Available online at http://ijcpe.uobaghdad.edu.iq and www.iasj.net
Iraqi Journal of Chemical and Petroleum Engineering
Vol.22 No.1 (March 2021) 1 – 13
EISSN: 2618-0707, PISSN: 1997-4884

An Experimental Assessment of Iraqi Local Cement and Cement Slurry Design for Iraqi Oil Wells Using Cemcade

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Abstract

This effort is related to describe and assess the performance of the Iraqi cement sample planned for oil well-cementing jobs in Iraq. In this paper, major cementing properties which are thickening time, compressive strength, and free water in addition to the rheological properties and filtration of cement slurry underneath definite circumstances are experimentally tested. The consequences point to that the Iraqi cement after special additives encounter the requests of the API standards and can consequently is used in cementing jobs for oil wells. At this research, there is a comparative investigation established on experimental work on the effectiveness of some additives that considered as waste materials which are silica fume, bauxite, and glass powder, and other conventional additives which are: (SCR -100 Retarder, HR-5, FWCA, Hollow Glass Spheres (HGS) and Halad-9) that currently used in our fields on local Iraqi cement and putting foreign cement results as a governor. Chemical analysis for Iraqi cement, imported cement, and waste materials samples was determined using the X-ray fluorescence (XRF) technique and found minor differences in composition between those samples and depending on the results of X-ray, we selecting the appropriate additives to prepare cement slurry samples. The X-ray fluorescence (XRF) results show that Iraqi Cement has a low value of silica which is about 18.63% while Omani cement about 37.58%. This research examined the potential of micro silica, bauxite, and waste glass powder to produce sustainable cement slurry. The results showed that adding micro silica and bauxite enhances the performance of Iraqi cement but also leads to a slight decrease in thickening time. To avoid this problem, Superplasticizer is used to make the process of cement pumping more easily, in other words, increase thickening time and increase compressive strength. Furthermore, adding glass powder increase the value of compressive strength. Both additives (waste and conventional) are used for the slurry design for achieving better slurry properties, but waste additives increase and enhance Iraqi cement performance than conventional additives, in other words, making it more effective than commercial cement. Depending on the results of the compressive strength test, the optimal concentration of the waste materials used in this research was found, and then the optimal concentration was used to prepare cement samples. The results showed that the use of waste materials to prepare cement slurry is a promising way to improve the efficiency of cement work and to reduce the negative environmental impact resulting from the industry. The results of the program CemCADE proved to be the sample A and C showed good performance through high cement bonding and ideal distribution of fluids designed to accomplish the cementing process.

Keywords: Iraqi cement, additives, slurry design, cementing properties, commercial cement.

Received on 16/08/2020, Accepted on 11/10/2020, published on 30/03/2021

https://doi.org/10.31699/IJCPE.2021.1.1

1- Introduction

Portland cement is the most widely used cement in the manufacture of oil wells and is involved in about 99% of the primary cementing. and well-cementing operations using the unusual cement called " G class cement ", its properties must match the specifications of the American Petroleum Institute (API)). Iraq, which gets high marks among the oil-producing countries, recently started manufacturing oil well cement. Cementing operations are an essential part of the oil drilling industry. His success is a critical issue in the continuation of the subsequent stage. Installation in oil wells entails inserting cement mortar suitable for good and durable cement bonding. Portland cement is a fine powder obtained by mixing a mixture of 80% limestone and 20% clay which are roasted to 1450 ° C. Certainly 99% of oil well-cementing operations worldwide are approved with this material [1].

The physical, chemical, and mechanical properties of Portland cement must match the specifications of the American Petroleum Institute (API) to be considered petroleum cement and thus can be used in oil well operations. The task of cementing in oil wells involves introducing cement slurry into the annular space between the liner and the rock formations. Petroleum cement is distinctive cement used in the process of cementing oil and gas wells. Protect casing from aggressive features that may be a source of corrosion. For the period of oil well cementation, fluid migration overdue the cased holes is the main problem in drilling together short and long terms subsequently cementing operations. Extraordinary formation pressures, high shrinkage degree of cement slurry, lack of mechanical seal and channeling due to meager cement slurry design, and those entire is the principal reason for expensive drilling and completion processes and from time to time well abandonment.

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Different additives are used [2] and numerous categories of cement slurry chemical admixtures for instance; superplasticizers, retarders, accelerators, and viscosity modifiers which are used for optimizing the flow properties of cement slurry [3]. Portland cement experiences major chemical and microstructural transformations under high-temperature conditions (>110◦C). Such a phenomenon is known as strength retrogression, which increases as long as the temperature increases beyond 110 ◦C [4 and 5]. During the strength retrogression transformation, calcium-rich products are formed in the cement matrix, which will increase the matrix porosity and permeability and deteriorate its mechanical properties. The accurate selection of chemical admixtures is essentially established on a trial and error technique established on Marsh cone flow, and the rheological tests [6].

There is a lot of research going on to utilize and recycle bauxite residue [7] including potential applications in the construction industry [8]. However, many processes seem not economically feasible yet to reuse the large amounts of available disposed of BR. The cement industry might be the only industry with sufficiently high volumes produced globally to tackle the high amount of bauxite residue produced every year and it is, therefore, necessary to also investigate the feasibility of BR to be used as supplementary cementitious material (SCM The performance of the chemical additives is intensely influenced by the physical and chemical properties of the cement [9 and 10].

There are several types of cement slurry chemical admixtures such as; superplasticizers, retarders, accelerators, and viscosity modifiers that are used to optimize the flow properties of cement-based products. Silica fume or micro silica initially vied as cement replacement material and in some areas, it is usually used as replaced by a much smaller quantity of silica fume micro silica may be used as pozzolanic admixtures [11].

Superplasticizer is a type of water reducer; however, the difference between superplasticizer and water reducer is that superplasticizer will significantly reduce the water required for concrete mixing [12 and 13]. Generally, there are four main categories of superplasticizer: sulfonated melamine- formaldehyde condensates, sulfonated naphthalene- formaldehyde condenses, modified lignosulfonates, and others such as sulfonic- acid esters and carbohydrate esters. Effects of superplasticizer are obvious, i.e. to produce concrete with very high workability or concrete with very high strength. The mechanism of the superplasticizer is through giving the cement particles a highly negative charge so that they repel each other due to the same electrostatic charge. By deflocculating the cement particles, more water is provided for concrete mixing [14].

Admixture is defined as a material other than cement water and aggregate that is used as an ingredient of concrete and is added to the batch immediately before or during mixing.

Pozzolanic admixtures are siliceous or aluminous material which is themselves possess little or no cementitious value but will in finely divided form and the presence of water chemically react with calcium hydroxide liberated on hydration at ordinary temperature to form compounds possessing cementitious properties. In our experiment, we are using micro silica as an artificial pozzolan. The early age and hardened properties of cement-based systems are highly dependent on the type and dosage of chemical admixtures used [15].

A wide variety of cement admixtures are currently available to enhance the oil well cement slurry properties and achieve successful cementation. For the local cement to be effectively used for oil well cementation, it is desirable to optimize the setting time and the thickening time of the cement slurry [16].

Accurate control of the thickening time and setting time is very important because a premature setting can have disastrous consequences due to loss of circulation in the well. Also, too long setting time can cause possible segregation of the slurry [17]. A setting and thickening behavior can be achieved by adjusting the composition of the retarders and the accelerators [18]. Million tons of waste glass is being generated annually all over the world. Once the glass becomes a waste it is disposed of as landfills, which is unsustainable as this does not decompose in the environment.

Glass is principally composed of silica. The use of milled (ground) waste glass in concrete as a partial replacement of cement could be an important step toward the development of sustainable (environmentally friendly, energy-efficient, and economical) infrastructure systems. When waste glass is milled down to micron size particles, it is expected to undergo pozzolanic reactions with cement hydrates, forming secondary Calcium Silicate Hydrate (C–S–H) [19]. The use of supplementary cementitious materials (SCMs) to offset a portion of the cement in concrete is a promising method for reducing the environmental impact from the industry. Several industrial by-products have been used successfully as SCMs, including silica fume (SF), Bauxite residue (BR), and glass powder (GR). Several investigators have proposed [20] these materials that are used to create blended cement which can improve concrete durability, early and long term strength, workability, and economy [21].

The goal of this work is to describe and evaluate the performance of Iraqi cement produced in Babel (local cement), according to the American Petroleum Institute (API). This analysis is an exertion for comparing the physical and chemical properties of locally factory-made cement in Iraq with the imported class G cement. In other words, this effort is related to the possibility of using Iraqi cement in cementing job operations in our field instead of using commercial cement.

Finally, this study achieves its objective of the possibility of using Iraqi cement in our oil fields instead of using commercial cement without any expected and serious problems.

2- Materials

2.1. Cement

The cement used in this study is produced in recent times by the Bebel cement plant (oil well cement, Class G, HSR) by way of its trade name, and this type of cement is also used in cement jobs in the east Baghdad field /southern zone.

2.2. Water

Along with the experiment, the normal drinking water was used to prepare our slurry mixture. According to API specification, distilled water was used for the specimen's planning; it is deionized water with zero melted solids but through field operation, they use drinking water not distilled water. However, in a primary cementing operation, a water-to-Class G cement (w/c) ratio of 0.44 is used as per the API standard which makes a cement density of approximately 15.66 lb./gal. [22].

2.3. Silicate, (silica fume)

Silicates structure around 75 percent of the chemical composition of cement in which the silicates be responsible for an enormous impact on the durability of cement. The silicates function is providing the strength of cement where the silicates chemically respond with different substances to transform the composition of cement [23].

Additionally specifically, water wants to be added to the silicates, for instance, tricalcium silicate, to undergo hydration to release calcium ions, hydroxide ions, and large quantities of heat. Micro silica, also identified as silica fume, is another sort of silicate that adds to the cement to increase durability. It is responsible for a better spreading and better volume of hydration products by declining the average size of pores in the cement paste. Silica fume particles are too small that they evenly disperse among the cement to create greater bond strength as well as raise electrical resistivity, creating micro silica a good protective reinforcement for cementing job [24].

2.4. SCR -100 Retarder

Is a non-lignosulfonate cement retarder that assistances simplify the designing of thixotropic slurries, is active in fresh water at bottom hole circulating temperature up to 250 °F (121 °C). It doesn't source any settling problems related to non-aqueous suspensions.

When treated for 24 hours at BHCT, this retarder aids be responsible for exceptional compressive strength the additives levels of SCR should not be higher than 4%. [25].

2.5. Hollow Glass Spheres (HGS)

Assistance to decrease slurry density without knowingly affects strength progress. It helps to reach a lighter weight slurry with high compressive strength and low density (non-foamed) the additives levels of HGS should not be higher than 3%. [25].

2.6. Halad-9 Additive

It is a mixture of cellulose derivative and dispersant. It makes available fluid loss control in all API classes of cement. It can be used in oil wells with bottom hole circulating temperatures (BHCTs) between 60° and 300°F (15.5°C and 149°C). In most cement, the additive concentrations should be about 1% or less for providing suitable fluid-loss control [25].

2.7. FWCA

It is an anti-settling polymer additive, which is used to prevent solids from settling. It is obtainable as a white solid powder that has 1.03 sp. gr, the additives levels should not be higher than 2%. [26].

2.8. Bauxite Residue (BR; also named "red mud")

It is an unwanted product from the Bayer method in constructing alumina (Al2O3) as rare material for aluminum metal-making. BR is an insoluble creation after bauxite digestion with sodium hydroxide. Bauxite residue has a multifaceted chemical composition and contains several crystalline phases, mostly iron oxides, and hydroxides, also have aluminum hydroxides, sodalities, quartz, rutile, and many others besides some organic materials.

It's a compressive strength additive that can provide good cement bond control in high-temperature wells, mainly when used on densified cement slurries. On the other hand, the addition of bauxite residue can raise the durability of cement. most of the studies in the literature approved assure: that the strength of cement in long term falls when the levels of the additive of BR are higher than 5%. [25].

2.9. HR-5 Additive

A chemically improved lignosulfonate that is retards the setting of slurry. It is designed for use in oil wells that it's circulating temperatures amongst 125°C and 206°F. HR-5 additive provides increasing concentrations of HR-5 additive enhancing the Expectedness of slurry thickening times.HR-5 additive drops the hazard of over-retarded slurries at the upper of a long cement column.

HR-5 additive is responsible for early slurry strength development. The additives levels of this material should be equal to or less than 5% to slow the thickening time. [26].

2.10. Super Plasticizer

The superplasticizer that used in this paper is Glenium 380. It is a novel superplasticizer, which not only appropriate for reducing the thickening time of slurry, but also for increase compressive strength.

Unique to its benefits, is that it can develop both early and final compressive strength. Furthermore, slump preservation and workability of slurry also improved by using Glenium 380, if associated with an old-style superplasticizer. Superplasticizer (SP) is essential to improve the workability and setting time of slurry. Also, aid to decrease shrinkage and thermal cracking. The additives levels of SP should be less than 15% of water to slow the setting rate of the slurry while keeping the flowing properties of the cement slurry. [27].

2.11. Glass Powder

The chemical compositions of glass powders mostly contain silica and the materials could be declared as pozzolanic material as per ASTM standard. glass addition can reduce the cost of cement production. A study on the durability of concrete with the waste glass pointed to better performance against chloride permeability in long term but there is concern about the alkali-silica reaction. Several types of research show that at the higher age recycled glass (15%) to 20% of cement replaced) with milled waste glass powder provides compressive strengths exceeding those of control cement slurry. Specific gravity and fineness of clear waste glass powders (prepared by ball mill) were 3.01 & 0.9% (#200 sieves) and the particle sizes approximately 300 μm [28].

3- Experimental and Slurry Design

Are done for obtaining fitting cement slurry properties, the cement slurries were prepared according to the API standard. These properties are important for getting cement slurry that is proper for oil well-cementing operations. With the aim of control, the performances of the local Iraqi cement, investigational tests were done on slurry. The experimental procedure followed for preparing the different testers is stated by the API Specifications 10A. These properties are as follows:

3.1. Free Water

Free fluid assessment for challenging cement slurries used for determining slurry ability for preventing fluids separation at static conditions. Extreme free fluid in cement slurry may because many problems with water pockets, channeling, sedimentation, and zonal isolation. For the measurement of free water substances, the cement slurry is equipped and conditioned typically to API specifications. Next the conditioning of slurry, slurry is emptied in a graduated cylinder and covered with aluminum to stop evaporation. Far along, it is subjected to 2 hours' test period.

At the end of the investigation duration, a syringe is used for extracting the free water separated at the top of the slurry and the quantity of water is measured in milliliters (ml)

3.2. Thickening time

Thickening time is a point to the era within that cement slurry stay pump able underneath well-simulated circumstances. The laboratory test situations should be representing the time, temperature, and pressure at which slurry will be exposed through pumping setups. Many factors that may affect the slurry's pump facility during a job cannot be simulated exactly through a test of thickening time which is: (fluid contamination, fluid loss to the formation, unforeseen temperature variations, and unplanned shutdowns in pumping).

For determining the thickening time, the consistency of slurry is measured. The consistency, stated in Bearden units of consistency (BC), is determined by the force executed by the slurry in contradiction of the paddle and dignified as a torque. The test is directed up to the time at which the slurry reaches a consistency deemed sufficient for making it unpumpable (for instance 70 or 100) Bc. The slurry consistency at which the thickening-time test was finished should be recognized and reported. The approval requirement for the extreme consistency for the duration of the 15 min to 30 min stirring era should be 30 Bc for cement class G. [27 and 29]

3.3. Compressive Strength

The compressive strength test governs the integrity of cement slurry and its capability to stand long-period forced stresses. The supreme pressure used for curing is generally 3,000 psi (API), except else specified. There are two approaches for measuring the compressive strength, first by devastating and additional is by the non-destructive way. [30].

3.4. Compressive Strength – Ultrasonic Cement Analyzer UCA

The sonic strength test is a non-harsh test done on slurry to guess its strength. Correspondences have been established to estimate the compressive strength of a slurry composition built on the time requisite for the ultrasonic signal to permit through the cement as it sets. Sonic strength and crush strength signs can vary significantly contingent on the temperature of the test and slurry composition.

The sonic compressive strength of cement slurry is measured by placing slurry in the autoclave part of ultrasonic cement analyzer (UCA) with temperature and pressure attuned to made-up downhole circumstances, [30].

3.5. X-ray Fluorescence Analysis (XRF)

Apparatus for elemental analysis and distribution imaging X-ray fluorescence analysis (XRF) uses characteristic X-rays (called ‘‘fluorescence X-rays’’) emitted under high-energy x-ray irradiation. XRF has some advantages in that X-ray fluorescence analysis (XRF) provides useful elemental information about cement components, is a non-destructive analytical technique used to determine the elemental composition of materials. XRF determines the chemistry of the sample by measuring the fluorescent X-rays emitted from the sample [31]. Table **1** gives us the chemical composition of Iraqi and Omani cement in detail and Table **2** gives us the chemical composition of silica fume, bauxite, and glass powder in detail.

Table 1. The chemical composition of Iraqi and Omani cement

Component	% in Iraqi Cement	% in Omani Cement	%API standard
MgO	1.77	0.766	0.9
Al_2O_3	2.996	2.428	5.6
SiO_2	18.63	37.58	24.66
SO_3	3.072	1.846	1.55
CaO	69.49	57.06	61.87
MnO	0.05061	0.0789	0.75
Fe_2O_3	5.587	4.964	0.38

Table 2. Chemical composition silica fume, bauxite, and glass

Compound	Glass powder	Silica fume	Bauxite residue
SiO_2	66	92	1.7
Al_2O_3	9	1.1	53
Fe_2O_3	<1	1.5	4.5
CaO	12	0.6	2.7
MgO	<1	0.9	0.7
K_2O	<1	–	–
Na_2O	11	–	0.03
SO_3	–	0.4	-
LOI	–	2	30.6
Moisture	–	–	–

3.6. Rheology Test

The rheology influences the performance of slurry and assists in defining the pumping ability of the slurry. At rheology test, flow properties: plastic viscosity and yield point of cement slurry are definite, using a rotational viscometer for instance HPHT Viscometer by Chandler at high-temperature conditions.

Principally, the cement slurry is set and conditioned conferring to API specifications. The conditioned cement is emptied in the pre-heated cylinder of viscometer, rheological parameters gotten by correlation of shear stress in contradiction of shear rate at the target temperature.

The slurry rheology is tested at different temperatures, which could be more than 2, to use those data in hydraulic simulators, surface temperature, and downhole circulating temperature (simulated or from API tables) [32].600 rpm is not a portion of the process for testing the rheology of slurries. Eq. (1) and Eq. (2) were respectively used to calculate the plastic viscosity and yield point of the cement slurry.

$$\mu p = 1.5 * (\Theta_{300} - \Theta_{100}) \tag{1}$$

$$Yp = \Theta_{300} - \mu p \tag{2}$$

Where:
μp: plastic viscosity of cement slurry.
Yp: yield point of the cement slurry.
Θ_{300} and, Θ_{100}: rotational speed of viscometer.

After recording the dial readings, divide the Up readings by the Down readings to get their ratio. If the ratio is other than 1:1 it can be an indication the slurry may have settling or gelation problems. There may be settling problems if the readings are 5 numbers less for the down readings than for the up readings. Rheology calculated by correlation of shear stress against shear rate. Test data obtained with Rotational Viscometer Rotational speeds: 300 rpm, 200 rpm, 100 rpm, 60 rpm, 30 rpm, and 6 rpm and3 rpm

3.7. Fluid Losses Tests

This test is performed as per API recommended practice for testing well cement, API does not identify ranges to follow it, but in API 65 they reference that has to be low, 46 ml/30 min is a low value, usually used for production zones. The table illustrated the amount and concentration of the designed slurry [32]. The material quantities used and the composition of the tested sample are given in Table **3**

Table 3. Experimental slurry quantities and their composition

Samples NO.	Iraqi Sample A	Iraqi Sample B	Sample C Iraqi	Sample D Omani
Cement (g)	792	792	792	792
Mix water (ml)	349	349	349	349
Micro silica% BWOC	0	25	30	0
Bauxite % BWOC	0	8	8	0
Super plasticizer (ml)	0	70	50	0
SCR -100 Retarder	0.76	0	0	0.76
Hollow Glass Spheres% BWOC	1	0	0	1
Halad-9 % BWOC	1	0.05	0.05	1
HR-5% BWOC	1	0	0	1
FWCA% BWOC	1.1	0	0	1.1
Glass powder	0	20	25	0

4- Results and Discussion

Some oxides in cement for instance MgO, free CaO, and SO3 may reason for expansive reactions with the time that principal to a reduction in cement compressive strength. If those oxides were found in high percentages, they lead to crucial destruction of cement. From x-ray analysis Iraqi cement has a MgO amount greater than Omani cement, on the other hand, the percentage of CaO in Iraqi cement (69%) is too higher than that in Omani cement (57%). SO3 in Iraqi cement about3.072% while in Omani cement about 1.846%.

The present study also was carried out to investigate the combined effect of those oxides contents in cement on the compressive strength of cement. The increase in MgO content results in a decrease in the compressive strength and a reduction in the cement durability. Iraqi cement is jelly cement, so it fast thickening time, also it has low compressive strength. If it still in this statement, this type of cement gives a bad cementing job because of its low durability.

The problem with Iraqi cement is the low percentage of silica which is about 18.63% depending on X-ray fluorescence analysis (XRF) while in Omani cement about 37.58%. Using micro silica and glass powder leads to a significant increase in the amount of silica which is an important element in cement.

The results of net cement show that the compressive strength tests for Iraqi oil well cement class G at 38°C are good and acceptable according to the API standard specification 10A (exceeded 300 psi), while the results at 60°C are not satisfy compared to the API specification 10A (not exceeding 1500 psi).

This can be attributed to the fact that high-temperature curing can get a negative impact on early strength development. Iraqi cement is used at cementing jobs operation in East Baghdad Field, but there are some problems related to Iraqi cement in this field, for example, low thickening time, Poor compressive strength, etc. From 2860m to 2910m (first part of production zone): amplitude low, VDL doesn't showcasing and formation signals.

Thin mud signals are visible (no cement bond) Squeeze cement is needed as shown in Fig.1. Fig.2. represents CBL (Cement Bond Log) and VDL (Variable Density Log) for zone cemented by using Iraqi cement in well at East Baghdad Field. From the log it clear that the zone 3000m to 3250m in other words, production zones have cement without bond to the formation, VDL shows that the light grey areas greater than the dark grey layer that mean the bond are not good.

Also, the high amplitude of CBL (Cement Bond Log) assures that meaning. VDL (Variable Density Log) shows a straight line, no formation signal.

The other zones in this log are considered partial cement because the amplitude is low and moderate and VDL shows both wiggly formation signals and straight casing signal (Poor compressive strength) Squeeze cement is needed if the channel is long enough

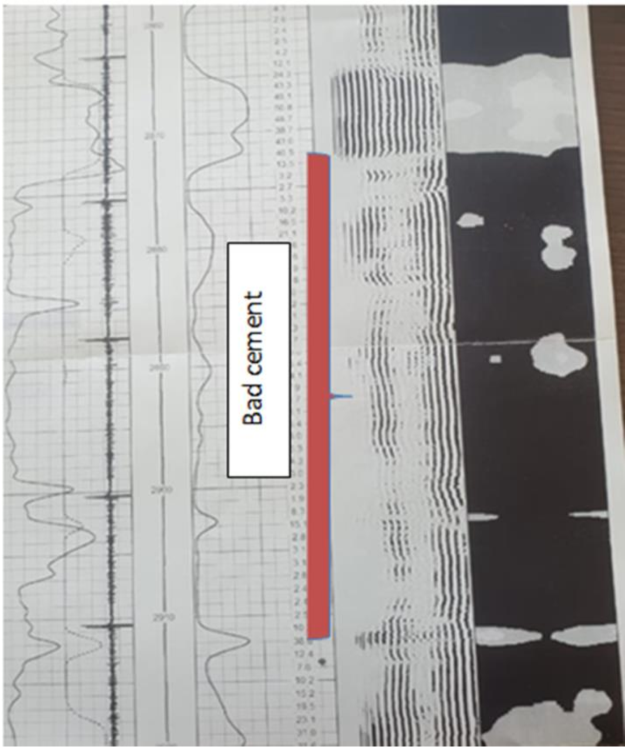

Fig. 1. VDL and CBL Log for well in at East Baghdad Field from (2860 to 2910) m

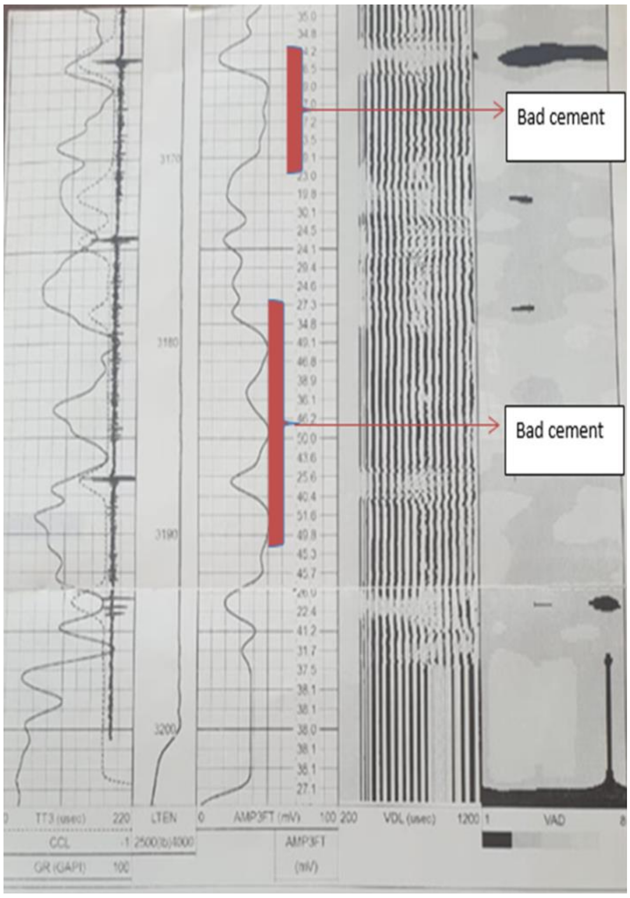

Fig. 2. VDL and CBL Log for well in at East Baghdad Field from (3000 to 3250) m

Since the problem of the strength of the compression of cement was the weakness of the Iraqi cement, which was evident from the tests of pure cement. I have two temperatures of 38 and 60 degrees Celsius, so in our research, we focused on this characteristic more than others.

Fig. **3** represents the effect of adding micro silica on the compressive strength of cement, and through it, we note that the higher the percentage of micro silica, the greater the value of the compressive strength of the cement. It should be noted that micro-silica was used as an additive and not as it was used before by Al-Jumailya et al.

As a replacement material for cement, which led to increase compressive strength and reduce free water to zero, silica reacts with cement component and hydrates very slowly, and contributes mainly to the long-term strength.

Fig. **4** represents the effect of adding bauxite on the compressive strength of the cement, the reason behind that is that bauxite has a high percentage of alumina about 53% that react with cement component and hydrates very rapidly and produces most of the heat of hydration and early strength observed during the first few days.

We note that the proportion is direct when the bauxite ratio is less than 8 percent compared to what was found before, from Rajendran et al., who founded that the bauxite ratio should not exceed 5%. We observe a rapid decrease in the compressive strength of the cement when the bauxite ratio is higher than 8 percent.

Fig. **5** illustrates the effect of glass powder on the compressive strength of cement, where we note that the proportionality is proportional when the ratio of the glass powder is less or equal to 25 percent and vice versa.

This is close to what has been proven before by Andreola et al because the high percentage of silica in glass powder about 66%, which is thought to be the major contributor to long-term strength. Fig. **6** summarizes the effect of adding a Superplasticizer on the value of compressive strength as the compressive strength of cement increases if the percentage of superplasticizer is less or equal to 20%.

This result is slightly greater than what was obtained before by Collepardi et al. It should be noted that a superplasticizer has been added to obtain pumpable cement slurry and to delay the thickening time to enable the cement slurry to reach the appropriate place. On the other hand, the addition of micro silica and bauxite leads to a reduction of the thickening time for the cementing process.

The superplasticizer was used to treat these effects Tri calcium aluminate C_3A and as shown in Fig. 7. It should be noted, that the powdered glass substance is considered an inert material that has no significant effect on the time the cement thickens.

Its effect is only by increasing the compressive strength of the cement because it fills the voids that may occur in the cement and thus increases the durability and strength of the cement.

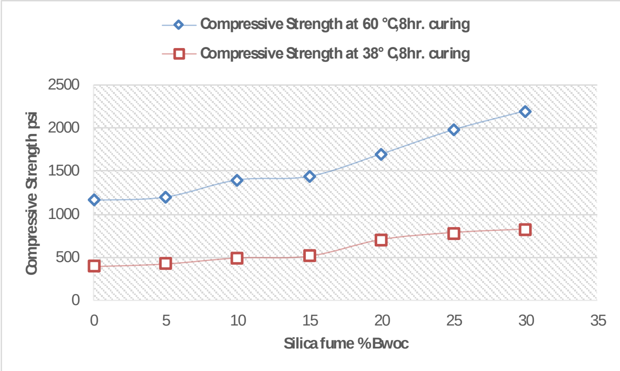

Fig. 3. The effect of micro silica on compressive strength of cement slurry at 60°C and 38°C

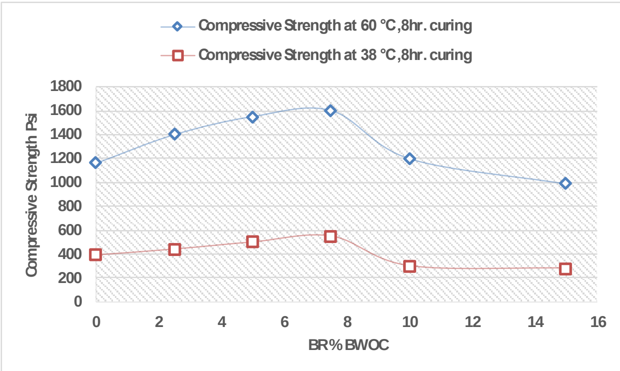

Fig. 4. The effect of BR on compressive strength of cement slurry at 60°C and 38°C

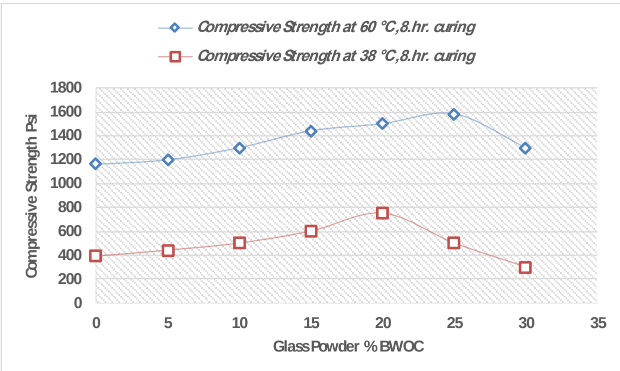

Fig. 5. The effect of Glass powder on compressive strength of cement slurry at 60 °C and 38°C

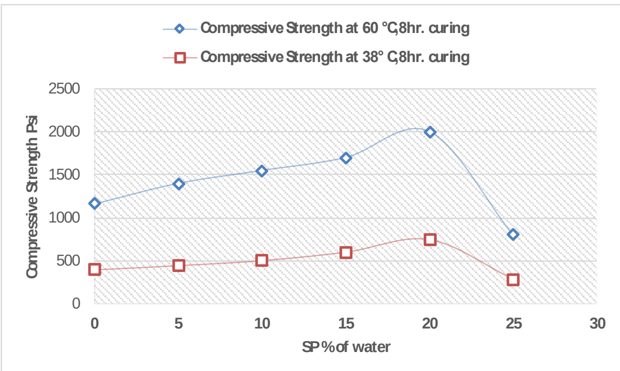

Fig. 6. The effect of SP on compressive strength of cement slurry at 60°C and38°C

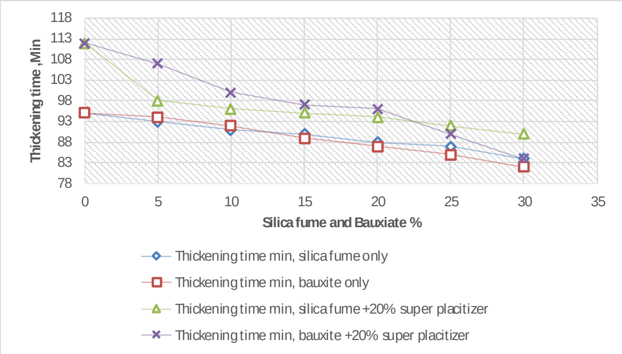

Fig. 7. The effect of superplasticizer on thickening time at pr.=5200psi, T=52°C

Table 4 and Table 5 show us the results of testing the designed slurry, the Iraqi cement was prepared into three samples which are A, B, and, C while sample D represents Omani cement.

Net Iraqi cement was also tested to make a complete Comparison between all tested samples. Samples B and D were prepared using waste material and superplasticizer, while samples A and D were prepared using conventional additives. Sample C has the maximum value of plastic viscosity and the lowermost value of yield point due to the presence of 30% BWOC micro silica, 25% BWOC glass powder, and 15%super plasticizer, and 5% bauxite. All those materials led to give good cement compressive strength for both temperatures 60 and38°C. Sample B gave the lesser density value comparing with the other tested samples because of the high value of SP which is about 20% from water, on the other hand, this sample gave a high value of thickening time due to the high value of SP which is about 20% and slightly low value of silica fume which is about 20% BWOC.

Furthermore, the consequences indicate that there are decreases in the value of density after adding micro silica, superplasticizer. Sample A gives the highest free water and fluid losses respectively, also this sample gave the lowermost thickening time all that due to the presence of conventional cement additives. However, sample D that represents Omani cement gave high thickening time and compressive strength respectively than sample A. Finally, it can be said that Omani cement showed good performance compared to Iraqi cement after adding traditional additives, but both of them showed good results for all the properties of cement, especially the compressive strength.

On the other hand, the added waste enabled Iraqi cement to perform much better than Omani cement. Since Iraqi cement shows the lowest compressive strength value and this is one of the main problems for Iraqi cement, sample C shows the best performance because it gave the highest compressive strength and this is considered an excellent design for cement mortar because it solves the Iraqi cement problem as shown in Fig. **8** and Fig. **9**.

Table 4. Result of the cement slurry design

Sample no.	Compressive strength Psi at 38 °C,8 hr. Curing	Compressive strength Psi at 60°C 8.hr. curing	Thickening time, min PR=5200, T=52°	Free water%
Sample A	400	2300	90	1.5
Sample B	800	2320	115	0.1
Sample C	990	2600	103	0
Sample D	450	2400	110	1.05
API standard	300	1500	90-120	5.9
Net cement	300	1162	95	2.5

Table 5. Result of the cement slurry design at Bottom Hole Circulating Temperature BHCT of 133F

Sample no.	Fluid losses ml./30 min	Pv cp	Yp lb./100ft^2	Density gm/cc
Sample A	29	46	24	1.5
Sample B	27	42	23	1.77
Sample C	22	47	20	1.78
Sample D	20	38	23	1.75
Net cement	42	51	37	1.88

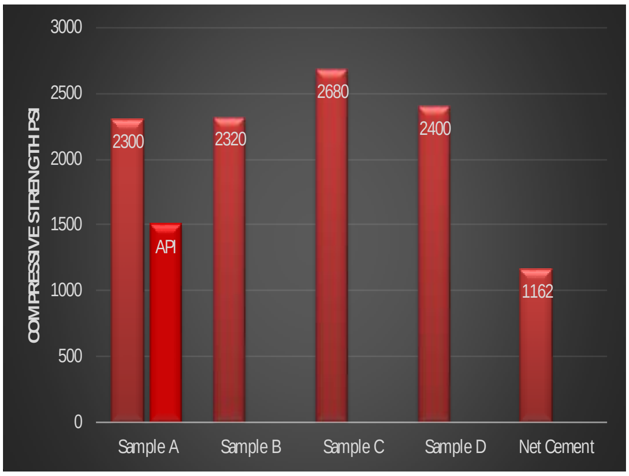

Fig. 8. Compressive strength results comparison at 60 °C and 8.hr. curing

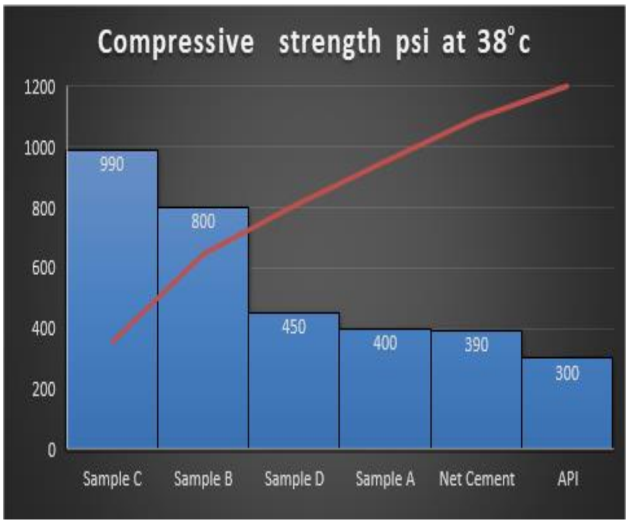

Fig. 9. Compressive strength results comparison at 38 °C and 8.hr. curing

4.1. CemCADE Results

A pre-job simulation is used for making guesses regarding the performance of the cement slurry to use it as well as the bottom hole and surface pressures to expect through the job. Significantly, perfect well data is used as input into this simulator. On the other hand, simulations supply a very good estimate of the conditions that are prospective to prevail through the implementation of a job. Currently, there are several marketable simulators on the market that offer an inclusive suite of applications that handle many wellbore configurations and slurry rheological models.

CemCADE is fully combined software covering different modules where all features of a cement job are accounted for Dynamic graphics are automatically updated with any change of data and several independent computers further for helping the user picking the suitable cementing job factors. From CemCADE program. sample C as tail slurry because of its density about 1.78 gm/cc and sample A is lead slurry because its density about 1.5 gm/cc. Since sample C gives the best performance of slurry design comparing with the other tested samples related to the compressive strength results, we chose it as an extraordinary sample to represent its results in the CemCADE program as tail slurry, furthermore, sample A shows good performance and its chosen as lead slurry. Information on cement slurry must be entered into the program for both selected samples, which are sample A as lead and sample C as a tail from the experimental results for those samples from Table 4 and Table 5. In addition to that, information regarding the well or section to be cemented must be entered as found in Table **6**.

Table 6. Design Parameters for Production casing

Well Information	values
open hole depth	2560 m
casing depth to be cemented	2557m
OD/ID of the casing	7/6.185 in
open-hole interval, as per caliper	8.9869 in
OD/ID previous casing size	9.625/8.7 in
previous casing shoe depth	2036 m
top of lead	1355m
top of tail	1936m
cased hole lead excess	0%
open hole tail excess	30%
BHST/BHCT	79/56 °C
NO .of centralizers	99

Fig. **10**.shows the rheological behavior of a lead and tail cement slurry measured using a Fann VG meter. The shear stress - shear rate response was curved fitted using the Herschel – Bulkley, where k=1.58E-2 and k=1. 44E-2 lbf.s /ft2,n= 0.75 and n= 0.87 , **Ty**=11.25 lb./100ft2 **and Ty**=10.88 lb./100ft2 for tail and lead slurries respectively.

Also, this figure represents the rheology of all used fluids and it clear that the cement is followed by modified power low The Herschel – Bulkley fluids combine the characteristics of power-law and Bingham fluids. Thus, there is minimum stress required for flow initiation but above that, the shear stress/shear rate relationship is similar to that of a Bingham fluid. The equations that describe the behavior of Herschel – Bulkley fluids are as follows in Eq. 3:

$$\tau = \tau y + k\gamma n \ when \ \tau > \tau y \qquad (3)$$

Where:
τ=shear stress lb/100ft ^{2} , k= consitency lb/100ft ^{2}, n= flow index, γ= shear rate RPM

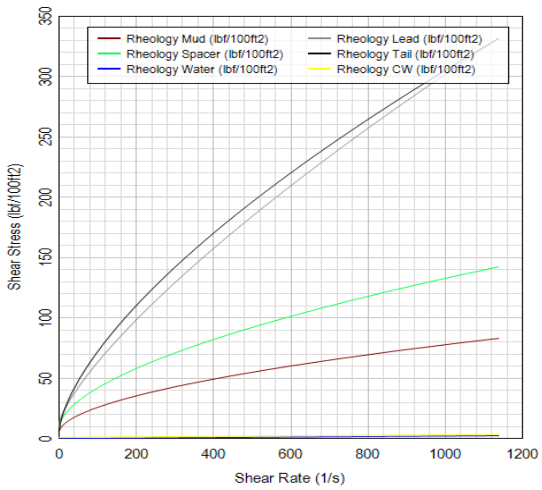

Fig. 10. Compressible Rheology Parameters displayed at P=1 atm and T=20° C (65°F)

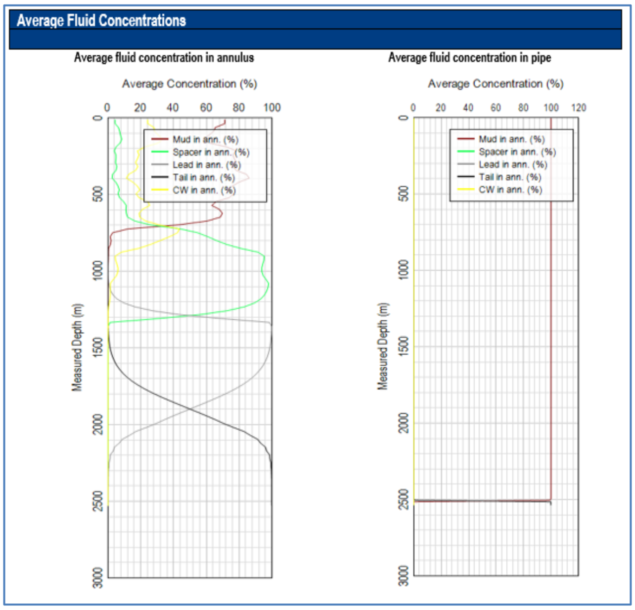

Fig. 11. Average fluid concentration

Fig. **11** and Fig. **12** showed the distribution of cement slurry in the annular space and casing. The cement slurry was distributed well as planned upon entering the information for the program except for a small transition area from 1900 meters to 2000 meters.

From the color of the concentrations of liquids distributed in the annular void, there is no contamination between the fluid and channels, all that is a good indication of the presence of a good cementitious bond.

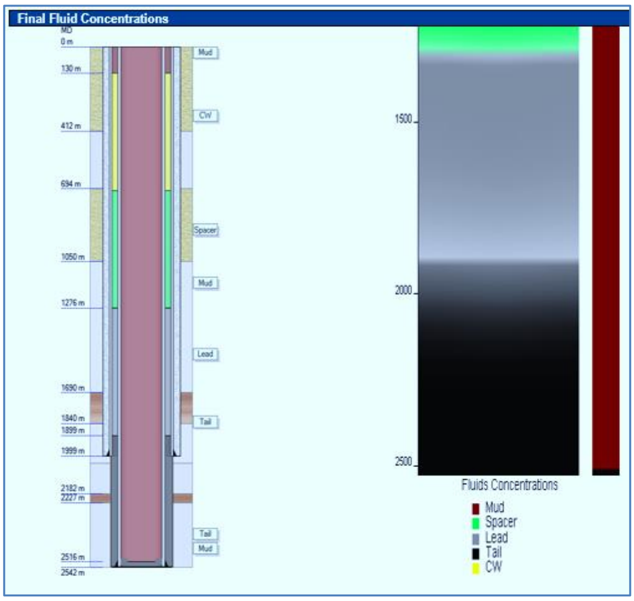

Fig. 12. Average fluid concentration

Also, from Fig. **13**, the compressive strength is obtained by ultrasound of sample C of a cement slurry which is about 2,691 psi after 24 hours. Handling is at 70 ° C, which is close to the device's measured value of 2,600 psi. From Fig. **14**, an assay of sample C shows HPHT cement at conditions of 5500 psi and 177 ° C for 7 hours. The cement was still pumpable and gave a consistency of 30 BC for three hours, which is the preferred field value

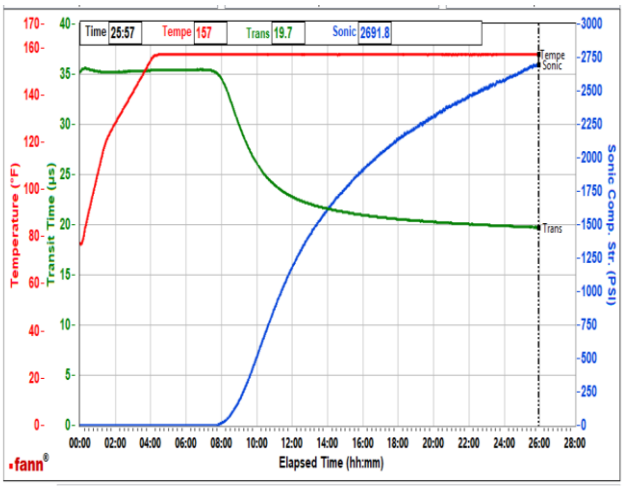

Fig. 13. Compressive strength for sample C from the USA after 24hr. curing and at 70°C

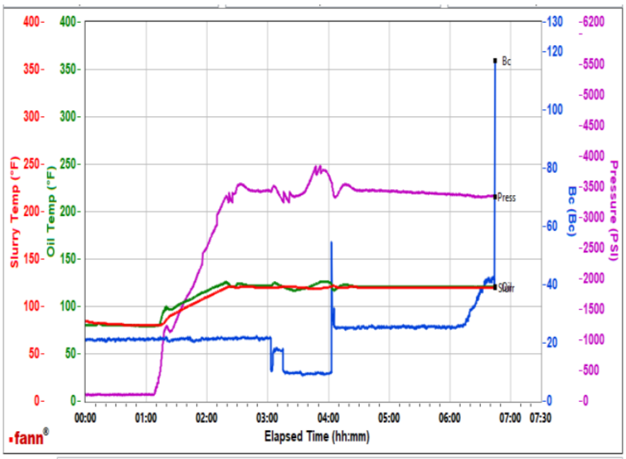

Fig. 14. HPHT curing for sample C slurry cement at 5500 psi and 177 ° C for 7hr

5- Conclusion

In keeping with the consequences acquired in this study, the following can be clinched; From XRF results, Iraqi cement has a high amount of these Oxides: MgO, CaO, SO3and Fe2O3 comparing with the standard API. That high oxide content in cement generally results in a decrease in compressive strength and durability;

Adding Bauxite inhibits the bad effect of an increasing the amount of MgO, CaO, SO3and Fe2O3 oxides in Iraqi cement and give us more sulfate resistance slurry. But the levels of the additive of BR should be less than 8% BWOC; From XRF results, Iraqi cement has a low value of SiO2 which is about 18.63% paralleling with the standard API, adding micro silica and glass powder lead to increase the extent of silica in Iraqi cement because these materials have a high amount of silica and that attributed to improving compressive strength and, at the same time, it reduces the free water percentage to zero; Addition of Superplasticizer (SP) is vital to develop the workability of slurry and increasing thickening time with the attendance of silica fume and bauxite. The additives levels of SP should be equal to or less than 20% from the used water to slow the setting rate of the slurry while keeping the flowing properties of the cement slurry.

The result of compressive strength for net cement sample at 60°C is not satisfied compared to the API specification 10A (not exceeding 1500 psi). This can be attributed to the fact that the high-temperature curing can get a negative impact on early strength development, but after adding micro silica, superplasticizer, glass powder, and bauxite, Iraqi cement gave high compressive strength better than Omani cement as in sample C;

Adding micro silica and Superplasticizer (SP) together lead to a slightly decrease in the value of slurry density but still in acceptable range; From CemCADE results, Sample C gave the best and good fluid distribution inside the pipe and in the annulus, and that be considered one of the indicators of good cement bond and no any contamination between the used fluids;

The other conventional additive which is: (SCR -100 Retarder, HR-5, FWCA, Hollow Glass Spheres (HGS), and Halad-9) that currently used in our fields in the south of Iraq play an important role to enhance and design special slurry be able to stand over downhole circumstance from temperature and pressure and sour gases; The laboratory test for compressive strength show that at the stage of above 25% of glass powder there are rabidly decline in the value of compressive strength, so the optimum value should be equal or below 25%. The results of the program CemCADE proved to be the sample A and C showed good performance through high cement bonding and ideal distribution of fluids designed to accomplish the cementing process.

Acknowledgments

The authors are very grateful to the Head of cement section in Petroleum R&D Center Mr. Qasim Abdulridha Khalti, also the authors are very grateful to senior engineer Ahmed Abdulah Haiwi from Basra oil company (BOC) for his support.

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تقييم ادائية الاسمنت المحلي العراقي بالاسمنت المستورد لتصميم ملاط السمنت لابار النفط العراقية

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الخلاصة

يتعلق هذا الجهد بوصف وتقييم أداء عينة الأسمنت العراقية المخطط لها لوظائف تدعيم آبار النفط في العراق. في هذا البحث ، تم اختبار الخصائص الرئيسية للأسمنت وهي زمن التثخين وقوة الضغط والمياه الحرة بالإضافة إلى الخواص الانسيابية وفلترة ملاط الأسمنت في ظل ظروف محددة بشكل تجريبي. تشير العواقب إلى أن الأسمنت العراقي بعد إضافات خاصة يلبي متطلبات معايير API ويمكن بالتالي استخدامه في تدعيم وظائف آبار النفط. يوجد في هذا البحث تحقيق مقارن تم إجراؤه على عمل تجريبي حول فعالية بعض المواد المضافة التي تعتبر مواد نفايات وهي دخان السيليكا والبوكسيت ومسحوق الزجاج ومضافات تقليدية أخرى وهي: (SCR –100 Retarder، HR–5، FWCA ، الكرات الزجاجية المجوفة ((HGSو Halad–9 التي تستخدم حاليًا في حقولنا على الأسمنت العراقي المحلي ووضع نتائج الأسمنت الأجنبية كمحافظ.

تم تحديد عينات التحليل الكيميائي للأسمنت العراقي والأسمنت المستورد وعينات النفايات باستخدام تقنية حيود الاشعه السينيه ووجدت اختلافات طفيفة في التركيب بين تلك العينات .واعتمادًا على نتائج الأشعة السينية ، نقوم باختيار الإضافات المناسبة لتحضير الأسمنت عينات الطين. أظهرت النتائج باستخدام تقنية حيود الاشعه السينيه أن الأسمنت العراقي يحتوي على نسبة منخفضة من السيليكا تبلغ حوالي 18.63٪ بينما في الأسمنت العماني حوالي 37.58٪. فحص هذا البحث إمكانات السيليكا الدقيقة والبوكسيت ومسحوق الزجاج المخلفات لإنتاج ملاط أسمنتي مستدام. أظهرت النتائج أن إضافة ميكرو سيليكا والبوكسيت يحسن من أداء الأسمنت العراقي ولكنه يؤدي أيضا إلى انخفاض طفيف في وقت التثخين. لتجنب هذه المشكلة ، يتم استخدام الملدنات الفائقة لجعل عملية ضخ الأسمنت أكثر سهولة ، بمعنى آخر زيادة وقت التثخين وزيادة قوة الضغط. علاوة على ذلك ، فإن إضافة مسحوق الزجاج يزيد من قيمة مقاومة الانضغاط. يتم استخدام كل من المضافات (النفايات والتقليدية) لتصميم الملاط لتحقيق خصائص ملاط أفضل ، ولكن إضافة النفايات تزيد وتعزز أداء الأسمنت العراقي مقارنة بالإضافات التقليدية ، بمعنى آخر ، مما يجعلها أكثر فعالية من الأسمنت التجاري. اعتمادًا على نتائج اختبار مقاومة الانضغاط ، تم العثور على التركيز الأمثل لمواد النفايات المستخدمة في هذا البحث ، ثم تم استخدام التركيز الأمثل لإعداد عينات الأسمنت. أظهرت النتائج أن استخدام المخلفات لتحضير ملاط الأسمنت يعد وسيلة واعدة لتحسين كفاءة أعمال الأسمنت وتقليل الأثر البيئي السلبي الناتج عن الصناعة. أثبتت نتائج برنامج CemCADE أن العينة A و C أظهرت أداءً جيدًا من خلال الترابط الأسمنتي العالي والتوزيع المثالي للسوائل المصممة لإنجاز عملية التدعيم.

الكلمات الدالة: السمنت العراقي, اضافات, تصميم الوحل , خواص الاسمنت, الاسمنت التجاري.