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GEOCHEMICAL SPECIFICATIONS FOR RAW MATERIALS USED IN GASIN CEMENT FACTORY IN KURDISTAN REGION NE-IRAQ

Chro M. Fatah

University of Sulaimani, College of Science, Department of Geology, Sulaimaniyah, Iraq,
Correspondence e-mail: chro.fatah@univsul.edu.iq

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ABSTRACT

This paper intends to provide background information on the chemically investigated raw materials used in the cement industry at the Gasin Cement Factory. Since it was found that the average carbonate ratio of $CaCO_3$ is 89.84 percent by weight ratio, the sulfide is less than 1 percent by weight ratio, and the magnesium carbonate is less than 3 percent, the raw materials entering the factory, including limestone, clay, iron, sand, and gypsum, were examined. Magnesium carbonate was less than or equal to 3 percent, in the iron with sand mixture, and the overall mixture carbonates were less than or equal to 76.24 percent. The findings of the analysis for silica oxides in the sand were greater than 82 percent. For sulfide oxide less than 1%, as well as for iron, the average value of ferric oxide that was examined in a laboratory was 35.51percent, from local iron ore, and an average reached 50.66% from Iranian iron ore, the percentage of alumina oxide that was tested in a laboratory was 9.37 percent and 3.40 percent from Local iron and Iranian iron respectively, silica oxide is more than 8.3 percent. As well as gypsum analysis, it was discovered that the average percentage of sulfur dioxide is higher than 40.97%. We identified the locations of the models that were evaluated and analyzed, as well as their storage locations.

1. INTRODUCTION

Cement is a hydraulic binder, a finely ground inorganic substance that, when mixed with water, forms a paste that sets and hardens through hydration reactions and processes, after hardening . The ancient Egyptians used materials like cement to make the entire construction of the pyramid. While the Greeks and Romans mixed volcanic ash with lime to make cement. In the current era of globalization, cement is required for human life, roads, bridges and many others (Halstead, 1961). Accordingly, the demand for cement products both qualitatively and quantitatively. The condition of the cement industry itself is now growing very rapidly. Many new cement companies have been built and new cement factories have been established (Dumez & Jeunemaître, 1998). They all compete for a significant market share in the society. Out of the competition that arises in the end, the strong will win. Reliable in terms of capital, production quality, and company profits. Meanwhile, cement factories face a dilemma situation where the natural resources used as raw materials for the cement industry are decreasing and limited in number. An increase in the number of existing cement plants and an expansion of production capacities lead to a reduction in the availability of raw material deposits that exist in nature.

Gasin Cement Company (GCC) is one of Faruk Holdings' strategic projects to build, promote, and improve strong infrastructure for the Kurdistan Region economy. GCC is located in the Bazian area, about 35 Km southwest of Sulaimaniyah city. Actual work on the project began in June 2013 and opened in July 2016. The plant was built on 2252 donum land by the SINOMA Company (China) at a total cost of 320 million dollars. Various raw materials were used in the factory such as (limestone, clay, sand, iron and gypsum). GCC is capable of producing various cement types such as OPC ordinary Portland cement, SRC sulfate-resistant cement and all other cement types according to market and customer demand with a capacity of 1,700,000 tons per year. In addition, GCC has paid great attention to the environment by implementing a filtration process through the use of four main house filter type filters within the facility. These filters can reduce the dust emitted from the chimneys into the atmosphere to less than 30 mg/m3. Thus, the GCC is considered an environmentally friendly project and has no negative impact on the environment. In Iraq, there are big differences in the quality of materials used in construction. This can be attributed to the weakness of local legislation in this sector, as well as the inadequate quality control procedure for imported building materials at border crossings. Applying for or implementing construction projects can suffer from the same problem. However, many construction companies have supplied or exported building materials and articles with a high level of quality control, especially to the Kurdistan Region. The cement industry of Sulaimani City has been built and expanded very rapidly in the last 16 years, before that time two cement companies were established (Sarchinar and Tasluja Cement Companies). Today, in addition to the Tasluja cement company, the industry includes 4 other production plants (Bazian, Mass, Gasin, and Delta cement companies). The Sarchinar cement company has now stopped production as it is located within the settlement area and cement production in the Kometan formation which does not have good cement quality as the proportion of silica in the limestone is too high. Therefore, this current work is a study to provide background information on raw materials limestone - clay - sand - iron ore, and gypsum and specifications of raw materials used in Gasin cement factory in the Kurdistan region to help researchers involved in the development of these set up work.

2. METHODOLOGY

Work started at the Gasin cement factory by tacking three samples of different raw materials (limestone – clay – sand – iron and gypsum) used in the factory over three different days and chemical analysis by use of X-ray fluorescence was carried out for each sample in the same Factory followed for other 3 samples of Kiln feed taken on different days. Calculation and expected chemical composition of kiln feed clinker was proposed by Lea & Parker (1935)and mentioned in Alao (1979) and modified by many, notably (WALTER, 1976)and finding the clinker phase using a modified Bogue calculation (Lin & Lin, 2006).

2.1. Raw Materials Mixing

The first step in the manufactures of cement is the raw materials and their grouping so that the required chemical composition reacts with the heat generated by the kilns. The raw materials used in the cement industry are ground so that the reaction can run smoothly. Mixed, prepared for the kiln and the grist heated to extremely high temperatures at a temperature of around 1500 °C, a well homogenized and finely ground mixture of limestone or chalk (calcium carbonate) and a reasonable amount of clay or shale. Since the final composition and properties of cement are defined within fairly narrow limits, it would be expected that the raw mix requirements would be similarly stringent. Because that often doesn't seem to be the case. While the correct ratio of calcium, silicon, aluminum, and iron is critical, the overall chemical composition and structure of each raw material can vary significantly. The reason for this is often that at very high temperatures in the furnace, many chemical components in the raw materials are burned and replaced with oxygen from the air. Table 1 lists just some of the different possible raw materials that commonly provide each of the most cement elements (Al-Naffakh et al., 2020)

Table 1. Raw ingredients used to provide each of the main cement elements (Al-Naffakh et al., 2020)

Calcium	Silicon	Aluminum	Iron
Limestone	Clay	Clay	Clay
Marl	Marl	Shale	Iron Ore
Calcite	Sand	Fly ash	Mill Scale
Aragonite	Shale	Aluminum	Shale
Shale	Fly Ash		Blast Furnace Dust
Sea Shells	Rice Husk Ash		
Cement Kiln Dust	Slag		

In general, there are three types of cement raw materials, namely clinker/slag cement (70% to 95%, which results from the combustion of limestone, silica sand, iron sand and clay), gypsum (about 5%, as a hardening retarder) and third-party materials such as limestone, pozzolan, fly ash, and others. The process of making cement consists of grinding the raw materials, intimately mixing them in certain proportions depending on their purity and composition, and firing them in a kiln at a temperature of about 1300 – 1500 °Cat which temperature the material sinters and partially melts to form nodular clinker. The clinker is cooled and ground to a fine powder with the addition of about 3 to 5% gypsum. The product formed by this process is Portland cement. In general, if the third element is no more than about 3%, it still meets the quality of OPC (ordinary Portland cement). However, when the content of the third material is higher and reaches a maximum of about 25%, then the cement will change to PCC (Portland Composite Cement) type (Ghosh, 2003) There are two processes known as wet and dry processes depending on whether the mixing and grinding of raw materials is carried out under dry processes at the Gasin cement factory. Ordinary Portland cement is the most common type of cement in general use around the world because it is a basic ingredient of concert, mortar, stucco, and most non-specialty grout (Mirza et al., 2016) resistance to sulfate and thermal hydration. Ordinary Portland cement contains the main compounds in Table (2).

Table 2. Composition of main cement compounds (Mindess et al., 2003)

Name of Compound	Formula	Abbreviated Formula
Tricalcium silicate	$3\ CaO.SiO_2$	C_3S
Dicalcium silicate	$2\ CaO.SiO_2$	C_2S
Tricalcium aluminate	$3\ CaO.Al_2O_3$	C_3A
Tetracalcium aluminoferrite	$4\ CaO.Al_2O_3.Fe_2O_3$	C_4AF
In addition to a small amount of gypsum, MgO, K_2O, and Na_2O		

C_3S and C_2S are the most dominant compounds in cement and provide cement properties. When exposed to water, C_3S will immediately hydrate and produce heat. Whereas C_2S reacts with water slower, so it only affects the hardening of the cement after more than seven days of age and provides ultimate strength. C_2S also makes cement resistant to chemical attack and reduces drying losses. The C_3A element (the third element) is exothermically hydrated and reacts very quickly to give strength after 24 hours. The fourth element, C_4AF, has less influence on cement hardness. The small iron content in white cement will give a little C_4AF content in cement, so the quality of cement will increase in terms of strength.

Gypsum material is an essential primary material added to cement in the final stage with 3% clinker where the acceptable mixing limits for sulfur oxide are from 31% to 40% for secondary gypsum and primary gypsum 40% to 44%.

2.2. Raw Materials of Cement

2.2.1. Limestone

Limestone is one of the most important of all sedimentary rocks fundamentally composed of the mineral calcite ($CaCO_3$). They may contain a few other carbonate minerals broadly utilized industry. Although limestone is the primary raw material for the cement manufacturing industry where chemical properties are important. Therefore, limestone material can be large and long-lived, quarrying layers of limestone that can be hundreds of feet thick over areas several square miles. About 75% of cement raw materials consist of lime (CaO)-containing materials (Lea, 1935) Dolomite and dolomitic limestone are unsuitable for cement production due to their high magnesia (MgO) content. In Sulaymaniyah, the cement industry uses the calcareous limestone in the Sinjar Formation (Early Eocene). Limestone is the main source of limestone raw materials in the Sulaymaniyah-Bazian area. This limestone tends to have low porosity and therefore low moisture content; hence the dry process is used in cement manufacture from these resources. Thus, limestone was brought from quarries of the Gasin cement factory, which is located near the factory, and then transferred to crushers and transported by the rubber conveyor, then stored in the warehouses of the factory and previously transferred to the feeding area of the mill’s laboratory, before they are sent to the feeding area.

2.2.2. Clay

It is a primary material used in the manufacture of cement, and it is considered to be the main source of SiO_2, Al_2O_3, and Fe_2O_3 (Fatah & Mirza, 2021). It contains 23.5% aluminum oxide, and 46.5% silicon dioxide and is used in the manufacture of white ceramics, packaging and paper coating. Also used as a filler in paints, rubber, plastics and many other products (Ridi, 2010). The proportions of aluminum oxide and silica vary depending on the type of clay. Since clay material plays a crucial role in the manufacture of cement, it is mixed in certain proportions with other materials used in the manufacture of cement, such as limestone, iron dust and other materials involved in the manufacture of cement. Where the Gasin cement factory uses the clay from the recent deposit, which is 50 Km from the cement factory.

2.2.3. Gypsum

Gypsum consists of calcium sulfate and quartz is the most common impurity. Most gypsum is a soft, friable rock that does not require explosives to mine. Gypsum material referred to as hydrous calcium sulfate is being brought to Gasin cement factory from the Fatha formation, previously referred to as the Lower Fars formation, where exploration was conducted in the Bazian-Takiya area. Primary and secondary gypsum contained in the cement industry due to the proximity to the factory and the material encountered Gypsum material is an essential primary material that is added to the cement in the penultimate stage at 3% clinker with the acceptable mixing limits for sulfur oxide being 31% to 40% for secondary gypsum and primary gypsum from 40% to 44% and the insoluble materials from 5% to 11% for secondary gypsum and from 3% to 6% for primary gypsum. Rejection in the presence of a sulfur oxide content greater than 30% for the secondary gypsum and also if the sulfur oxide content for the primary gypsum exceeds 43% and is discarded if the proportion of non-receptive materials increases.

The solubility is about 8% for secondary gypsum and more than 6% for primary gypsum. Thus, if the gypsum does not meet the above- accepted mixing limits, it will be discarded and replaced with excellent- quality for mixing.

2.2.4. Sandstone

Nearly a quarter of the sedimentary rocks in the geological record are sandstones. The framework portion of sandstone is composed of sand and large silt particles that range in size from 1/16 to 2 mm. Sandstones can also have varied concentrations of cement and matrix (material less than 0.03 mm), which are present in the empty pore space and the interstitial pore space between the framework grains (porosity). Since quartz is the most common form of silica, sandstone is utilized at the Gasin Cement Plant as a corrective additive to replenish SiO_2. The sandstone from the Fatha Formation in the Bazian-Takya region is used for SiO_2 correction in the Gasin Cement Plant.

2.2.5. Iron ore

Iron is one of the most common elements on earth. Almost every human construction contains at least some iron. It is also one of the oldest metals, having been first made into utility and ornamental objects at least 3,500 years ago. Pure iron is a soft, off-white metal. Although iron is a common element, pure iron is rarely found in nature. The only pure iron known to exist naturally comes from fallen meteorites. Most iron is found in minerals formed by combining iron with other elements. Iron oxides are the most common. Those minerals near the surface of the earth that have the highest iron content are called iron ores and are mined commercially. Iron ores are primarily iron oxides and include magnetite, hematite, limonite, and many other rocks. The partial replacement of the cement with iron powder significantly improved the compressive strength compared to the concrete without iron powder (Fe_2O_3) particles. In the Gasin Cement Factory, iron is used for cement production in two different places, one from local iron and the other from Iranian iron.

2.3. Quality of the raw materials

Portland cement is made by powder heating a batch mixture of limestone, clay and/or other materials (sand and iron) to a temperature of ~1450 °C. Partial fusion occurs and nodules or clinker balls are formed. The clinker is a ground mixture containing 5% raw gypsum to control the rate of dilution of the cement produced. The cement clinker typically has a composition in the range of 67% CaO, 22% SiO_2, 5% Al_2O_3, 3% Fe_2O_3, and 3% other components and normally contains four main phases; alite, belite, Ca-aluminates, and ferrite phases(Kosmatka et al., 2003). Other phases such as alkali sulfates and calcium oxide are usually present in small amounts (Taylor, 1997).

Cement experts pay attention to several factors that determine the quality of the raw materials. The most important factors are the lime saturation factor (LSF), the silicate ratio (SR), and the aluminum ratio (AR) (Schneider et al., 2011) The LSF is used to dose the raw mixture. It is the ratio of CaO to the other three main oxides and is calculated as follows: $LSF = CaO/ (2.8SiO_2 + 1.2Al_2O_3 + 0.65Fe_2O_3)$ and varies between 0.88 and 0.95 for Portland cement. The SR is the weight percentage of SiO_2 divided by the weight percentage of Al_2O_3 and Fe_2O_3 is < 3 for most cement products. The AR is the weight percentage of Al_2O_3 divided by the weight percentage of Fe_2O_3, it is less than 2 and the preferred range should be between 1.6 and 1.8 as lower values result in lower clinker temperature. The other controlling factors are the MgO, SO_3, and Cl content. If higher concentrations of SO_3 and Cl exit in the raw materials, malfunctions in the kiln during firing are to be expected. The MgO content should not exceed 5% in the raw material as it forms small periclase crystals that slowly expand in the cement or concrete causing cracks. Clays usually contain limited amounts of Na_2O, K_2O, SO_3

and Cl < 0.3.2% and 0.015% respectively, they would be suitable for the manufacture of cement, while silica must not exceed three times the percentages of $Al_2O_3 + Fe_2O_3$ as mentioned by Youssef (1994).

3. RESULTS AND DISCUSSIONS

3.1. Quantitative chemical analysis of raw materials

Laboratory chemical analyses for the raw materials used in the manufacture of cement material for the period from 03/02/2022 to 05/02/2022 were carried out in the laboratories of the Gasin cement factory in the Bazian area. As the raw materials play an essential role in the quality and stability of the product, the raw materials should have tight, unvarying specifications. The results of the chemical analyses meet the requirements for the raw materials needed to produce cement within the required limits.

3.2. Quantitative chemical analysis of the limestone samples

The main component of limestone is calcium carbonate ($CaCO_3$), which breaks down into CaO and CO_2 when heated. The chemical (laboratory) requirements for the raw materials needed to produce cement as required limits for the magnesium carbonate present in the limestone are less than or equal to 3% compared to the average value of 1.95% determined by the laboratory tests. According to the data in Table (3), the average range of silica is 3.60%, these contents are relatively reasonable range. The Average ranges of alumina, iron oxide, and lime contents are 1.28%, 0.72%, and 50.34%, respectively. The high level of lime (CaO) is related to the carbonate rocks of Sinjar Limestone. The average ranges of alkali content (Na_2O, K_2O) are each between (0.03 – 0.09) percent. The required value for sulfate in limestone is less than or equal to 1%, while the average value obtained in the laboratory was 0.14%. The average range of the lime saturation factor is 428.69%. This range is very high and should be a consistent range by adding clay materials near the study area. While the silica ratio and the aluminum ratio average 1.80% and 1.70%, respectively. The high silicate content is mainly due to the high levels of silica SiO_2 and low levels of aluminum oxide Al_2O_3 and iron oxides Fe_2O_3. The average total amount of carbonates is 89.94%, while the non-carbonate content is around 9.8% – 10.8%. The loss on ignition average reaches 41.51% Table (3). Accordingly, the limestone in the Sinjar Formation used in the Gasin cement factory is of good quality for cement industry based on the above-mentioned factors and their ranges.

3.3. Quantitative chemical analysis of the Clay samples

According to the data shown in Table (4), the average range for contents is silica (37.93%), alumina (10.04%), iron oxides (4.59%), lime (20.28%), magnesia (3.07%), alkalis (0.05 and 0.03%) and sulfates (0.33%). The calculated average value of the lime saturation factor is 18.63%, these values are relatively low due to the increasing content of silica, alumina, and iron oxides. The average percentage of silica and aluminum is 2.59% and 2.19%, respectively. The loss on ignition averaged 22.48%. For clay, the ratio of silica to iron oxide and alumina is around 2 (within the recommended range), which is reasonable for cement industry.

3.4. Quantitative chemical analysis of the gypsum samples

According to the data shown in Table (5), the average range for silica (4.05%), alumina (1.35%), iron oxide (0.63%), lime (25.05%), magnesia (8.38%), alkalis (0.26 and 0.22%) and sulfates (41.15%). The loss on ignition average reached 18.22%. For gypsum, the required sulfate level is greater than or equal to 31%, while the laboratory average for sulfates was 41.15%. Thus, the gypsum material is considered to be good and acceptable in the manufacture of cement and within specification.

3.5. Quantitative chemical analysis of the sand samples

The results shown Table (6) showed that the average value of silica in sand material recorded in the laboratory is 83.29%, so the required value is greater than or equal to 85% according to the required specifications. The average range for contents of alumina (4.09%), iron oxides (4.20%), lime (1.34%), magnesia (0.66%), and alkalis (0.18 and 0.07%). The loss on ignition average reached 4.55%. While the sulfate value in the sand was less than or equal to 1% as required, the laboratory average is 0.04%. Thus, the sand material is regarded as acceptable and valid in cement manufacture.

Table 3: The average chemical analysis of limestone samples used at the Gasin cement factory.

Oxides %	Limestone 1	Limestone 2	Limestone 3	Average %
SiO_2	3.66	3.17	3.98	3.60
Al_2O_3	1.11	1.28	1.44	1.28
Fe_2O_3	0.69	0.70	0.77	0.72
CaO	49.99	50.55	50.48	50.34
MgO	2.00	1.99	1.87	1.95
SO_3	0.14	0.14	0.13	0.14
K_2O	0.09	0.09	0.09	0.09
Na_2O,	0.04	0.03	0.03	0.03
L.O. I	41.60	41.97	40.95	41.51
Total	99.12	99.92	99.74	99.99
$CaCO_3$	89.22	90.22	90.09	89.84
LSF	428.07	478.90	387.98	428.69
SR	2.03	1.60	1.80	1.80
AR	1.61	1.83	1.87	1.78

Table 4: The average chemical analysis of clay samples used in the Gasin cement factory.

Oxides %	Clay 1	Clay2	Clay3	Average %
SiO_2	37.82	38.01	37.95	37.93
Al_2O_3	10.00	10.16	9.95	10.04
Fe_2O_3	4.96	4.62	4.19	4.59
CaO	20.14	20.25	20.44	20.28
MgO	3.12	2.98	3.11	3.07
SO_3	0.32	0.35	0.33	0.33
K_2O	0.03	0.03	0.08	0.05
Na_2O,	0.04	0.03	0.03	0.03
L.O.I	22.96	22.51	21.98	22.48
Total	99.39	98.94	98.06	98.80
LSF	18.56	18.49	18.83	18.63
SR	2.53	2.57	2.68	2.59
AR	2.02	2.20	2.37	2.19

Table 5: Chemical analysis of Gypsum samples used in Gasin Cement Factory

Oxides %	Gypsum 1	Gypsum 2	Gypsum 3	Average %
SiO_2	4.13	3.09	4.03	4.05
Al_2O_3	1.35	1.42	1.29	1.35
Fe_2O_3	0.63	0.61	0.64	0.63
CaO	24.40	25.11	25.65	25.05
MgO	8.65	8.33	8.15	8.38
SO_3	41.46	40.97	41.03	41.15
K_2O	0.26	0.26	0.26	0.26
Na_2O,	0.22	0.22	0.21	0.22
L.O.I	18.67	17.96	18.03	18.22
Total	99.77	98.87	99.29	99.31

Table 6: Chemical analysis of Sandstone samples used in Gasin Cement Factory.

Oxides %	Sandstone 1	Sandstone 2	Sandstone 3	Average %
SiO_2	83.84	83.73	82.31	83.29
Al_2O_3	4.86	3.07	4.35	4.09
Fe_2O_3	3.80	4.62	4.19	4.20
CaO	1.16	0.99	1.87	1.34
MgO	0.72	0.48	0.79	0.66
SO_3	0.01	0.01	0.10	0.04
K_2O	0.27	0.14	0.14	0.18
Na_2O,	0.14	0.03	0.03	0.07
L.O.I	4.67	5.01	3.96	4.55
Total	99.47	98.08	97.74	98.43

3.6. Quantitative chemical analysis of the Iron samples

Regarding triple iron oxide, the required iron dust ratio is greater than or equal to 55% within the standard, while the average value obtained through laboratory tests was 35.51% from local iron and 50.72% from Iranian iron Tables (7 and 8). Likewise, for triple alumina, the proportion of iron dust is less than or equal to 10%, while the average value obtained for alumina in the laboratory is 3.40 from Iranian iron, the average value reaches 9.37% for local iron. As shown in Tables (7 and 8), this clarifies the values of raw materials used in the cement industry that obtained in the laboratory.

3.7. The chemistry of the raw mix in the factory

Cement is generally a combination of limestone, shells or chalk, and shale, clay, sand, or iron ore, usually mined from a quarry near the plant. The basic chemical components of Portland cement are calcium (Ca), silicon (Si), aluminum (Al), and iron (Fe). The percentage of limestone and clay-forming raw material mix varies from mill to mill depending on available material, and mill specifications. By the way; percentage of cement raw materials are attempts that meet a certain standard. It is common for the components to make up about 75% of the mix and the clay to make up about 25%. Therefore, assuming that in one round of the previous quantities, the limestone and clay are to be used as raw materials, ready-made examples of quartz sand, high silicate clay, and iron are used as additives Table (9). Average chemical analysis of clay, limestone, and other additives on site are shown in Tables (3, 4, 5, 6, 7, and 8).

3.8. Optimized chemical composition of clinker

After determining the proportion of the mixture contribution of clay and limestone, which is a suitable proportion, the chemical composition of the final mixture is obtained by adjusting the proportion of each oxide of both clay and limestone after correction, adding sand, iron as an additive for correction or minimization, oxides are determined. Then the concentration of each oxide in the final mixture is obtained by the sum of these fields obtained in the laboratory of the Gasin Cement Plant (Table 9). The next step is to find the expected chemical composition of the clinker. Considering that the clinker has no loss through burning, (L.O.I) for the clinker is equal to zero, and then the process of recalculation is carried out for all the remaining oxides in the mix in the absence of (L.O.I) to find the expected percentage of each oxide in the clinker (Table 10).

Table 7: Chemical analysis of local iron samples used in the Gasin cement factory.

Oxides %	Iron1	Iron2	Iron3	Average
SiO_2	29.50	23.12	30.01	27.54
Al_2O_3	9.79	10.40	7.93	9.37
Fe_2O_3	31.44	39.55	35.55	35.51
CaO	13.53	11.70	13.10	12.78
MgO	13.92	13.50	11.37	12.93
SO_3	0.47	0.73	0.48	0.56
K_2O	00.37	0.39	0.35	0.37
Na_2O	0.44	0.13	0.23	0.27
L.O.I	0.00	0.00	0.00	0.00
Total	99.46	99.52	99.02	99.33

Table 8: Chemical Analysis of Iranian Iron Samples used at Gasin Cement factory.

Oxides %	Iron1	Iron2	Iron3	Average
SiO_2	8.38	9.18	9.93	9.16
Al_2O_3	3.65	3.11	3.44	3.40
Fe_2O_3	50.52	50.97	50.66	50.72
CaO	9.17	9.00	8.77	8.98
MgO	10.72	9.98	10.94	10.55
SO_3	0.06	0.09	0.16	0.10
K_2O	0.35	0.37	0.35	0.36
Na_2O	0.31	0.35	0.33	0.33
L.O.I	16.18	15.38	15.04	15.53
Total	99.25	99.59	99.07	99.30

Table 9: Chemical analysis of Kiln feed (raw mix).

Oxides %	Kiln feed 1	Kiln feed 2	Kiln feed 3	Average %
SiO_2	13.28	13.29	13.22	13.26
Al_2O_3	2.93	2.90	2.92	2.92
Fe_2O_3	3.27	3.26	3.22	3.25
CaO	42.72	42.87	43.03	42.86
MgO	1.15	1.14	1.15	1.15
SO_3	0.08	0.08	0.08	0.08
K_2O	0.26	0.26	0.26	0.26
Na_2O,	0.12	0.10	0.10	0.11
L.O.I	35.56	35.62	35.75	35.64
Total	99.37	99.49	99.73	99.55

Table 10: Calculate the composition of the expected clinker with some properties.

Oxides %	clinker 1	clinker 2	clinker 3	average %
SiO2	20.81	20.81	20.66	20.76
Al2O3	4.59	4.54	4.56	4.57
Fe2O3	5.12	5.10	5.03	5.09
CaO	66.95	67.12	67.26	67.11
MgO	1.80	1.78	1.80	1.79
SO3	0.13	0.13	0.13	0.13
K2O	0.41	0.41	0.41	0.41
Na2O	0.19	0.16	0.16	0.17
L.O.I	0.00	0.00	0.00	0.00
Total	100.00	100.05	100.00	100.02
C3S	75.85	76.93	78.60	77.08
C2S	2.45	1.63	1.23	1.37
C3A	3.50	3.40	3.57	3.50
C4AF	15.59	15.52	15.31	15.49
LSF	100	100	101	101
SR	2.14	2.16	2.15	2.15
AR	0.90	0.89	0.90	0.90

3.9. Clinker Phases

The properties of Portland cement are determined mainly by the proportion of its four principal clinker phases which are the impure forms of Ca_3SiO_5 (alite), Ca_2SiO_4 (belite), $Ca_3Al_2O_6$ (tricalcium aluminate) and C_4AF tetracalciumalumino ferrite (4CaO. Al_2O_3 Fe_2O_3). (Mirza et al., 2016) and (Mirza & Fatah, 2018). Other phases such as periclase (MgO), quartz (SiO_2), free lime (CaO), etc. may also be present in minor quantities, usually less than 1%w. The clinker phases C_3S, C_2S, C_3A, and C_4AF in the studied samples range between (75.85 – 78.60) %, (1.23 – 2.45), (3.40 – 3.57) and (15.31 – 15.59) % respectively (Table 10). Comparing these results with typical constituents of C_3S, C_2S, C_3A, and C_4AF in normal Portland cement by (Newman & Choo, 2003) and (Brandt et al., 2009) Table (11). It becomes clear that three studied samples are out of the range of Portland cement except for the aluminate within range. Therefore, the Gasin cement factory is able can produce ordinary Portland cement OPC, sulfate resistance cement SRC, and any other cement types. The percentage of C_3A is ranges between (3.40 – 3.57) %, according to Iraqi specification no. (6) Limits - max. C_3A content of 3.5% is more suitable for Producing sulfate resistance cement SRC and according to American standard (ASTM) - Max C_3A content by 5%. According to standard specifications higher content of C_3S and C_3A (C_3S > 55%, but sometimes as high as 70%) is more suitable for Producing rapid-hardening Portland cement (R.H.P.C).

Table 11: Mineralogical composition expressed as a percentage of Portland cement (based on (Newman & Choo, 2003) and (Brandt et al., 2009)

Cement notation	Mineral name	Typical level (mass %)	Typical range (mass %)	Typical range (Studied samples %)	Chemical composition
C_3S	Alite	57	38 – 60	75.85 – 78.60	$3CaO. SiO_2$
C_2S	Belite	16	15 – 38	1.23 – 2.45	$2CaO. SiO_2$
C_3A	Aluminate	9	7 – 15	3.40 – 3.57	$3CaO. Al_2O_3$
C_4AF	Ferrite	10	6 – 18	15.31 – 15.59	$CaO. Al_2O_3. Fe_2O_3$

4. CONCLUSIONS

- The average ratio of MgO obtained in the laboratory was 1.95%, which is regarded to be within the needed standard, and we infer that the percentage required is less than or equal to 3% within the specifications of the magnesium carbonate evaluation and specific control equipment. The limestone's sulphate sulfate concentration is excellent and within the required range
- The sulfate content in the sand is an ideal ratio as the laboratory average was 0.04% while the required value is less than or equal to 1% within the stated specifications.
- The average sulfate content in gypsum according to laboratory tests was 41.15%, while the required ratio is greater than or equal to 31% within the established specifications. Thus, the gypsum material is considered to be good and acceptable in the manufacture of cement and within specification.
- The average silica content in the limestone tested in the laboratory was 3.60%, while the required content within the established standard is less than or equal to 5% and is therefore considered within the standard. Therefore, at low rates, it is preferable to find a better limestone and not to exceed the percentage of silica in it by 5%.
- The sand that enters the cement industry is considered an acceptable and good material as it has an average silica content of 83.29% when tested in the laboratory. In contrast, the required percentage within the set specification is greater than or equal to 85%, and thus the sand material is considered acceptable and valid for the manufacture of cement.
- The proportion of iron trioxide in the iron dust should be the required percentage according to the established specifications greater than or equal to 55%, while the average value that the examined laboratory achieves at 35.51% of local iron and an average of 50.66% of Iranian iron. This is considered Iranian iron is better than local iron used to make cement. Thus, iron dust is an excellent material in the manufacture of cement.
- According to the established and accepted norm, the average alumina level in iron should be less than or equal to 10%, however, the laboratory test results for Iranian and local iron were 9.37% and 3.40%, respectively. Iranian iron is regarded as having a low percentage even if this local iron meets the criteria. To stay within the acceptable level, it is preferred that the amount of alumina in iron dust be raised, but not above 10%.

- According to the required standard, the silica content in the clay should be in the range of (38% – 42%), while the value tested in the laboratory was 37.93%. Thus, the clay material is acceptable and valid for its use in the manufacture of cement.
- According to the standard specification, silicate content (C_3S) of more than 75% is more suitable for the production of Rapid Hardening Portland Cement (R.H.P.C).

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