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Comparison between local petroleum cements "GICA Setif and LAFARGE M'sila"

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يقول النبي "من لا يشكر الناس لا يشكر الله"

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We would also like to present our sincere thanks to the members of the jury

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Abbreviations list

Abbreviation	Definition
M	Magnesia.
API	American Petroleum Institute.
SCAEK	La société des Ciments de Ain El Kebira.
GICA	Groupe Industriel des Ciments d'Algérie.
SNMC	Société Nationale des Matériaux de Construction.
ERCE	Entreprise des ciments et derives de l’est.
SAS	Société par Actions Simplifiée.
B-L	Low-alkali cement.
L-H	Low heat of hydration.
SR	Sulphate Resistant.
A-L	The cement contains limestone as a secondary mineral additive.
NA442	A product code or identifier specific to the manufacturer.
CEM	Cement.
HSR	High Sulphate Resistant.
SCAEK	Société des Ciments d'Ain El Kebira.
LOI	Loss On Ignition.
IR	Insoluble Residue.
µm	Micrometer.
SGSA	Static gel strength analyzer.
ISO	International Organization for Standardization.
HTHP	High-Temperature High-Pressure.
ASTM	American Society for Testing and Materials.
XRF	X-ray fluorescence.
Annex C	Calibration and Verification of Well Cement Testing Equipment.

Units list

units	Definition
°C	Degree Celsius.
g	Gram.
L	Liter.
ml	Milliliters.
psi	Pounds Per Square Inch.
Bc	Bearden Consistency.
ft	Foot.
m	Meter.
h	Houre.
min	Minute.
sec	Second.
°F	Degree Fahrenheit.
mm	Millimeter.
in	Inche.
PPG	pounds per gallon.
r/s	Rotate per second.
MPa	Megapascal.
°C/min	Degree Celsius per minute.
°F/min	Degree Fahrenheit per minute.
g/Cm^2	Grame per Square centimeter.
r/min	Rotate per minute.
g/cm^3	Grame per cubic centimeter.
DZD	Designating the Algerian dinar.
Km	kilometer

Nomenclature

Chemical formula	**Element**
CaO	Lime.
SiO_2	Silica.
Al_2O_3	Alumina.
Fe_2O_3	Hematite.
SO_3	Sulfur Oxide.
K_2O	Potassium Oxide.
MgO	Magnesium Oxide.
SO_3	Sulfur Trioxide.
$3*CaO.SiO_2$	Tricalcium Silicate.
$3*CaO.Al_2O_3$	Tricalcium Aluminate.
C_3S	Tricalcium Silicate.
C_2S	Dicalcium Silicate.
C_3A	Tricalcium Aluminate.
C_4AF	Tetracalcium Aluminoferrite.
Na_2O	Sodium Oxide.
TiO_2	Titanium and Oxygen.
Mn_2O_3	Manganese(III) Oxide.

ملخص

نظرا للطلب المتزايد على الاسمنت البترولي في بلادنا والاعتماد على الاستيراد، تهدف هذه الدراسة لتحسين نوعية الاسمنت المنتج محليا (مصنع لافارج المسيلة و مصنع جيكا سطيف) وهو ما قد يكون حافزا للمصانع الاخرى (مركب الاسمنت حجار السود سكيكدة، مركب الاسمنت بسكرة، مركب الاسمنت زهانة معسكر...) لتوفير هذه المادة مما يقلل استيرادها وبالتالي توفير العملة الصعبة.

لتحقيق الهدف المراد قمنا بمقارنة التركيبة الكيميائية والخصائص الفيزيائية للإسمنت البترولي المنتج محليا بالتركيبة الكيميائية والخصائص الفيزيائية للإسمنت البترولي البورتلاندي ووجدنا ان الكثافة هي العامل الممكن تغييره للحصول على اسمنت مطابق للمعايير الموضوعة من طرف المعهد الامريكي للبترول.

الكلمات المفتاحية: تحسين، الاسمنتالبترولي ، اسمنت محلي، اسمنت بورتلاندي.

Abstract

Due to the increasing demand for petroleum cement in our country and dependence on imports, this study aims to improve the quality of cement produced locally (LAFARGE M'sila factory and GICA Setif factory), which may be an incentive for other factories (Hajjar As-Soud Skikda cement complex, Biskra cement complex, Zahana cement complex Mascara...) to provide this material, which reduces its import and thus saves hard currency.

To achieve the desired goal, we compared the chemical composition and physical properties of petroleum cement produced locally with the chemical composition and physical properties of Portland petroleum cement, and we found that density is the factor that can be changed to obtain cement that conforms to the standards set by the American Petroleum Institute.

Keywords: petroleum cement, local production, improvement.

Résumé

En raison de la demande croissante en ciment pétrolier dans notre pays et de la dépendance aux importations, cette étude vise à améliorer la qualité du ciment produit localement (usine Lafarge M'sila et usine Gika Sétif), ce qui peut être une incitation pour d'autres usines (Hajjar As -Cimenterie de Soud Skikda, Cimenterie de Biskra, Cimenterie du camp de Zahana...) pour fournir ce matériau, ce qui réduit son importation et économise ainsi des devises fortes.

Pour atteindre l'objectif recherché, nous avons comparé la composition chimique et les propriétés physiques du ciment pétrolier produit localement avec la composition chimique et les propriétés physiques du ciment pétrolier Portland, et nous avons constaté que la densité est le facteur qui peut être modifié pour obtenir un ciment conforme aux normes établies par l'American Petroleum Institute.

Mots clés : ciment pétrolier, production locale, amélioration.

General introduction

The cementation process during oil exploration is considered the basic tool to protect the well. This process is crucial because it guarantees the reliability of production, and it is considered an essential step that has a direct impact on the life span of the oil wells. For petroleum engineering, this process is very critical depends on several factors including the quality of the cement.

The thesis titled "Development of local cement characteristics to achieve standard Portland cement characteristics by adding local material" focuses on exploring the potential of different materials from local sources and their impact on the properties and performance of cement. The study involves extensive laboratory testing, analysis, and experimentation to evaluate the effect of these local materials on composition, time, compressive strength, and other key properties of cement. By carefully adjusting the proportions and composition of the local materials, the aim is to achieve a cement product that closely complies with the standards characteristics Portland cement.

This work is presented as follows:

• The first chapter intended for the bibliographical study on the cement, in this chapter we exposed the cementation and methods of manufacture of cement,

• The second chapter in which we present the SCAEK Setif factory and BJSP Company the experimental tests carried out to characterize the Algerian cement and the cement slurries prepared by the latter.We wanted to do some experiments on three cement samples,

• The last chapter, we compared the chemical and physical properties of each of the local cement of LAFARGE Company and SCAEK Company with Portland cement and presented some results and ideas.

Chapter I

General informations on cementing and Portland cement

I.1. General informationson cementing

I.1.1. Introduction

The drilling of wells is carried out in stages due to the complexity of drilling a well from the surface to the oil or gas pay zone in a single run. It is highly likely to encounter issues during the drilling process that could lead to complete failure of the operation or even catastrophic consequences, resulting in the abandonment of the well. Therefore, it is essential to drill the well in stages.

Cementing the casing string is a crucial part of well-bore construction, and the success of this operation is vital for the drilling to continue. The construction of an oil and gas well follows a specific sequence of operations based on a previously established drilling-casing plan. Each phase of the program represents a drilled interval that must be adequately protected before moving on to the next phase.

I.1.2. The principle of cementing

Cementing involves the mixing of cement and water slurry and pumping it down through casing to critical points in the annulus around the casing or in the open hole below the casing float collar. The cementing process serves two primary functions: to restrict fluid movement between formations and to bond and support the casing.

To ensure that cementing is carried out correctly, several factors need to be taken into consideration.

- The well hole must be clean and regular to avoid changes in flow speed,
- The casing must be properly centered in the hole,
- The slurry should effectively displace all mud without mixing with it,
- The cementing operation should not cause any loss,
- The cement should adhere well to the walls,
- The volume of the slurry must be accurately calculated,
- The slurry should be of good quality, and its pump ability time should allow for the completion of the operation under safe conditions.**[1]**

I.1.3. Cementing objectives

The primary purpose of cement in oil and gas well drilling is to create an impermeable seal. Therefore, the use of cement in oil well drilling has served several major objectives since it was introduced in the 1920.

- To isolate the production zone from other permeable zones,
- To support the borehole,
- To close an abandoned portion of the well,
- To protect and support the casing string,
- To prevent the movement of fluid through the annular space outside the casing,
- To protect the casing from corrosive fluids in the formation, figure (I-1),
- To preserve ground water quality.**[2]**

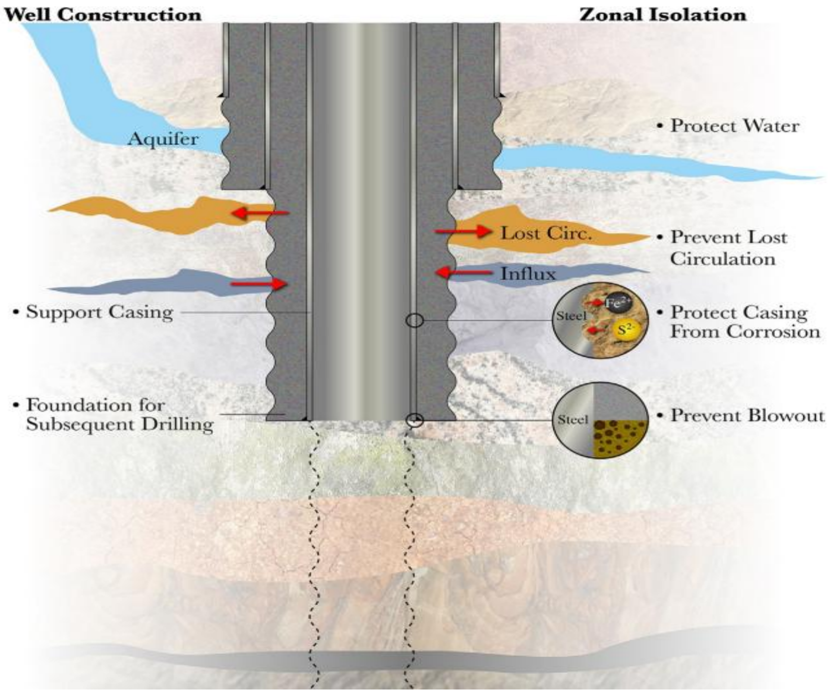

Figure I-1 : *The different zones through which the casing passes***. [3]**

I.2. Portland cement

The process of producing Portland cement involves grinding clinker, which is the material obtained after calcining or burning the feed material in a cement plant's rotary kiln. Clinker mainly consists of hydraulic calcium silicates, calcium aluminates, and calcium aluminoferrite. To make the finished product, one or more forms of calcium sulfate, typically gypsum, are interground with the clinker. The raw materials used in manufacturing Portland cement clinker must contain appropriate amounts of calcium, silica, alumina, and iron compounds, and their composition is closely monitored through frequent chemical analysis to ensure consistent quality. **[4]**

Table I-1: *Chemical notations of the main constituents of Portland cement.*

Name	Mass content
Lime (CaO)	62-67%
Silica (SiO_2)	19-25%
Alumina (Al_2O_3)	2-9%
Hematite (Fe_2O_3)	1-5%
Sulfur oxide (SO_3)	1-3%
Potassium oxide (K_2O)	///
Periclase (MgO)	0-3%
Water (H_2O)	28-42%

I.2.1. Portland cement manufacture

1) Raw materials

Depending upon the location of the cement plant, a great variety of natural and artificial raw materials is employed.

To create Portland cement clinker, a combination of two types of raw materials is required: calcareous materials that contain lime, and argillaceous materials that contain silica, alumina, and iron oxide.

Sedimentary and metamorphic limestone, coral, shell deposits, and "cement rock" are among the most important naturally occurring calcareous materials used in the production of Portland cement, as their composition closely resembles that of the final product. Additionally, artificial calcareous materials such as precipitated calcium carbonate and waste products from various industrial processes may also be utilized.

Commonly utilized raw materials that are naturally occurring and composed of clay-like substances are clays, shale, marls, mudstones, slate, schist, volcanic ashes, and alluvial silt. On the other hand, the most significant artificial sources are blast-furnace slag obtained from steelworks and fly ash obtained from coal-fired power plants.

The mineralogical composition of the clinker primarily dictates the properties of Portland cement. The mineralogical composition of conventional Portland cement clinker is shown in

Table (I-2). For special cements, the content of C_3A and C_4AF can differ significantly. The main oxides make up about 95%:

CaO 60–70%

SiO_2 18–22%

Al_2O_3 4–6%

Fe_2O_3 2–4%.

Table I-2: *Mineralogical Composition of Classic Portland cement Clinker.* **[1]**

Oxide Composition	Cement Notation	Common Name	Concentration (%)
$3CaO \cdot SiO_2$	C_3S	Alite	55–65
$2CaO \cdot SiO_2$	C_2S	Belite	15–25
$3CaO \cdot Al_2O_3$	C_3A	Aluminate	8–14
$4CaO \cdot Fe_2O_3 \cdot Al_2O_3$	C_4AF	Ferrite phase	8–12

The total content of minor compounds such as CaO (free lime), MgO, K_2O,Na_2O,TiO_2, Mn_2O_3 , and SO_3 is normally under 5%.

When choosing raw materials and kiln fuels, it is crucial to consider impurities that can adversely impact the characteristics of the final cement product. These impurities consist of manganese, magnesia (M), chlorides, phosphates, lead oxide, zinc oxide, alkalis, and fuel residues. Upon clinkering in the kiln, such impurities frequently exist in solid solution within the main cement phases, leading to a modification of reactivity. If these impurities surpass the specified limits, they can affect the cement properties, for instance, hindering the growth of strength, causing a significant reduction in the strength of the cement, and creating serious issues in the firing zone of the kiln. All of these effects can result in a decrease in the quality of the cement. **[1]**

2) Raw material preparation

Prior to being calcined in the kiln, the raw materials need to be ground into a fine powder and thoroughly mixed to ensure that the overall composition corresponds to the requirements for producing a specific type of Portland cement. The homogenization of raw materials is a crucial technological step, as the kiln feed must have a highly consistent chemical composition. While each cement plant may have its own unique approach, there are two primary methods in use today: the dry process and the wet process. In the dry process, the grinding and blending operations are performed using dry materials. Conversely, in the wet process, the grinding and blending steps use watery slurry.

The wet process was a popular choice for many years due to the increased precision of controlling the raw mix. However, the dry process has become the prevalent method due to its lower heat consumption, typically utilizing 3,000 kJ/kg of clinker compared to the 5,500 kJ/kg for wet material. In recent times, technology has advanced to the point where excellent control of raw material composition can be achieved using the dry process.

The raw materials undergo a series of steps, including crushing, drying in rotary driers, proportioning to achieve the desired bulk composition, and then grinding in a roller mill that integrates crushing, grinding, drying, and size classification into a single unit. The resultant ground material is stored in multiple silos. **[1]**

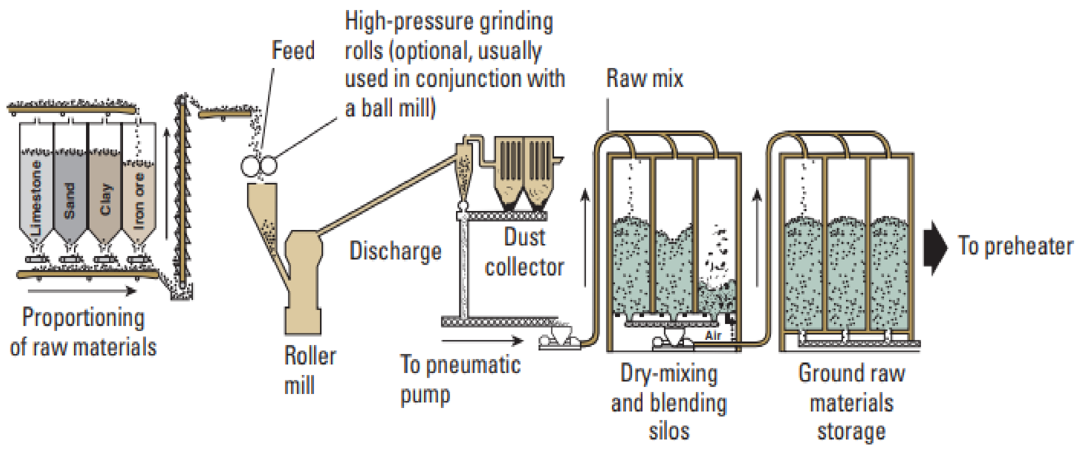

Figure I-2:*Schematic flow diagram of dry process*. **[6]**

Figure (I-3) depicts the wet process. The raw materials are initially proportioned in their dry state. Water is added, and additional size reduction occurs via a grinding mill. The resulting slurry is then subjected to size classification by being pumped past a vibrating screen. Any coarser material is sent back to the mill for regrinding. The slurry is stored in basins with rotating arms and compressed air agitation to maintain homogeneity.

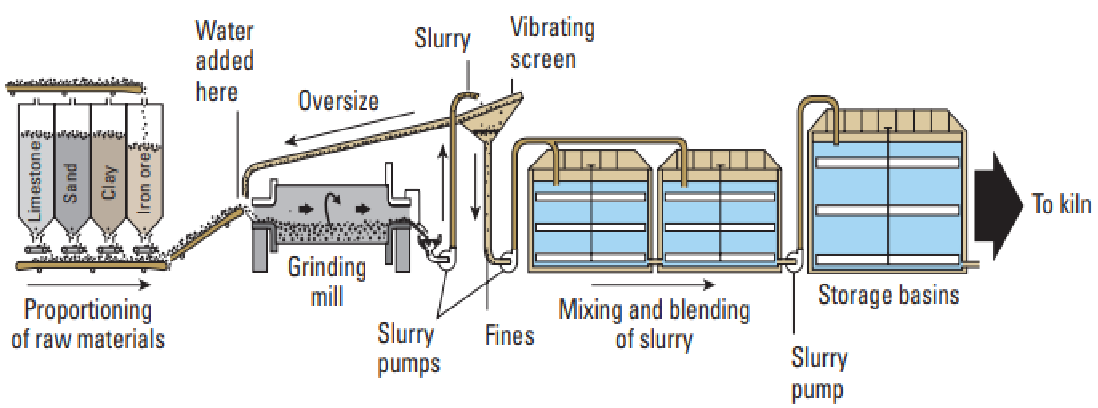

Figure I-3:*Schematic flow diagram of wet process*. **[6]**

3) Heat treatment

Once the raw materials have been properly reduced in size, classified, and blended, they undergo heat treatment in a rotary kiln, which is often preceded by a preheater in modern cement plants. The kiln is slightly inclined and rotates at a speed of 1 to 4 revolutions per minute, allowing the solid materials to move through it as it rotates.

The kiln is where a complex series of reactions occur to transform the raw materials into clinker. The kiln is divided into six temperature zones, each with a specific temperature range and reaction profile, which are described as follows:

- Zone I(Up to 390 [700] (°F[°C])) Evaporation of free water.
- Zone II (390 to 1,470 [200 to 800] (°F[°C])) Preheating, dehydroxylation of the clay minerals occurs.
- Zone III (1,470 to 2,010 [800 to 1,100] (°F[°C])) Decarbonation,
- Zone IV (2,010 to 2,370 [1,100 to 1,300](°F[°C])) Exothermic reactions,

In Zones III and IV, several important reactions occur. Dehydroxylation of clay minerals is completed, and the products crystallize. Calcium carbonate decomposes to free lime, releasing large quantities of carbon dioxide. The production of various calcium aluminates and ferrites also begins.

- Zone V (2,370 to 2,820 to 2,370 [1,300 to 1,550] (°F[°C])) Sintering, the formation of C_2S and C_3S is completed. The uncombined lime, alumina, and iron oxide are contained in the liquid phase.
- Zone VI (2,370 to 1,830 [1,300 to 1,000] (°F[°C])) Cooling, the liquid phase disappears, resulting in the crystallization of C_3A and C_4AF. Some residual free lime is always present in the clinker. **[5]**

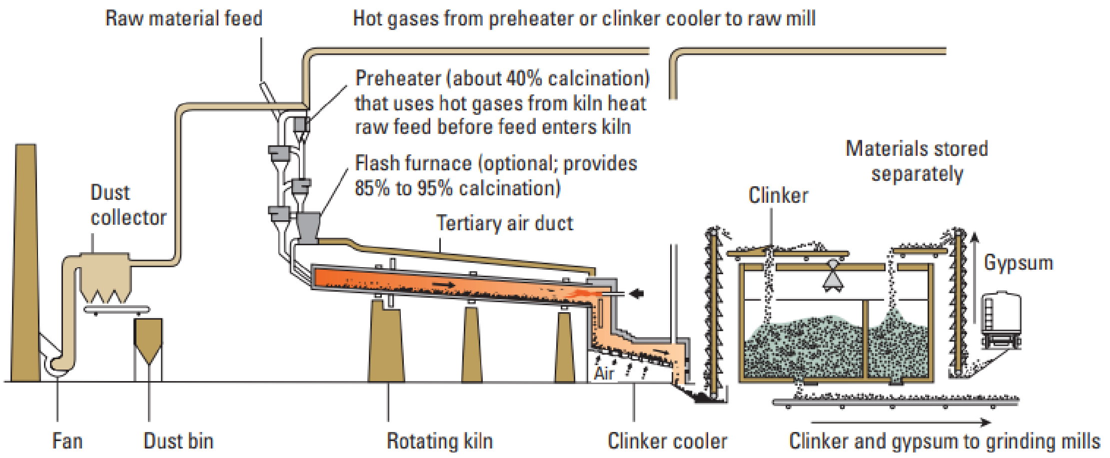

Figure I-4:*Schematic flow diagram of the burning process*. **[6]**

4) Cooling

The thermal profile, particularly the cooling rate, has a significant impact on the quality of the clinker and finished cement. The highest-quality clinker is produced by slow cooling to approximately 2,282°F [1,250°C], followed by rapid cooling at a rate of around 32° to 36°F/min [18 to 20°C/min].

When the cooling rate is slow, 7° to 9°F/min [4° to 5°C/min], the C_3A and C_4AF develop a high degree of crystallinity, the C_3S and C_2S crystals become highly ordered, and the free MgO forms crystals (mineral name: periclase). This results in less hydraulically active cement. When hydrated at ambient temperatures, the early compressive strength is high, but the long-term strength is low.

When the cooling rate is fast, the liquid phase formed at Zone V in the kiln solidifies to a glass. The C_3A and C_4AF remain trapped in the glassy phase, and the crystallinity of the C_2S and C_3S is less ordered. The free MgO also remains in the glassy phase; as a result, it is less active and the resulting cement is less apt to demonstrate unsoundness. Early compressive strength is lower, but longer-term strength is higher. **[5]**

5) Grinding

As shown in figure (I-5), the production of finished cement involves grinding the clinker with calcium sulfate, usually gypsum, prevents a phenomenon known as flash set. Most clinker is ground in tubular mills that are partly filled with hard steel balls. The clinker is ground to a specific fineness, depending on the type of cement being produced, and the resulting cement grains vary in size from 1 to 100 μm. The ball milling process used for grinding is known to be inefficient, with 97-99% of the energy input converted to heat. Consequently, this requires continuous cooling of the mill to avoid excessively high temperatures, which can cause the gypsum to dehydrate and form calcium sulfate hemihydrate. Although dehydrated calcium sulfate compounds are still able to prevent flash set, they can cause another issue known as false set. It is important to note that during the production of well cements, the use of grinding aids is prohibited, as these compounds may interfere with the performance of additives used to control the behavior of well cement slurries. **[5]**

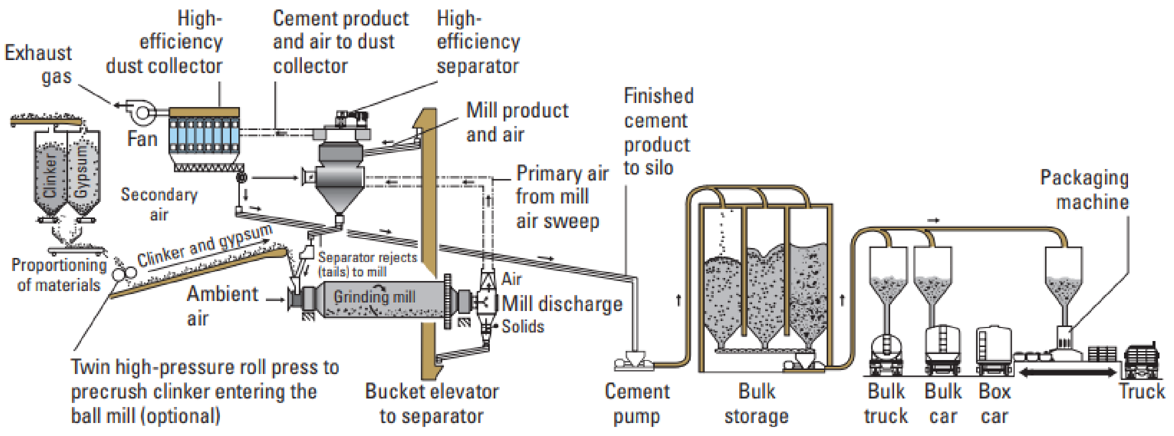

Figure I-5:*Schematic flow diagram of the grinding process and storage***. [6]**

6) Storage

Portland cement is a substance that can be affected by moisture. When stored in a dry environment, its quality can remain unchanged for an indefinite amount of time. However, if it comes into contact with damp air or moisture, it may set more slowly and not develop as much strength. Typically, bulk cement is stored in large silos at the cement plant. If bagged cement is being stored in a warehouse, it's important to keep the relative humidity as low as possible. In situations where multiple silos are being used for a specific type of cement, blending the cement from different silos can help maintain a more uniform product. **[5]**

I.2.2. Cement classes according to API specifications

The American Petroleum Institute (API) has drawn up a classification of oil-well cements based primarily on depth as follows:

Class A: Intended for use from the surface to 6000 ft. (1830 m) depth when special properties are not required,

Class B: Intended for use from the surface to 6000 ft. (1830 m) depth when conditions require moderate to high sulfate resistance,

Class C: Intended for use from the surface to 6000 ft. (1830 m) depth when conditions require high early strength (available in ordinary, moderate and high sulfate-resistant types). Class C cements are characterized by extreme fineness, allowing a high hydration rate and, consequently, high early strength,

Class D: Intended for use from 6000 to 10,000 ft. (1830 to 3050 m) depth under conditions of moderately high temperatures and pressures. Available in both moderate and high sulfate resistant types,

Class E: Intended for use from 10,000 to 14,000 ft. (3050 to 4270 m) depth under conditions of high temperatures and pressures. Available in both moderate or high sulfate-resistant types. Its thickening time is adjusted by a retarder added in the plant by the cement manufacturer,

Class F: Intended for use from 10,000 to 16,000 ft. (3050 to 4880 m) depth under conditions of extremely high temperatures and pressures. Available in both moderate and high sulfate resistant types. Its thickening time is adjusted by a retarder added in the plant by the cement manufacturer,

Class G: Intended for use from the surface to 8000 ft. (2438 m) depth. Its range of use can be extended from the lowest to the highest temperatures, thanks to its compatibility with all additives. Available in moderate and high sulfate-resistant types,

Class H: Identical to Class G but intended for higher density slurries (1.98 instead of 1.90). **[7]**

I.3. Cement slurry

I.3.1. Definition

In the oil and gas industry, cement slurry refers to a mixture of cement, water, and additives. The exact composition of the cement slurry may vary depending on the specific well conditions and the requirements of the operation. Different types of cement, water to cement ratios, and additives may be used to achieve the desired properties and performance of the cement slurry.

I.3.2. Composition of cement slurry

The composition of cement slurry in the oil and gas industry typically consists of the following components:

- **Cement:** The primary component of the slurry is typically Portland cement, which is a fine powder as we knew it previously. The cement provides the binding properties of the slurry and forms the hard, durable structure that seals the wellbore.
- **Water:** Water is added to the cement powder to form slurry with the desired consistency and workability. The water-to-cement ratio is an important factor in determining the strength and durability of the cured cement.
- **Additives:** Additives are substances that are added to well cement slurry to modify its

properties and improve its performance. These additives serve various purposes and can be classified into different categories:

1) Retarders: These additives slow down the setting time of the cement, allowing for better placement and proper cementing operations. They are commonly used in situations where longer pumping or placement times are required,
2) Accelerators: Conversely, accelerators are used to speed up the setting time of the cement. They are beneficial in situations where rapid strength development is needed, such as in cold weather or when early well production is desired,
3) Fluid Loss Additives: These additives help to reduce the loss of water from the cement slurry into the formation during placement. They improve the efficiency of the cementing process by maintaining the desired slurry consistency and preventing excessive dehydration,
4) Dispersants: Dispersants are used to improve the flowability of the cement slurry. They help to prevent the formation of clumps or agglomerates, ensuring a more uniform distribution of the cement particles,
5) Strength Enhancers: These additives are designed to enhance the compressive strength and long-term durability of the hardened cement. They can improve the bond strength between the cement and the formation, resulting in a more robust and reliable cement sheath,
6) Gas Migration Control Additives: In situations where gas migration is a concern, specific additives can be used to reduce the potential for gas to migrate through the cement sheath and into the wellbore,
7) Rheology Modifiers: Rheology modifiers are used to adjust the flow characteristics of the cement slurry, such as viscosity and pumpability. They ensure that the slurry can be properly pumped and placed in the well without issues.

It's important to note that the selection and use of additives in well cementing operations require careful consideration of well conditions, desired properties, and compatibility with other additives. The dosage and specific type of additive used will vary depending on the specific requirements of the well and the cementing operation. **[8]**

I.3.3. Characteristics of cement slurry

The characteristics of cement slurry used in oil well cementing can vary depending on the specific application and conditions of the well. However, there are some general characteristics that are desirable for most oil well cementing operations. These include:

- **Density:** The density of the cement slurry should be high enough to provide adequate hydrostatic pressure to control the formation fluids and prevent blowouts, but not so high that it causes formation damage or lost circulation. Typically, the density of the cement slurry ranges from 12 to 16 pounds per gallon (1.44 to 1.92 g/cm³),
- **Compressive strength:** The cement slurry should develop sufficient compressive strength to provide zonal isolation and support the weight of the casing and any subsequent loads. Depending on the API class of cement used, the compressive strength can range from 3,000 to 12,000 psi (20.7 to 82.7 MPa),
- **Consistency:** The consistency of the cement slurry should be uniform and within the range specified by the API or the cement manufacturer. The consistency affects the pump-ability, thickening time, and settling of the cement slurry,
- **Rheology:** The rheological properties of the cement slurry should be carefully controlled to ensure proper displacement and placement of the slurry. The rheological properties include viscosity, gel strength, yield point, and fluid loss,
- **Setting time:** The setting time of the cement slurry should be sufficient to allow for proper placement and displacement, but not so long that it delays the completion of the well. Typically, the setting time can range from 2 to 8 hours, depending on the well conditions. **[9]**

Chapter II
Experimental test

II. Experimental tests

We did an internship at the cement company Ain el-kebira and at the level of BJSP in which we have the chance to assist the measurements carried out to determine the composition and characteristics of cement and cement slag. In the following lines, we present the two companies.

II.1. Presentation of the SCAEK Cement plant in Ain EL Kebira Setif

The cement company of Ain EL-kebira (SCAEK) is a joint stock company. It is a subsidiay of the cement industrial complex of Algeria (GICA). Its capital is 2,200,000,000 DZD.

The factory covers an area of 50 hectares, and is located 20 km north-east of the municipality of Setif and 7 km south of municipality of Ain EL-Kebira. The headquarters of the general directorate is located in the city of Setif, in the Bounchada district, Abasha Ammar Street.

The Ain El Kebira cement factory (figure (II-1)) is located near the quarry, whose reserves allow it to meet the factory’s needs in the long term, with an expected age of more than 100 years according to the latest estimates. **[10]**

Figure II-1:*SCAEK company.* ***[11]***

II.1.1. The birth of the company

Within the framework of the economic and social development policy, which was launched to meet the requirements of the hour and decided by the government, the National Building Materials Company (SNMC) started in the early 1970s a large investment program to restore the lines inherited from LAFARGE and complete several new cement production lines, including the Ain Al-Kebira line.

Line 01:

- Signed a contract with SNMC on 07/23/1974 Completion periods of 45 months,
- Temporary receipt on 08/01/1978,
- Date of entry into production: September 1978,
- Capacity 1,000,000 tons,

SNMC restructuring in 1982 which gave birth to four (04) concrete complexes: East, west, Middle and Chlef.

Our company is one of the subsidiaries of the restructured ERCE complex in 1998 with the dissolution of the ERCE complex and the creation of the GICA complex (Algeria Cement Industrial Complex), SCAEK became a subsidiary to this complex since November 26, 2009.

Line 02:

- Signing of the contract 08/21/2013 with POLYSIUS SAS France,
- Contract entry into force on January 23, 2014,
- Date of entry into production April 2017,
- Capacity 2, 000,000 tons**. [10]**

II.2. Factory products

- «MOUDHAD» CEM I / B-L 42.5 L-H/SR5 NA 442 Sulphate resistant cement. Cement for aggressive environments (Sahara, seaside). Used for dams, desalination and purification stations, maritime and hydraulic work....
- «INDJAZAT» CEM II / A-L 52.5 N NA 442 The high-performance solution for major works requiring high resistance. Used in buildings and works of art, prefabricated works...
- «BETON» CEM II / A-L 42.5 N NA 442 Limestone Portland cement. Cement for making mortars and all reinforced concrete work.
- «BENIAN» CEM II / B-L 32.5 N NA 442 Ideal for routine masonry work (bricklaying, roughcasting of walls, screeds, etc.).

- «WELL CEMENT» CLASS G CIMENT HIGH SULPHATE RESISTANT (HSR). Oil cement for oil and gas wells, a very high quality cement for all oil drilling. **[9]**

Figure II-2:_The products manufactured by the factory of_ SCAEK. _**[11]**_

II.3. Petroleum cement Ain al-Kebira plant

In an effort to diversify its product offerings, the Ain Al-Kebira Cement Company successfully developed a unique type of cement designed for companies working in the oil fields. This petroleum cement was introduced in 2018 and was supported by an accreditation obtained in 2019, allowing the company to produce and market this type of cement to approved companies recognized by the American Petroleum Institute. This accreditation is highly regarded as it is the only organization in the world that grants it. By providing this specialized cement, the company is able to eliminate the need for importing this material from overseas, thereby saving valuable foreign currency. **[10]**

II.4. Presentation of BJSP Company

The Algerian Company of Stimulation of Wells Producers of Hydrocarbons "BJSP" is a joint stock company specialized in the provision of oil services.

BJSP has operational management in Hassi Messaoud and districts located in Hassi R'mel, Ourhoud, In Amenas and Hassi Bir Birkine. It covers a large part of this market through its interventions on oil sites, by carrying out cementing, stimulation and fracturing operations on gas and oil producing wells. The professional activity carried out:

- Cementing of wells during drilling,
- Stimulation of hydrocarbon producing wells,
- Hydraulic fracturing to penetrate deep into the formation.**[12]**

II.5. Presentation of experimental tests

The tests carried out tests help to ensure that the cement is suitable for its intended application and meets the required specifications. There is test on slurry cement and other test on samples cement.

II.5.1. Presentation of experimental tests carried out on cement powder

I.1.1.1. The Insoluble Residue (IR) test

Is a method for determining the amount of non-soluble material in a cement sample. It is commonly used to evaluate the purity of raw materials used in cement manufacturing, as well as to determine the quality of the final product. The IR test involves several steps, including sample preparation, acid digestion, filtration, washing, and ignition.

a) Apparatus

- Analytical balance,
- Muffle furnace,
- Porcelain crucibles,
- Filter paper,
- Vacuum filtration system,
- Beakers,
- Hot plate.

Chemicals:

- Hydrochloric acid (HCL),
- Distilled water,
- Ethanol.

b) Calibration

It is important to note that the IR test results are influenced by the quality and purity of the raw materials used in cement production. High levels of IR may indicate the presence of impurities or undesirable minerals, which can affect the strength and durability of the final cement product.

c) Procedure

1. Weigh approximately 1 gram of the cement sample to the nearest 0.01 gram using an analytical balance and transfer it to a clean and dry porcelain crucible.
2. Heat the crucible on a hot plate at 105°C for 1 hour to remove any moisture in the sample.
3. After cooling, weigh the crucible with the sample and record the weight.
4. Add 10 ml of 10% hydrochloric acid (HCl) to the crucible, and gently heat the crucible until the sample dissolves. Do not let the acid boil.
5. Remove the crucible from the heat and let it cool to room temperature.
6. Add 50 ml of distilled water to the crucible and stir the mixture thoroughly with a glass rod.
7. Place a filter paper in a vacuum filtration system and wet it with distilled water.
8. Filter the contents of the crucible through the filter paper and wash the residue with distilled water until the washings are free from acid.
9. Transfer the filter paper with the residue to a porcelain crucible and dry it in a muffle furnace at 105°C for 1 hour.
10. After cooling, weigh the crucible with the residue and record the weight.
11. Heat the crucible with the residue in a muffle furnace at 950°C for 3 hours.
12. After cooling, weigh the crucible with the residue and record the weight.
13. Calculate the Insoluble Residue (IR) percentage as follows: **[13]**

$$\text{IR\%} = \frac{(\text{Weight of Residue after ignition} - \text{Weight of Crucible})}{(\text{Weight of Sample taken})} \text{x}100\%$$

I.1.1.2. Detection of the concentration of some compounds in cement

X-ray analysis is used to detect the concentrations of some compounds present in cement by analyzing the radiation absorbed or discharged by these compounds. The process is carried out by exposing the sample to be examined to X-rays and analyzing the radiation discharged or absorbed in the material. This analysis can determine the concentration of materials present in the sample and can be used to determine the raw cement and cement used in the well as well as to monitor production and quality processes.

a) Apparatus

- X-ray machine,
- Polab® APM- Sample preparation for cement laboratory automation. Pressed tablets are the common way to prepare samples for both XRF and XRF analysis in the cement and other industries. In many cases the same pressed tablet can be used for both analysers, thus reducing cost and sample preparation time.

Figure II-3: *X-Ray machine.* ***[14]***

Figure II-4:*Device that spreads cement on a test disc.* ***[14]***

b) Procedure

The cement sample is dried in a desiccant oven at 105 °C for 2 hours to dry completely,

Take 12g of cement and put it in the Polab® APM device with the addition of a substance that helps spread the cement in the disc,

Put the final disc in X-Ray machine,

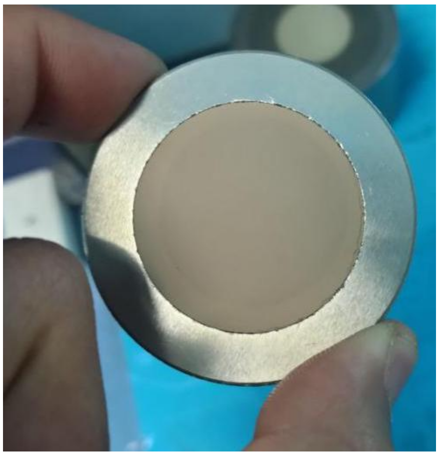

Figure II-5: *The cement sample of X-ray test.* ***[14]***

The results of the concentrations of some of the compounds present in the cement are shown on the computer linked to the X-ray device. **[14]**

II.5.2. Presentation of experimental tests carried out on cement slurry

II.5.2.1. Preparation of slurry

Two slags were prepared using GICA local cement which has the following compositions (792 g cement and 349g of water), (500g cement, 20g bentonite and 488.55g water).

- A No. 20 wire cloth sieve (openings 850 μm), in accordance with the requirements given in ISO 3310-1, shall be used for sieving cement prior to slurry preparation.
- The mixing devices for the preparation of well cement slurries shall be a 1 L size, bottom-drive, blade-type mixer.

Figure (II-6) displays commonly used mixing devices. The mixing container and the mixing-blade assembly must be constructed from sturdy and corrosion-resistant materials. The mixing-blade assembly should be designed in a way that allows for easy removal of the blade for weighing and replacement. It is necessary to weigh the mixing blade initially and periodically thereafter. Once a 10% loss in mass has occurred, the blade must be replaced with a new one. Additionally, if there is any noticeable deformation of the blade, it must be replaced. If the mixing device leaks at any point during the process, the contents must be disposed of, the leak fixed, and the procedure restarted.

The mixing device shall be calibrated annually to a tolerance of ± 200 r/min (± 3,3r/s) at 4 000 r/min (66,7r/s) rotational speed, and ± 500 r/min (± 8,3r/s) at 12 000 r/min (200r/s) rotational speed.

Figure II-6 :*Cement-mixing devices.*

- The temperature of the mix water in the container and the temperature of the cement within 60 s prior to mixing shall be 23 °C ± 1 °C (73 °F ± 2 °F)
- The slurry ingredient quantities must be used for testing accurately. So that the percentage of cement is 792 g ± 0.5 and water percentage 349 g ± 0.5. for API test
- The mixing container with the required mass of mix water, as specified in previous point, shall be placed on the mixer base, the motor turned on and maintained at 4 000 r/min ± 200 r/min (66,7 r/s ± 3,3 r/s) while the cement sample is added at a uniform rate during no more than 15 s. After 15 s at 4 000 r/min ± 200 r/min (66,7 r/s ± 3,3 r/s), place the cover on the mixing container and continue mixing at 12 000 r/min ± 500 r/min (200 r/s ± 8,3 r/s) for 35 s ±1 s. **[15]**

II.5.2.2. Thickening-time tests

Thickening time tests are conducted to determine the time taken by the cement slurry to reach a certain level of consistency, which is an important parameter in oil well cementing operations. This parameter helps to ensure that the cement slurry remains fluid enough to be pumped into the wellbore, but also sets and hardens within a reasonable time to form a strong and stable bond. **[16]**

a) Apparatus

The pressurized consistometer is composed of a cylindrical container that rotates and holds a mixture, and a stationary paddle assembly. It is housed in a pressure vessel that is capable of withstanding high pressures and temperatures. The gap between the container and the pressure vessel walls should be filled with mineral or synthetic oil. The system should be equipped with a heating system that can increase the temperature of the oil bath at a minimum rate of 3°C/min (5°F/min). To monitor and manage the temperature of the cement mixture at the center, a temperature-measuring system is required. The container should rotate at a speed of 150 r/min ± 15 r/min.

Figure II-7: *Consistometer HTHP*. ***[14]***

b) Calibration

In order to determine the thickening-time of cement slurry, it is essential to ensure that the pressurized consistometer's different operational systems are calibrated and maintained. This includes consistency measurement, temperature-measuring systems, temperature controllers, motor speeds, timers, gauges, and the slurry container assembly for wear. All of these components are calibrated based on the guidelines presented in Annex C. To measure the consistency of the cement slurry, a torque measurement device (typically a potentiometer mechanism, as illustrated in Figure (II-8)) and a voltage measurement circuit are used. Both of these have also been calibrated following the procedures described in Annex C. The consistency of the cement slurry is measured in Bearden units of consistency Bc.

Figure II-8:*Potentiometer*.

The temperature-measuring system used must be precise, with an accuracy of ±1 °C (±2 °F), The motor used in the pressurized consistometer must meet the specifications outlined in Annex C.

Timers used in the system must be accurate to within ±5 seconds per hour.

Calibration of the equipment should be conducted against a dead-weight tester or master gauge. To verify the dimensions of the pressurized consistometer and wear of slurry container assembly parts, a caliper with an accuracy of at least 0.1 mm (0.005 in.) is require.

c) Procedure

To begin the measurement process, place the filled slurry container onto the drive table in the pressure vessel and initiate the rotation of the container. Secure the potentiometer mechanism or any other appropriate device for measuring consistency in a way that engages the paddle shaft drive bar. Then, commence the filling of the vessel with oil. During this process, the paddle shaft should not be rotating.

Secure the head assembly in the pressure vessel and insert the thermocouple through its fitting, and partially engage the threads. After the pressure vessel is completely filled with oil, tighten the threads of the thermocouple.

Begin the thickening-time test by applying the initial pressure and starting the temperature ramp. No more than 5 min should have elapsed after cessation of mixing of the slurry and the beginning of the test.

Specification Acceptance Requirements: the acceptance requirements for the maximum consistency during the 15 min to 30 min period after the initiation of the test shall be 30 Bc, and Bc=100 the minimum and the maximum should be between (90min-120min). **[15]**

II.5.2.3. Compressive Strength Tests

Compressive Strength Tests are one of the most important tests conducted on oil well cement to ensure that it meets the required specifications. The compressive strength of oil well cement is a measure of its ability to withstand axial loads and maintain its structural integrity under compression. **[17]**

a) Apparatus

Compression strength-testing machine: This machine is used to apply a compressive force to the cement specimens until they fail. The machine should meet the requirements of ASTM C109 (American Society for Testing and Materials) or other relevant standards.

Figure II-9:*Compression strength testing machine.* ***[14]***

Molds: The molds are used to cast the cement specimens in the desired shape and size.

Curing bath: is a container or vessel used to provide a controlled environment for curing cement or concrete specimens(38°C, 60°C) Figure (II-10). The purpose of a curing bath is to maintain a consistent temperature and humidity during the curing process, which is essential for proper cement hydration and strength development.

Figure II-10:*Water curing bath A)38°C, B)60°C.* ***[14]***

Cooling bath: as showing in Figure (II-11) is a container or vessel used to cool down a heated substance or sample (27°C). The cooling process is important because it helps prevent thermal cracking and ensures that the specimen is at a consistent temperature before testing.

Figure II-11: *Water cooling bath 27°C.* ***[14]***

We need also other equipment like hummer, timer and tamping rod…

Figure II-12: *Hummer, Timer, Molds.* ***[14]***

b) Calibration

The calibration of compressive strength testing equipment for oil well cement involves verifying that the machine is accurately measuring the compressive strength of the cement samples. This is typically done by placing a calibration cylinder or block of known compressive strength on the machine, applying a load at a specific rate of deformation, and recording the maximum load at failure. The calculated compressive strength of the calibration cylinder or block is then compared to the known value to ensure that the testing machine is within acceptable limits of accuracy (usually ± 1% of the known value). If the machine is not within acceptable limits of accuracy, adjustments or repairs may be necessary. Calibration should be done regularly (e.g., every 12 months) and according to specific testing protocols and standards (e.g., API, ISO).

c) Procedure

The procedure for conducting compressive strength tests on oil well cement involves the following steps:

1. Prepare the cement samples by mixing the cement and water according to the manufacturer's specifications,
2. Fill the molds with the prepared cement and level the surfaces,
3. Cover the molds with a damp cloth and allow the samples to cure in a curing bath for 7h15min (one at 38°C and the other in 60°C). after that in cooling bath for 45min at 27°C,
4. Remove the samples from the molds and trim any excess material,

5. Place the sample on the lower platen of the compressive strength testing machine and center it under the loading platen,
6. Apply a compressive load at a specific rate of deformation (usually 0.5 to 2.0 MPa per second) until failure occurs,
7. Record the maximum load at failure and calculate the compressive strength of the sample,
8. Repeat the testing procedure for each sample,
9. It is important to follow the specific testing protocol and standards (e.g., API, ISO) for compressive strength testing to ensure accurate and reliable results.

Compressive Strength Specification Requirements for oil well cement class G:

The minimum Compressive Strength at indicated curing period 8h for:

- ✓ 38°C: 300 psi,
- ✓ 60°C: 1500 psi. **[15]**

II.5.2.4. Free-fluid Test (free-water)

It's used to determine the amount of free water or fluid in cement slurry.

a) Apparatus

Atmospheric Pressure Consistometer: is a device used in cement testing to determine the consistency and flow properties of cement slurries at atmospheric pressure. Shall be used for stirring and conditioning the cement slurry for the determination of free-fluid content.

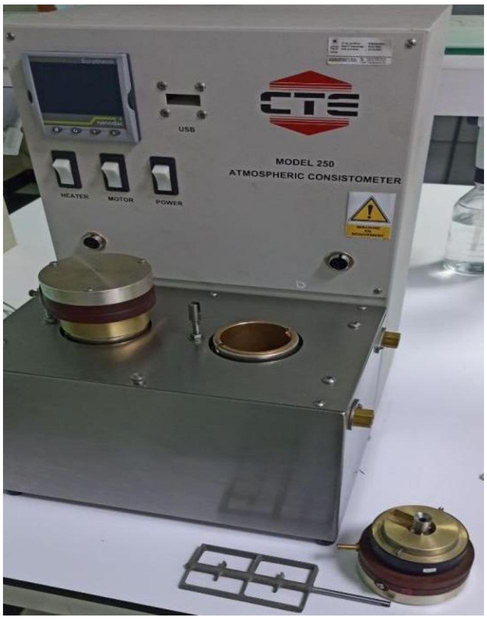

Figure II-13: *Consistometer atmospheric.* ***[14]***

Test Flask: a wide-mouth general-purpose conical glass flask (Erlenmeyer) with a capacity of 500 mL shall be used. Which has a conical base and a cylindrical neck.

b) Procedure

a) Prepare the slurry,

b) For an atmospheric pressure consistometer, fill a clean and dry consistometer slurry container to the fill groove,

c) Assemble the slurry container and associated parts, place them in the consistometer, and start the motor and starting of the consistometer shall not exceed 5 minutes,

d) Stir the slurry in the consistometer for a period of 20 min ±30 s while the temperature of the slurry is 27 °C ±2 °C (80 °F ±3 °F) and atmospheric pressure throughout the stirring period,

e) Transfer 760 g ±5 g of slurry directly into the clean, dry 500-mL conical flask within 1 min of the end of stirring,

f) Set the slurry-filled flask on a surface that is nominally level and vibration-free.

  1) The air temperature to which the slurry-filled flask is exposed shall be 23 °C ±3 °C (73 °F ±5 °F),

  2) Let the slurry-filled flask remain undisturbed for a period of 2 h ±5 min.

g) Remove the supernatant fluid that has developed with a pipette or syringe at the end of the 2 h ±5 min period,

  1) Measure the volume of supernatant fluid to an accuracy of ±0.1 ml,

2) Record the measure volume as "milliliters free-fluid", VFF.

The volume fraction, φ, of free-fluid in the slurry, expressed as a percentage, is then calculated using Equation

$$\varphi = \frac{V_{FF} \times \rho}{m_s}$$

Where

V_{FF} Is the volume of free-fluid (supernatant fluid) collected, expressed in milliliters,

ρ Is the density of slurry, equal to 1.91 g/cm3 for Class G at 44 % water; if the density of the base cement is other than the typical value of 3.18 g/cm3 ±0.04 g/cm3 , the actual specific gravity of slurry should be calculated and used,

m_s Is the initially recorded (starting) mass of the slurry, expressed in grams.

Acceptance Requirements the free-fluid for Class G well cements shall not exceed 5.9 % of the slurry volume. **[15]**

II.5.2.5. Static gel strength analyzer

Gas migration and water flows through cement are two of the biggest problems facing the petroleum industry. One of the critical measurements required to evaluate the potential for fluid inflow migration problems is the determination of the static gel strength development of the cement slurry.

a) Apparatus

A breakthrough instrument, the Model 5265 SGSAAs shown in the picture simultaneously measures both slurry's compressive strength development and its static gel strength development while it is cured under downhole temperature and pressure conditions.

Figure II-14: *SGSA Model 5265.* **[18]**

b) Procedure

We have prepared the following:

Table II-1: *Worksheet of the experience for SCAEK cement.*

Subject	**Quantity**
Cement class G (GICA) (g)	500
D-42L (ml)	0.50
Bentonite (g)	20
Water (g)	448.55
Slurry weight (g)	9690.5
Slurry density (PPG)	13.18

Table II-2: *Worksheet of the experience for LAFARGE cement.*

Subject	**Quantity**
Cement class G (LAFARGE) (g)	500
D-42L (ml)	0.50
Bentonite (g)	20
Water (g)	444.54
Slurry weight (g)	9690.5
Slurry density (PPG)	13.18

We have mixed the bentonite with water first and let the bentonite soaks. Then we added cement and let the slurry mixing, whenever foam appears, we add anti-foaming D-42L,

Filling the cylinder of the SGSA device with a specified quantity,

After making sure of the correct connection and connecting the gauges, we leave the device for 24 hours to measure.

- Unfortunately, we did not succeed in conducting some experiments.

Because we were in the process of working on different samples of cement (petroleum cement from the LAFARGE factory and another from SCEAK and imported petroleum cement), by adding a local material, which is bentonite, and conducting several tests such as API. These experiments aimed to explore the potential of this material and its effect on the properties and performance of cement.

Chapter III

Results and Interpretation

III.1. Presentation of experimental results

III.1.1. Presentation of results of powder cement tests

At first we presented the results of analysis of the composition of two petroleum cements produced locally, namely the cement produced at the company LAFARGE and the cement produced at the company Ain El-kebira. Then, we compared the results obtained with the composition of Portland class G cement (imported). It is noted that the analysis of the composition of the petroleum cement of the company LAFARGE is carried out the past year by the students "Aiche Omar, Chouiref Abdelhadi Houcine, Kadi Aymen".**[19]**

a) Technical specifications for Algerian petroleum cement

Table (III-1) represents the chemical characteristics of petroleum cement produced by Algerian factories GICA and LAFARG.

Table III-1: *Chemical characteristics of Algerian oil well cement.* ***[8]***

Parameters involved	**Cement class G SCAEK**	**Cement class G LAFARGE**
CHIMICAL COMPOSITION		
Magnesium Oxide (MgO) Sulfur Trioxide (SO_3) Loss On Ignition (LOI)	1.28 2.46 1.04	1.8 2.0 0.8
Insoluble Residue (IR)	0.51	0.3
Tricalcium Silicate (3*CaO.SiO_2) Tricalcium Aluminate (3*CaO.Al_2O_3) 2*C_3A + C_4AF	57.03 1.89 21.95	62 2 18
Alkali content (expressed as Na_2O equiv.)	0.32	0.5

Table (III-2) represents the chemical characteristics of petroleum cement in API specification 10A.

Table III-2: *Chemical characteristics of API specification 10A.* **[15]**

Parameters involved	**API spec 10A requirements**
CHEMICAL COMPOSITION	**Board 01**
Magnesium Oxide (MgO) Sulfur Trioxide (SO_3) Loss On Ignition (LOI)	Max. 6% Max. 3% Max. 3%
Insoluble Residue (IR)	Max. 0.75%
Tricalcium Silicate (3*CaO.SiO_2) Tricalcium Aluminate (3*CaO.Al_2O_3) 2*C_3A + C_4AF	Min. 48 / max.65 Max. 3% Max. 24%
Alkali content (expressed as Na_2O equiv.)	Max. 0.75%

The comparison of the cements compositions shows that the local cements have slightly different compositions and which are within the API standards.

Table (III-3) represents the physical characteristics of petroleum cement produced by Algerian factories GICA and LAFARGE.

Table III-3:*Physical characteristics of Algerian oil well cement***.** ***[8]***

Parameters involved	**Cement class G SCAEK**	**Cement class G LAFARGE**
PHYSICAL PERFORMANCE		
Compressive strenght, Neat (8h) -Curing Temp. 100°F (38°C) -Curing Temp. 140°F (60°C)	355 psi 1604 psi	871 psi 1813 psi
Theckening time 100Bc (min)	118	106
Bc (15 min to 30 min)	11.33	11
Free water content Finesse (Blaine) (Cm/g)	4.89 3763	5 NR
Cement density (g/Cm²)	3.22	3.18

Table (III-4) represents the physical characteristics of petroleum cement in API specification 10A.

Table III-4:*Physical characteristics of API specification 10A.* **[15]**

Parameters involved	**API spec 10A requirements**
PHYSICAL PERFORMANCE	**Board 02**
Compressive strenght, Neat (8h) -Curing Temp. 100°F (38°C) -Curing Temp. 140°F (60°C)	Min. 300psi Min. 1500psi
Theckening time 100Bc (min)	Min. 90 / Max. 120
Bc (15 min to 30 min)	Max. 30Bc
Free water content Finesse (Blaine) (Cm/g)	Max. 5.9% NR
Cement density (g/Cm²)	3.16

b) Interpretation

The comparison of the cements physical properties shows that the local cements have an obvious difference in the density and compressive strength after curing temp. 100 °F. There is a big difference in the compressive strength estimated at approximately 500 Psi, and this is due to the difference in the density value. Itnoted that both are in within the API standards.

Where there are several factors that can contribute to the increase in the density of the final cement powder during its manufacture at the factory level, these two factors are essential in raising the density:

Selection of raw materials: The choice of raw materials used in the cement manufacturing process can affect the density of the final product. Certain types of limestone or other mineral additives with higher density can be selected to increase the overall density of the cement powder.

Curing conditions: The curing conditions during the cement manufacturing process, such as temperature and humidity, can affect the density of the cement powder. Optimal curing conditions can promote proper hydration and densification of the cement particles.

Where there are other factors to mention: curing conditions, mixing and blending…

To address the issue of high density in the final cement powder during its manufacture, several steps can be taken:

Raw material selection: Choose raw materials with lower density, such as specific types of limestone or mineral additives, that can help reduce the overall density of the cement powder.

Mix design optimization: Adjust the proportions of raw materials in the mix design to reduce the overall density of the cement powder. This may involve decreasing the amount of denser materials or adjusting the ratios of existing materials.

Calcination control: Monitor and control the calcination temperature during the manufacturing process. Optimize the firing conditions to prevent over-calcination, which can lead to higher density in the cement powder.

III.1.2. Presentation of results of slurry cement tests

Table III-5: *Result for SGSA test for SCAEK cement*

	Compressive strength	Gel strength	Transit time
Results after 24h	542 psi	1191.3 lb/100ft2	12.27 micro sec/in

Due to some obstacles, we were unable to conduct the second test of LAFARGE Cement and imported cement.

Conclusion

Conclusion

The present work focuses on exploring the potential of different materials from local sources and examination of their impact on improvement of the properties cement.

We concluded through this study that the most used type of petroleum cement in oil wells in Algeria is the cement of the LAFARGE Company, and this is due to its properties close to Portland cement (imported), after several LAB tests. Although the Ain El-Kebira plant provides this cement according to API standards, the demand for it is very low as a result of the noticeable increase in density, which in turn affected the compressive strength, as we noted in the third chapter.

We recommend trying to improve the product of the Ain Al-Kabira factory and motivate the rest of the factories in order to provide this material according to API standards, as it deserves encouragement and more investment in the Algerian market

Unfortunately, we were not successful in conducting some experiments on different samples of cement by adding a local substance, bentonite. These experiments aim to explore the potential of this substance and its effect on the properties and performance of cement.

In general, this thesis shed light on the possibility of developing the properties of local cement to achieve the standard properties of Portland cement. The research serves as a basis for further studies and practical applications in the field of cement production, with the ultimate goal of developing locally oriented and sustainable cement manufacturing practices.

BIBLIOGRAPHIC REFERENCES

[1] Nelson, E.B. and Guillot, D. (2006). Well Cementing. Elsevier. First Edition,

[2] IADC Drilling Manual eBook Version (V.11),

[3] APPLIED WELL CEMENTING ENGINEERING Edited by GEFEI LIU Pegasus Vertex, Inc., Houston, TX, United States,

[4] ASTM International. (2019). Standard Specification for Portland Cement. ASTM C150/C150M - 19. DOI: 10.1520/C0150_C0150M-19,

[5] Nelson, E.B., and Guillot, D. (2018). Well Cementing, Second Edition. Gulf Professional Publishing**,**

[6] Portland cement Association. (2002). Design and Control of Concrete Mixtures (14th Edition). Skokie, IL: Portland cement Association,

[7]CEMENTING TECHNOLOGY AND PROCEDURES 1993 Editions TECHNIP 25 rue Ginoux, 7501 5 PARIS, FRANCE,

[8] American Petroleum Institute. (2010). Specification for Well Cementing. API Specification 10A, 22nd Edition,

[9] The API Recommended Practice 10B-2/ISO 10426-2 standard provides information on the characteristics of cement slurries,

[10] SCAEK magazine,

[11] Website of GICA: https://www.gica.dz/gica-portland-cement/

[12] http://wikimapia.org/16927089/BJSP-Hassi-Messaoud

[13] Mehta, P.K. and Monteiro, P.J.M. (2013). Concrete: Microstructure, Properties, and Materials (4th Edition). New York: McGraw Hill Education,

[14] Pictures and information taken at the laboratory level of SCAEK factory,

[15] API SPECIFICATION 10A TWENTY-FIFTH EDITION, MARCH 2019,

[16] SPE/IADC 143640, "A New Approach to Improve the Accuracy of Thickening Time Predictions of Oil well Cement Slurries" (2011),

[17] ASTM C109 / C109M - 20a, "Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)",

[18] Laboratory of BJSP Company.

[19] Thesis graduate « La caractérisation du ciment pétrolier local » framed Dr. M Bouhadda 2022.