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An Experimental Investigation of the pH Effect on the Properties of Iraqi Cement Class G: A Comparative Study with UAE Cement

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Abstract

The cement process is a crucial operation in the drilling of oil and gas wells, in which errors would be extremely costly and time-consuming to rectify. Some of the technical parameters that influence this process include the pH of water used in the preparation of the cement slurry. This study investigates the impact of water pH on the properties of Class-G cement slurry. The cement slurries have been mixed using distilled water and four water samples at pH 9.5, 10, 11, and 12, respectively, with no additives. Iraqi and UAE cements' physical and chemical analyses were performed according to API standard specifications. The findings indicate that UAE cement largely meets the API specifications. However, Iraqi cement has some deviations due to a difference in manufacturing processes, which caused failures when the tests were conducted with fresh water. The findings of three physical tests demonstrated that mixing cement with alkaline water (pH>7) has a negative effect on the cement physical properties, especially compressive strength and density. On the other hand, the thickening time test for two kinds of cement demonstrated that when the pH level increases, it contributes to a delay in the thickening time of roughly 50 minutes for both types. This study considers pH effects in the preparation of cement slurries to ensure that bonding was not impaired and exclude post-operational failures.

Keywords: Cement Class G, pH impact, physical test, Iraqi and UAE cement.

دراسة تجريبية لتأثير الرقم الهيدروجيني على خصائص الأسمنت العراقي صنف :G دراسة مقارنة مع الأسمنت الإماراتي

الخلاصة:

تعد عملية الأسمنت عملية بالغة الأهمية في حفر آبار النفط والغاز، حيث تكون الأخطاء مكلفة للغاية وتستغرق وقتًا طويلاً لتصحيحها. تشمل بعض المعايير الفنية التي تؤثر على هذه العملية الرقم الهيدروجيني للمياه المستخدمة في تحضير ملاط الأسمنت. تبحث هذه الدراسة في تأثير الرقم الهيدروجيني للمياه على خصائص ملاط الأسمنت من الفئة G. تم خلط ملاط

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الأسمنت باستخدام الماء المقطر وأربع عينات مياه بدرجة حموضة 9.5 و10 و11 و12 على التوالي، بدون أي إضافات. تم إجراء التحليلات الفيزيائية والكيميائية للأسمنت العراقي والإماراتي وفقًا لمواصفات API القياسية. تشير النتائج إلى أن أسمنت الإمارات العربية المتحدة يلبي إلى حد كبير مواصفات API، في حين أن الأسمنت العراقي لديه بعض الانحرافات بسبب اختلاف عمليات التصنيع، مما تسبب في حدوث أعطال عندما أجريت الاختبارات بالمياه العذبة. أظهرت الاختبارات الفيزيائية التي أجريت أن خليط الماء القلوي، الذي يزيد الرقم الهيدروجيني له عن 7، يضعف خصائص الأسمنت فيما يتعلق بقوة الضغط والكثافة، بينما يتأخر وقت التكثيف بحوالي 50 دقيقة عند قيمة الرقم الهيدروجيني الأعلى. دعت هذه الدراسة إلى مراعاة تأثيرات الرقم الهيدروجيني في تحضير ملاط الأسمنت لضمان عدم إضعاف الترابط واستبعاد الأعطال بعد التشغيل.. وأخيرا، تكمن أهمية هذا العمل في الأخذ بعين الاعتبار تأثير الرقم الهيدروجيني عند تحضير الملاط ذو الرابطة الجيدة، بالإضافة إلى تجنب فشل عملية الأسمنت بعد أداء المهمة.

1. Introduction

Oil well cementing is a critical part of the drilling and completion operations [1], [2], [3]. Generally, there are two main types of cementing operations: primary cementing and remedial cementing. Primary well cementing is an essential process to fulfill a variety of functions, including stopping fluid interaction between the borehole formations and the wellbore, as well as isolating the flow between different formations, subsidizing the drilled formations and casing string, and protecting the casing from invasion of corrosive fluids [1], [4], [5]. Several parameters influence the performance of cement operations; thus, it must be considered [6]. Because the physical and chemical properties of well cements are varied dramatically at high temperatures and pressures, strict rules must be followed when designing the cement system to ensure appropriate casing preservation and zonal separation over the life of the well. This is called “thermal wells” [5]. Furthermore, the existence of corrosive zones and poor formations must be taken into account on a regular basis[7]. As a consequence of cement sheath failures, numerous issues may occur during the well life, including casing corrosion and gas migration to the surface, leading to a loss of well integrity[8]. In addition to all of these problems, permanent damage to the casing might be simultaneously occurred, resulting in an increase in the repairing tasks and maintenance costs. Therefore, successful cementing techniques begin with the creation of effective cement slurries, which are then enhanced or modified to produce the necessarily cement qualities [2], thus, the well integrity can be achieved [9].

Numerous both liquid and solid chemical additives are often employed to manage the various qualities of the cement slurry. Rheological properties, density, thickening time, compressive strength, fluid loss volume, permeability, porosity, and free water partition may all be modified by the chemical additives [2], [9]. Typically, the elements of these additives for cement design are chosen based on many factors, such as the kind of formation, depth, pressure, and temperature[10]. Extensive testing and research have been carried out to employ a wide range of

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nano-materials and polyremes to boost the efficiency of the cement slurry [11], [12], [13], [14], [15], [16]. However, the use of these materials involves high expenses and not eco-friendly [3]as well as hazards for the workers.

Ordinary cement and Portland cement are the two most prevalent forms of cement. Portland cement, which includes API classes (A, B, C, D, E, F, G, and H), is commonly used in the oil industry to fulfill the technical criteria including high mechanical strength, thickening time, low viscosity, fluid loss control, and low free fluid[17], [18]. In literature, there are two sorts of strategies for checking the efficacy of cement: log tool evaluation [19], [20] and experiment techniques[21]. Both of these strategies are required for cement assessment, whether before or after the cementing process [2]. Cement class G is the most frequent forms of Portland cement used during drilling operations. It may be used at high depths with the inclusion of additives to render it adequate for a specific scenario[3]. Technically, at high-temperatures (>110^{o} C) conditions, Portland cement undergoes to significant chemical and microstructural changes. Strength retrogression is a phenomenon that may occur when the temperature rises over 110 degrees Celsius[7]. The result is that calcium-rich products are generated in the cement matrix during the strength retrogression process, thus increasing the matrix permeability and porosity while degrading the mechanical characteristics [22].

Water content accounts a significant portion of cement slurry preparation. According to the API requirements, the ratio of utilized water to prepare cement Class G (w/c) is 0.44, resulting in a cement density of roughly 1.96 g/cm^3 [3], [23]. Typically, water content can alter during cement hydration due to ion migration from the cement matrix to the solvent. The storing of different materials together might cause the movement of different ions and the disturbance of findings [24]. Several studies have investigated the influence of pH on the creation of cement slurry, demonstrating that the pH of the surrounding environment significantly impacts cement properties. In 2008, Camilleri and Pitt Ford found that glass ionomer cement (GIC) exhibited increased porosity and marginal leakage in acidic conditions with fluctuating pH levels. However, mineral trioxide aggregate (MTA), which creates an alkaline environment, showed better resistance to pH changes but was susceptible to internal dye uptake in such conditions. [25]. Sumra Yousuf et al. discussed the effect of the high initial pH of cement-based materials (12.0 to 13.8) on concrete durability, emphasizing the role of pH in ensuring long-term performance. They concluded that pH has a direct impact on durability, with a reduction in pH over time compromising the material's longevity[26].

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Zhang Qin-li et al. conducted several experiments to examine the influence of pH levels on cemented paste backfill (CPB). They discovered that non-neutral environments, such as acidic (pH 3) and highly alkaline (pH 13), contribute to increased shear stress and apparent viscosity of CPB. Higher pH values, in particular, accelerate cement hydration, producing denser hydration products that improve the structural properties of the cement [27]. Similarly, Pavel Šiler et al. studied the effects of pH on Portland cement hydration and observed that alkaline conditions (pH 12) promote faster hydration and the highest portlandite formation. In contrast, acidic and neutral environments resulted in slightly higher compressive strength after 28 days [24].

Lin Zhao et al. developed a superabsorbent polymer (SAP) that is highly sensitive to pH fluctuations. They found that SAP exhibited higher water absorption in neutral and mildly alkaline conditions, making it effective in sealing microcracks in oil well cement. This indicates that the optimal pH level, in conjunction with SAP, enhances the self-healing properties and durability of the cement[28].

This study builds upon previous research by exploring the impact of water pH on the preparation of cement slurry. In this investigation, two types of Class G cement were examined, and various cement slurries with differing pH environments were created to assess the effect of water pH on cement characteristics. Three assessment strategies were applied to evaluate the physical properties of Class G cement, and chemical tests were conducted on both types of cement to determine the influence of pH on their composition.

2. Theoretical Background

2.1. Cement Evaluation techniques

There are two times to evaluate and predict the efficiency and success of a cement operation. Firstly, before implementing the job of cement operation, which means performing many physical and chemical experiments to confirm its identically to standard specifications. Therefore, because the maintenance or secondary processes require a lot of cost, these experiments are considered very important to examine the validation of the use this cement in order to avoid the failure of cement operations. Secondly, after executing the cement job or injecting cement into the wellbore, which means using Log tools evaluation to take them down into the well to assess the cement bond, such as Cement Bond Log (CBL), Variable Density Log (VDL), Gamma Ray (GR), and Casing Collar Locator (CCL).

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The success or failure of a cementing job relies on the features of the cement, spanning from the initial blending of cement slurry elements on the surface to the subsequent pumping through surface lines, casing, and the annulus. This process continues until the cement reaches the hydration and setting phase in the targeted location. During the slurry pumping phase, critical properties include density, thickening rate, filtration rate, and rheology. Subsequently, as the cement solidifies, paramount attributes encompass permeability, compressive strength, soundness, and fineness [2].

Following the completion of the cement project, a number of log instruments, such as the CBL, VDL, GR, and CCL, are lowered into the well to verify the efficiency and performance of the cement bond between casing and formation. The purpose of utilizing many log tools at the same time is to compare them and obtain a more precise evaluation[2], [19], [20]. As can be seen in Figure (1), several log evaluation tools demonstrate the efficacy of cement bond for two intervals. Furthermore, the simple assessment of cement bond based on two logs is that at the first interval, the cement bond is good because the reading of VDL does not contain channels and the CBL reading is close to zero. Contrarily, at the second interval, the cement bond is poor because VDL's reading shows obviously more channels and the CBL's reading is high.

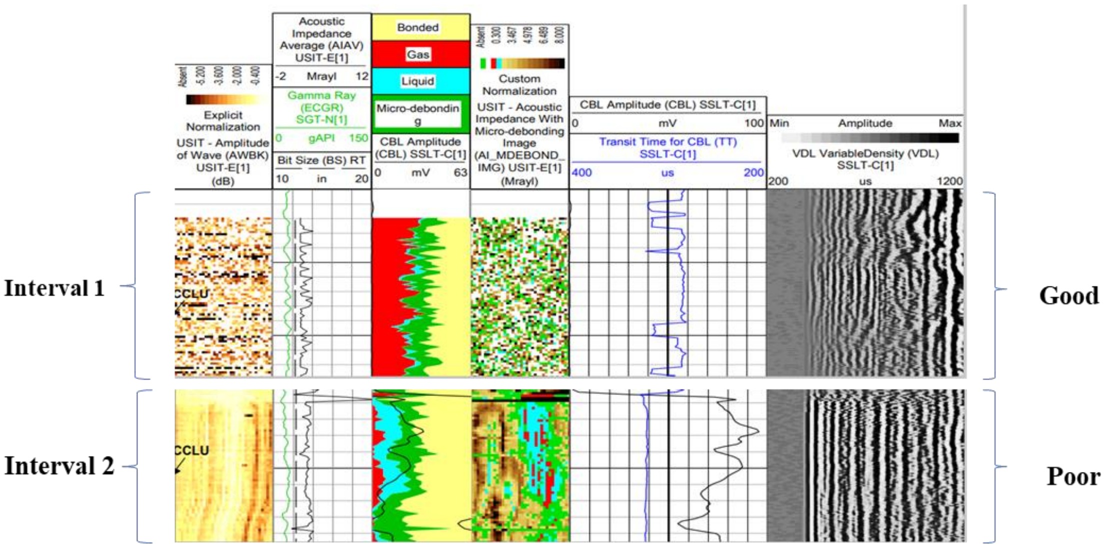

Fig. (1): Implies cement log tools evaluation [29]

2.2. API Specification of Cement Class G

In order to assess the efficacy of cement class G, the API specification will be followed to verify the matching of physical properties and chemical composition for each type of cement [30]. API specifications are illustrated in Table (1).

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Table (1): API standard specification of the slurry of cement class G [30]

Methods	Unit	Standard value
Compressive Strength @ 38°C after 8 hours	Psi	≥ 300
Compressive Strength @ 60 °C after 8 hours	Psi	≥1500
Thickening Time	min	Min 90 min Max120min
Density of cement Slurry	g/cm^3	Min 1.76 Max 1.97

2.3. pH Effect

The pH of water can have a significant effect on the properties of cement in a well, thus, it is important to monitor the pH of the water used in cementing and adjust it as necessary. Water with a neutral pH (around 7) is typically recommended for cementing operations. However, in some cases, additives may be used to adjust the pH of the water and improve the performance of the cement [31].

The pH of water can affect the chemical reactions that happen during the cement hydration process, which can influence the strength, setting time, and durability of the cement [32]. If the pH of the utilized water in cementing is too low or too high, it can impact the performance of the cement. At low pH values, the cement is expected to set too quickly, leading to a weak bond between the cement and the surrounding formation[25]. On the other hand, at high pH values, the setting time of cement can slow down and the strength of the cement is reduced [27].

In addition, the pH of water has impact on the setting time and the strength of cement, can also affect the permeability of the cement. A high pH value can increase the permeability of the cement, making it more susceptible to damage from acids and other corrosive substances in the well. This can lead to issues such as cement degradation and gas migration.

3. Methodology

To achieve the objective of this study, two types of cement class G (Iraqi & UAE) were utilized. Four types of water with different pH environments (pH=9.5, pH=10, pH=11, pH=12) were also prepared under standard conditions by the “Department of Analytical and Ecology in Petroleum Research and Development Center (PRDC)”. NaOH and HCl were used for adjusting pH percentage to the desired value. The percentage of NaOH and HCl need to reach a specific pH,

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including moles of OH^- (from NaOH) and H^+ (from HCl), is calculated by the following equations[33]:

$$M_1 \times V_1 = M_2 \times V_2 \quad (1)$$

$$pH = -\log[H^+] \quad (2)$$

$$Kw = [H^+][OH^-] = 1 \times 10\text{-}14 \text{ at } 25°C \quad (3)$$

$$pOH = -\log[OH^-] \quad (4)$$

$$pH = 14 - pOH \quad (5)$$

The concentration of NaOH solution (e.g., 1 M NaOH), you can use the formula:

$$\text{Volume of NaOH (L)} = \text{Moles of NaOH} / \text{Concentration of NaOH (M)} \quad (6)$$

To calculate the moles of NaOH required, use the formula:

$$\text{Moles of NaOH} = [OH^-] \times \text{Volume of water (L)} \quad (7)$$

The goal of this study is to determine the extent at which pH will influence the properties of cement class G. In the technical procedure, water was used in a proportion of around 44 percent to prepare the cement slurry based on API. All of cement tests were concocted according to API specifications [30]. There are plenty of physical properties that are very significant and used to judge the validation of cement before executing a job, such as compressive strength, rheological properties, density, thickening time, fluid loss volume, permeability and porosity tests, and free water separation. Among these tests, three important cement physical properties tests will be included in this study to reveal the effect of pH degree on the behavior cement class G: compressive strength, density, and thickening time. The flowchart outlining this study is presented in Figure (2). To analyze the cement composition, chemical tests were performed on two types of cement, as outlined in Tables (2) and (3).

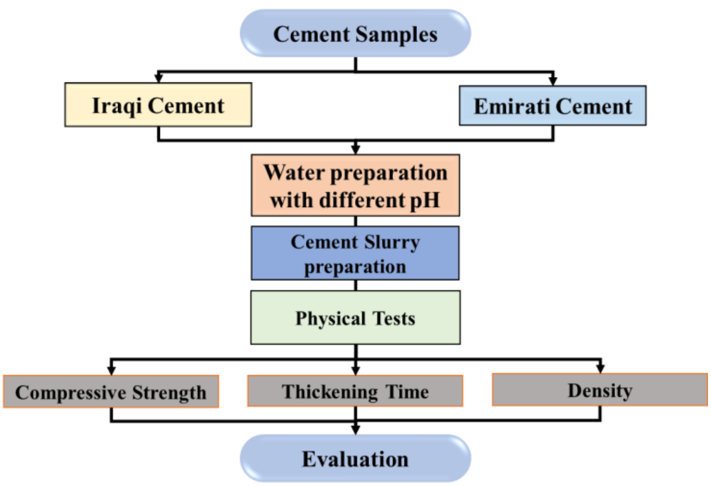

Fig. (2): Workflow diagram of this study

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Table (2): Chemical composition test of Iraqi Cement.

	MgO	SO_3	Loss on Ignition	C_3A	C_3S	C_4AF+2C_3A	Na_2O
Cement Type G%	1.3	0.06	2.2	52.78	2.48	17.18	0.57
API Standard%	6	3	3	65/48	3	24	0.75

Table (3): Chemical composition test of UAE Cement.

	MgO	SO_3	Loss on Ignition	C_3A	C_3S	C_4AF+2C_3A	Na_2O
Cement Type G%	3.8	0.156	1.069	43.76	9.57	30.69	0.53
API Standard%	6	3	3	65/48	3	24	0.75

3.1. Specimen Preparation

In this research, a standardized API recipe of cement class G for oil wells based on (API 10A, 2019)[30] was employed as a reference sample. The most prevalent type of Portland cement for cementing wells is cement class G. Based on API guidelines, the water-to-cement ratio used to generate the cement slurries was (W/C - 0.44). The cement slurry for the two types was created with distilled water firstly since the tap water includes chloride sulfate and other contaminants that might damage the cement, modify its hydration and influence its strength, and impact other parameters [3]. It was determined that no further cement additives were required for this investigation, just Portland cement Class G with different water pH. The preparation of cement slurries and a number of laboratory tests were implemented in accordance with API Standard 10 A requirements [30] and API RP 10-B2 requirements [34]. The dry cement was incrementally dumped into the container of an OFITE WARING industrial blender containing water and mixed for 15 seconds at a low speed of 4000 rpm. In a further phase, the blender mixing speed was raised to 12000 rpm for 35 seconds, until obtaining a homogenous cement slurry. The mixing took place at atmospheric pressure and ambient temperature (25℃). The studies were conducted on the impact of different water pH concentrations and then compared to the fresh slurry cement sample.

4. Experimental Techniques

Five samples of cement slurries with different pHs were prepared according to API 10 specifications (10A, 2019) by taking 349 g of water with 792 g of cement and under mixing for each type of cement. Following that, three experimental techniques are used to analyze the physical characteristics of oil well cement class G and explore its validation. Furthermore, the investigations of pH effect on the properties cement class-G have been done based on the physical tests.

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4.1. Compressive Strength Test

The compressive strength test is a prevalent test conducted on cement used in oil wells to assess its strength and its ability to withstand pressure. This test is crucial in ensuring the safety and reliability of the well, as it defines the maximum load the cement can bear before it fails [35], [36].

In this study, the mechanical strength of the cement was evaluated utilizing a compressive strength machine, as shown in Figure (3). This apparatus measures the compressive strength by preparing the cement slurry. After preparation, the slurry is cast into cubic molds, which are then submerged in a water bath held at temperatures of 38 °C and 60 °C for 8 hours[36]. For each test, three cubic samples were prepared to calculate the average and ensure greater accuracy in the results. This assessment was carried out within a time frame of 20 to 80 seconds, with these readings being automatically recorded by a computer connected to the device. The findings of the test are used to verify that the cement matches the minimum strength requirements specified by industry standards, such as those published by the American Petroleum Institute (API). The following formula is used to compute the compressive strengths based on the compression force surface area of the cube [35], [36].

$$\text{Compressive Strength} = \text{Force of Compression} / \text{Cross-Sectional Area} \quad (8)$$

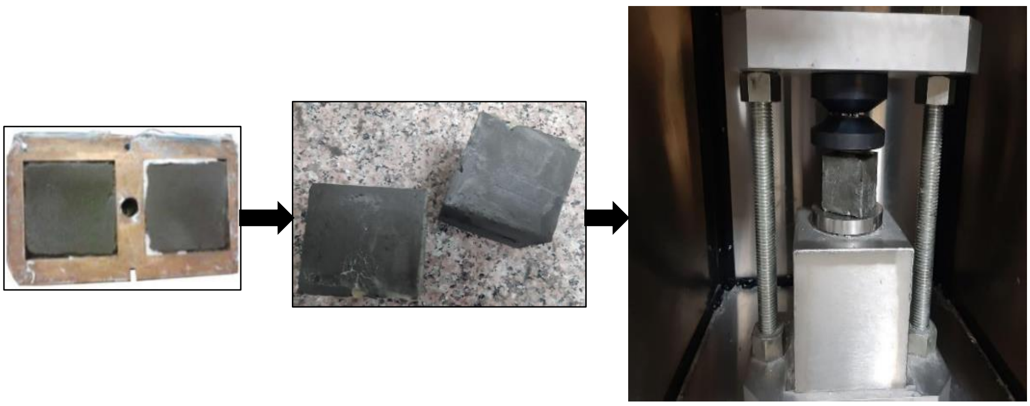

Fig. (3): Cement Compressive Strength Tester

4.2. Thickening Time Test

Thickening time refers to the period during at which the cement slurry maintains its fluidic state, allowing it to be effectively pumped. This assessment of thickening time is conducted within downhole conditions, utilizing the HPHT Consistometer [2], [37], as depicted in Figure (5). As illustrated in Figure (4), the point at which the cement consistency reaches 100 Bc marks the

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threshold for the upper limit of pumpability. The thickening time of the cement slurry is influenced by various factors, including downhole pressure and temperature [38]. Since the thickening time properties are essential for evaluating the pumpability of cement during cementing operations, this study will focus on the formation of five cement slurries using water with different pH levels for two types of cement. The goal is to investigate the influence of water quality on the thickening time characteristics. All tests were executed in strict accordance with the instructions outlined in API specifications. Following the preparation of each sample, the cement slurry was carefully poured into the safety cup. To mimic the downhole conditions accurately, both temperature and pressure were methodically increased until the desired point was reached, as outlined in the procedure. Subsequently, the test continued until the slurry reached a consistency considered sufficient to render it unpumpable, often at points like 70 Bc or 100 Bc.

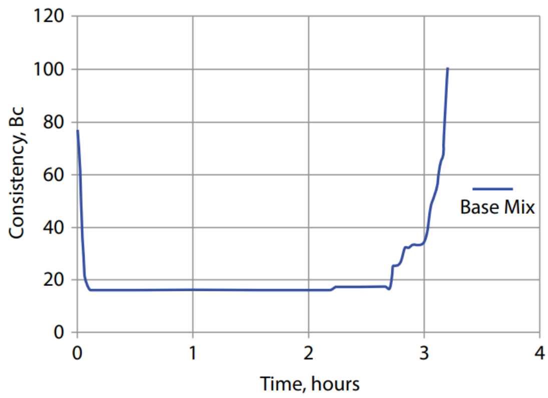

Fig. (4): Shows thickening time of cement slurry under HPHT conditions

Fig. (5): HPHT Consistometer Apparatus

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4.3. Density Test

Density plays a crucial role in influencing the hydrostatic pressure exerted by the cement slurry within a well[2]. In this study, the density of the cement slurry was determined using the Model 140 Fann Mud Balance, as shown in Fig.6. Immediately after preparing the sample, the mud balance cup was filled with the cement slurry. Subsequently, the cup was sealed with a lid and any extra cement on the exterior was carefully cleaned, particularly around the lid opening. Thus, the cup was meticulously balanced by positioning it on a fulcrum and making precise adjustments with a sliding weight until both sides achieved equilibrium. The density of the cement was then read from the ruler on the device arm and expressed in pounds per gallon (lb/gal). It's important to highlight that each test was carried out twice for two types of the slurries to ensure the consistency and reliability of the results.

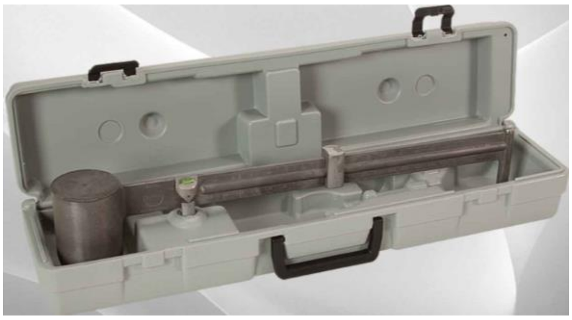

Fig. (6): Pressurized Mud Balance Apparatus

5. Results and Discussion

5.1. Effect pH on Compressive Strength of Cement

The findings of compressive strength for both UAE and Iraqi cement kinds demonstrate a clear reducing trend as the pH level rises from 7 to 12. To prepare the cement specimens with different conditions for pH value and temperature, two conditions of temperature (38°C and 60°C) was selected. As presented in Figure (7, a and b), at fresh water (pH=7), both cement sorts show their highest compressive strength, with the UAE cement reaching approximately 1600 psi at 60°C and the Iraqi cement implies similar values. As the pH of the used water in the mixture increased, there was a corresponding decrease in the compressive strength of the cement. This reduction in strength is observed across both cement types. Furthermore, it is obviously that the influence of pH on the compressive strength of the cement is more pronounced at a temperature of 60°C compared to 38°C.

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As demonstrated in Figure (7a), especially for UAE cement, that there was a sharp decline in compressive strength at 38°C and 60°C as the pH increased. At pH 10, where the strength at 38°C fell to about 500 psi and at 60°C to around 1200 psi. Subsequently, at pH 12, strength drops even further at about 400 psi at 38°C and at 600 psi at 60°C. With an increase in pH, the compressive strength also decreases for Iraqi cement. The compressive strength at 60°C becomes about 1100 psi at pH 9.5 while at 38°C it comes down to about 600 psi, whereas for pH of 12 the strength is around 300 psi at and 500 psi at 60°C. The general trend of both cements is that at a lower pH of 9.5, the compressive strength was higher at 60°C compared to 38°C, while the difference between strengths at the two temperatures diminished into higher pH levels 10, 11, and 12. Generally, the results indicate that higher pHs closer to pH 12 significantly reduce the compressive strength of the Class-G cement; thus, more alkaline conditions may be detrimental to the structural integrity of cements deployed in oil well operations. This is perhaps due to the difference in chemical composition between UAE and Iraqi cement types, setting off different reactions within the slurry when mixed with water.

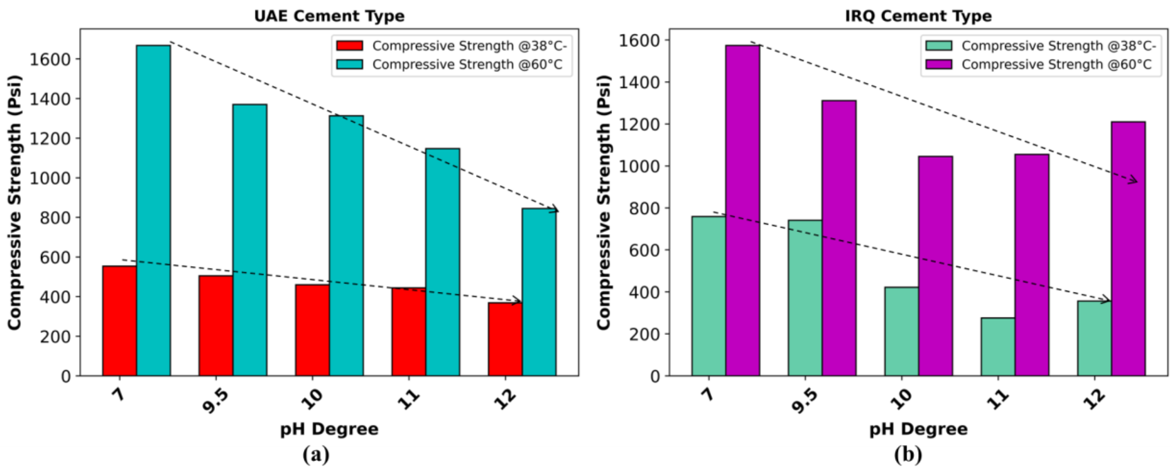

Fig. (7): Effect of pH on the compressive strength (a) Iraqi cement (b) UAE cement.

5.2. Effect pH on Thickening time of Cement

The two graphs below represent the relation between pH and voltage drop count (VDC) in terms of time for Iraqi and UAE types of cement. In the cement from Iraq, in Figure (8a), at pH 7, the VDC presents the greatest increase within the time frame. It started around 1 and reached approximately 8 up to 100 minutes. On the other hand, by increasing pH, such as pH 9.5, 10, 11, 12, it decreases the VDC, reaching only about 5.5 at pH 12 for the same time frame. This indeed shows an explicit trend for the reduction of VDC with the increase in pH, which implies reduced cement hydration or strength development in higher pH levels. This same pattern for UAE cement

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is observed in Figure (8b), with pH 7 still showing the highest VDC peaking at about 7.5 at 160 minutes. While UAE cement indicates a less steep drop in VDC with increased pH—a smoother slope of lower VDCs at the higher pH values, which reaches at pH 12 the value of 5.5 at 160 minutes. In general, Iraqi cements seem to be more sensitive to pH variation; they show higher reductions in terms of VDCs. On the contrary, UAE cement appears more stable at high pH values, possibly due to differences in its chemical composition. Both products have optimum performance at pH 7. Higher pH, like pH 12, impairs the properties badly, especially Iraqi cement.

Figure (9a and b) are shown the consistency Bc of the Iraqi and UAE types of cement at two time intervals which are 15 minutes and 30 minutes across different ranges of pH. In the Iraqi cement, the consistency at pH 7 starts very low at 15 minutes with around 20 BC and grows to about 40 BC at 30 minutes. With a major increase of pH to 9.5, the consistency of Bc that is at 15 minutes reaches approximately 60 BC and rises to nearly 80 BC at 30 minutes. At pH 10, the consistency keeps on growing where Bc values are above 80 BC for both time intervals. The highest consistency is given at pH 12 with approximately 90 BC in both 15 and 30 minutes. From these results, it's clear that an increase in pH level yields a stronger and well-consistent mix of cement. Contrary to this, UAE cement has shown variation in the trend. At pH 7, the consistency is quite high; at 15 minutes, Bc is approximately 16 BC, while slightly lower when at 30 minutes. From pH 9.5 to 10, the consistency falls to a Bc of around 12-14 BC for both time spans and continues to fall even more at pH 11 and 12, with Bc around 10-12 BC. This means that with the rise of pH, UAE cement becomes less consistent, whereas Iraqi cement becomes more consistent. Based on all the results, it can be inferred that Iraqi cement prefers more alkaline conditions as its consistency goes up, while UAE cement's consistency drops with increased pH.

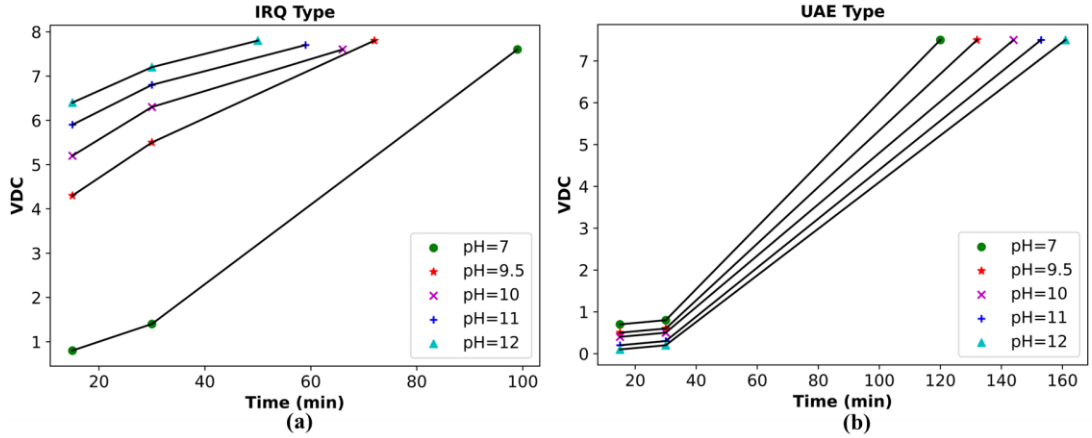

Fig.(8): Effect of pH on Thickening time (a) Iraqi cement (b) UAE cement

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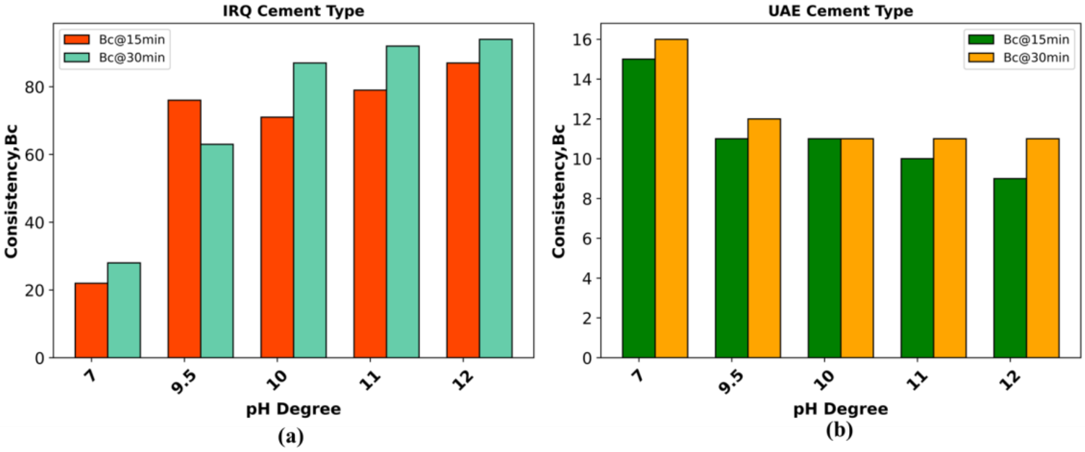

Fig.(9): Effect of pH on the consistency Bc,(a) Iraqi cement (b) UAE cement

5.3. Effect PH on Density of Cement

The relation between pH levels and the density of Iraqi and UAE cement types is represented in Figure (10). The y-axis represents the density in gm/cc, while the x-axis represents different pH degrees, starting from 7 up to 12. The UAE cement is represented by the black line, where at pH 7, the density is about 1.900 gm/cc, and it decreases regularly by increasing the pH. It decreases to about 1.895 gm/cc at pH 9 and further to 1.880 gm/cc at pH 11, after which it remains constant up to pH 12. From pH 7, the Iraqi cement represented by the blue line starts its density at an approximate value of 1.890 gm/cc while showing a steeper slope than that for UAE cement. At pH 9, the density goes as low as approximately 1.885 gm/cc and remains at approximately 1.875 gm/cc by pH 11, further going down to 1.870 gm/cc at pH 12. This would definitely reflect a trend: the increase in pH for both types of cement would result in a decrease in density where Iraqi cement experiences a greater reduction. The data would actually indicate that higher pH environments, closer to pH 12, decreased the density of cement and could affect its overall performance and structural properties.

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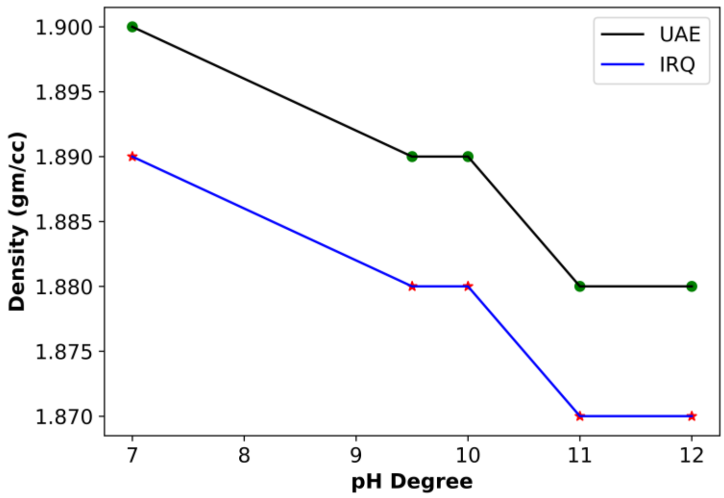

Fig. (10): Effect of pH on Density of UAE and Iraqi cement.

5.4. General Impact

To vividly demonstrate the extent of pH's influence on cement properties, UAE cement was selected as the focal point to assess the impact of water pH ranging from 7 to 12 on three key cement characteristics, such as; Compressive strength at 60°C, Density, and Thickening time-Bc at 30 minutes. Compressive strength at 60°C is the highest ranked in the chart, with a share of 61.0% of the total, which means that this parameter is most influential regarding the performance of the cement under high-temperature conditions. It is observed that Thickening time at 30 minutes contributes 37.8%; these show the importance of the cement consistency as well but with less influence compared to compressive strength. Finally, density only contributes 1.2%, showing that though this is a factor at play, the effect is much smaller than those of compressive strength and thickening time. This breakdown underlines that, for UAE cement, the compressive strength at high temperatures is the most critical factor, while thickening time holds the second place in the ranking, and density has a lesser impact on the overall performance.

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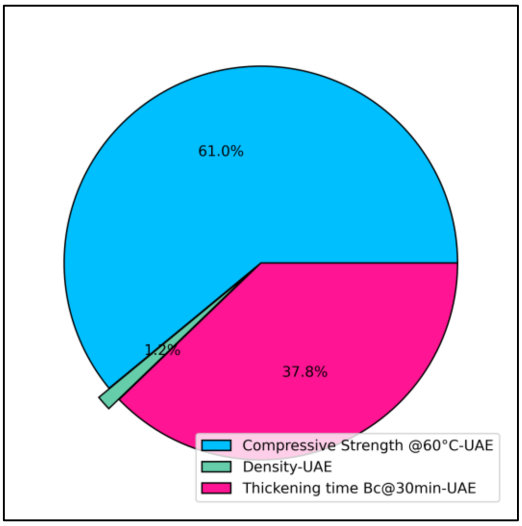

Fig. (11): Percentage impact of pH on cement properties.

6. Conclusions

This work has focused on the effect of water pH on some physical properties of Class-G cement slurries for Iraqi and UAE cement types. It can be seen from the results that with the increase in pH, there is an abrupt change in both compressive strength and consistency and density of cement slurries. Compressive strength for both cements decreases with the increase in pH from 7 to 12. Based on that, the key conclusions drawn from this research are as follows:

1. At 60°C, the compressive strength of UAE cement, which is about 1600 psi at pH 7, reduces to about 800 psi at pH 12, a reduction by 50%. In the case of Iraqi cement, the reduction is from about 1600 psi at pH 7 to about 700 psi at pH 12, reflecting a reduction by more than 55%.
2. As the consistency is concerned, the thickening behavior also varies with pH. In Iraqi cement, for instance, the consistency at 30 minutes increases from about 40 Bc at pH 7 to near 100 Bc at pH 12, which obviously reflects a retarded thickening process in more alkaline conditions. For the UAE cements, there is a decrease in the Bc values from a pH of around 16 to a pH of about 12, indicating a loss in consistency. This would imply that UAE cements have low resistance for maintaining consistency under extremely high pH conditions
3. Density measurements further illustrate the impact of pH changes. For the UAE cement, it decreases from about 1.900 g/cm³ at pH 7 to 1.880 g/cm³ at pH 12. The Iraqi cements show a very similar trend, with the density decreasing from about 1.890 g/cm³ at pH 7 to 1.870 g/cm³ at pH 12. This forms the basis for a decrease in the compactness of the cement matrix

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with an increase in the pH value, which may affect the structural stability of the cement encountered under wellbore conditions.

In general, this study indicated that the pH of water highly affects the properties of cement. For instance, compressive strength and density will be reduced, while thickening time will be altered when pH is above 7. The results of this study have highlighted the importance of pH control in cementing operations to guarantee that the cement slurry offers optimum performance and durability in oil and gas well drilling applications.

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