and transparent laminates (Plate 2 and 3).

In clinker that is either low in alkali or free of alkali, Tricalcium aluminate often consists of crystals that are uniformly tiny, xeromorphous to rectangular, and ranging in size from 1 to $60\ \mu\text{m}$ (Campbell, 1999). But alkaline Aluminate tends to crystallize in the shape of laminae, which can sometimes look like laths or long staves (Taylor, 1964) (Plate 3). Ferrite is characterized by its great reflectivity, which gives it a white appearance. It can be found in dendritic or lath-like forms (Stutzman and Leigh, 2002) (Plate 3).

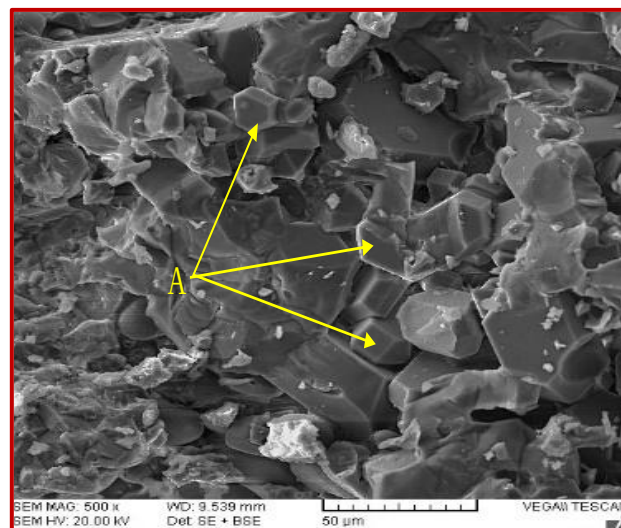


Plate 1. Micrograph by SEM of Mix2, A-Alite.

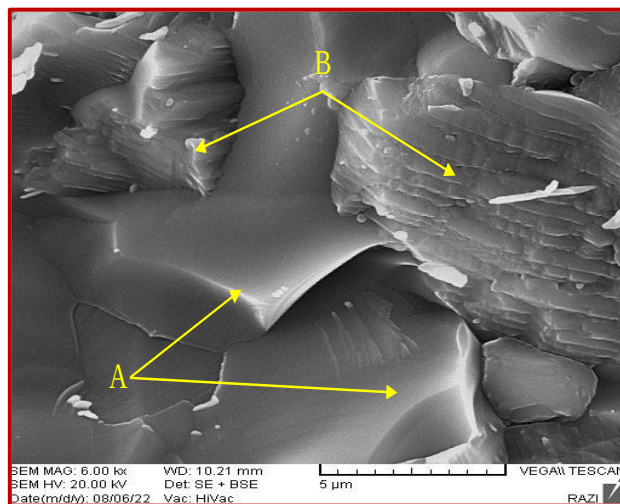


Plate 2. Micrograph by SEM of Mix1, A-Alite and B-Belite.

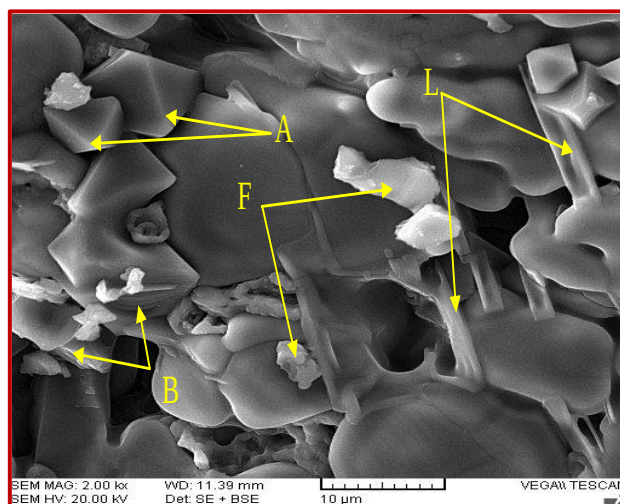


Plate 3. Micrograph by SEM of Mix2, A-Alite, B-Belite, L-Aluminate and F- Ferrite

Chemical analyses of clinker

(Table 5) shows the chemical analysis of two clinker samples using XRF technology. The results showed that CaO is the dominant oxide in the two mixtures. The percentages of oxides in the first mixture, Mix1 (without additives) and the second mixture, Mix2 (with additives), were respectively as follows. CaO (63.44%, 64.14%). SiO₂ (21.38%, 21.76%). Al₂O₃ (6.33%, 5.12%). Fe₂O₃ (2.31%, 2.15%). MgO (3.43%, 3.13%). Finally, SO₃ (1.27%, 0.97%) and compare it with (Duda, 1985).

Table 5: Chemical analyzes of produced cement clinker

specifications	(Duda, 1985)							(Rao <i>et al.</i> , 2011)		
Oxides and parameters	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Na ₂ O +K ₂ O	CaO	MgO	SO ₃	LSF%	SR	AR
specification values	16-26	4-8	2-5	0-1	58-67	1-5	0.1-2.5	92-98	2-3	1-4
clinker product Mix1	21.38	6.33	2.31	0.88	63.44	3.43	1.27	92.90	2.47	2.74
clinker product Mix2	21.76	5.12	2.15	0.64	64.14	3.13	0.97	94.51	2.99	2.38

Clinker phases

Bogue's formula is used to calculate the percentage of each mineral phase is likely to be in the clinker. Bogue's formulae for the major compounds in clinker are presented below (Table 6) (Chatterjee, 2018).

Table 6: Bogue's Equations for calculating the main phases of clinker

Clinker phases	If $\text{Al}_2\text{O}_3 / \text{Fe}_2\text{O}_3$ (alumina ratio) ≥ 0.64	If $\text{Al}_2\text{O}_3 / \text{Fe}_2\text{O}_3$ (alumina ratio) < 0.64
C_3S	$4.071\text{CaO} - 7.602\text{SiO}_2 - 6.719\text{Al}_2\text{O}_3 - 1.430\text{Fe}_2\text{O}_3 - 2.852\text{SO}_3$	$4.071\text{CaO} - 7.602\text{SiO}_2 - 4.479\text{Al}_2\text{O}_3 - 2.859\text{Fe}_2\text{O}_3 - 2.852\text{SO}_3$
C_2S	$2.867\text{SiO}_2 - 0.754\text{C}_3\text{S}$	$2.867\text{SiO}_2 - 0.754\text{C}_3\text{S}$
C_3A	$2.650\text{Al}_2\text{O}_3 - 1.692\text{Fe}_2\text{O}_3$	0
C_4AF	$3.043\text{Fe}_2\text{O}_3$	$2.10\text{Al}_2\text{O}_3 + 1.702\text{Fe}_2\text{O}_3$

The results showed that the C3S, C2S, C3A, and C4AF phases of clinker for Mix1 were (46.28, 26.40, 12.87, and 7.02) respectively. While the Mix2 were (55.45, 20.58, 9.93 and 6.54). When comparing the results with (Newman and Choo, 2003), the Mix2 is better than the Mix1 because it conforms to the specification, as shown in the (Table7).

Table 7: Results of the main phases of the clinker product

Clinker Phases	C3S	C2S	C3A	C4AF
Mix1	46.28	26.40	12.87	7.02
Mix2	55.45	20.58	9.93	6.54
Newman and Choo, 2003	45-65	10-30	5-12	6-12

Conclusions

1- According to fieldwork in the study area, it was found that the Serigakni Formation has significant thicknesses and extensions the limestone that can be exploited for many industries, specifically what concerns our study in the manufacture of ordinary Portland cement.

2 - Oxides of limestone are within the specification's limits of raw material for cement manufacturing.

3- The LSF, SR and AR values of the both mixtures theoretical are conform to international specifications.

4- The produced clinker phases were identified by XRD and several Alite reflections showed a high percentage of this phase.

5- The main phases of the clinker (C3S, C2S, C3A, and C4AF) are within the specification limits specified by (Newman and Zhou, 2003). Mix2 was better than mix1 because the increase in silica oxide compared to aluminum oxide led to an increase in the Alite phase.

6- SEM results showed that the crystals of the mineral phases of the clinker were very clear, indicating rapid cooling.

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