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The use of superplasticizer for concentrated slurry density control

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Abstract: Given the constant development of the oil and gas industry and increasing requirements for well drilling efficiency, the study of concentrated slurry density control is critical to ensure drilling processes' safety and stability and prevent adverse environmental impacts. The study aims to investigate the possibility of using an additive to pure Portland cemented slurry to form high-density concentrated slurry. The mentioned groups are crucial for creating robust cement formulations to line the wellbore at intervals with abnormally high pressure effectively. Laboratory experiments were conducted utilizing various equipment such as the ZM-1003 consistometer, "Sroki" autoclave, "Vicat apparatus," and AzNII cone. These experiments were based on standard methodologies for analyzing cement slurry and paste properties. During these tests, a particular reagent was introduced, demonstrating the ability to plasticize cement slurries, enhancing their fluidity and enabling precise control over the density of concentrated slurries. The laboratory findings regarding the control of concentrated slurry density were particularly noteworthy. These experiments involved analyzing compositions consisting of pure Portland cement and cement slurries augmented with the hyperplasticizer reagent. The results underscored this additive's significance in enhancing cement slurry properties, offering improved fluidity and enabling effective density control. This contextualization highlights the pivotal role of the mentioned reagent in optimizing cement formulations for the challenging conditions encountered in well drilling and cementing operations. The added reagent was found to effectively plasticize the pastes, increasing their fluidity and reducing the water-cement ratio, which leads to the formation of paste with increased strength. The results of industrial testing of the reagent during cementing of production string in one of the wells confirmed the possibility of preparing concentrated slurry with a density of 2.4 $g \cdot cm^{-3}$, thus ensuring successful cementing operations under high-pressure conditions. This study provides practical value for well drilling companies and cementing service providers, justifying the use of reagent-hyperplasticiser in concentrated slurries, which opens new perspectives for the creation of high-strength cement slurries when drilling wells, especially in conditions of abnormally high-pressure zones, thus improving cementing technologies and providing more reliable casing slurry strength.

Keywords: Reagent, Hyperplasticiser, Flowability, Cementing process, Well drilling.

Resumo: Dada a constante evolução da indústria do petróleo e gás e os crescentes requisitos de eficiência na perfuração de poços, o estudo do controle de densidade de lama concentrada é atualmente crucial para garantir a segurança e estabilidade dos processos de perfuração e prevenir impactos ambientais negativos. O estudo visa investigar a possibilidade de usar um aditivo em pasta de cimento Portland puro para formar lama concentrada de alta densidade. Os grupos mencionados são cruciais para criar formulações de cimento robustas, visando revestir eficazmente o poço em intervalos com pressão anormalmente alta. Foram realizados experimentos laboratoriais utilizando diversos equipamentos, como o consistômetro ZM-1003, autoclave "Sroki", aparelho "Vicat" e cone AzNII. Esses experimentos foram baseados em metodologias padrão para análise de lamas de cimento e propriedades de pastas. Durante esses testes, um reagente específico foi introduzido, o que demonstrou a capacidade de plastificar as lamas de cimento, aumentando sua fluidez e permitindo o controle preciso da densidade de lamas concentradas. Os resultados de laboratório sobre o controle de densidade de lama concentrada foram particularmente notáveis. Esses experimentos envolveram a análise de composições compostas por cimento Portland puro, bem como lamas de cimento com o reagente hiperplastificante. Os resultados destacaram a importância desse aditivo na melhoria das propriedades das lamas de cimento, oferecendo maior fluidez e possibilitando um controle eficaz da densidade. Essa contextualização destaca o papel fundamental do reagente mencionado na otimização de formulações de cimento para as condições desafiadoras encontradas na perfuração de poços e operações de cimentação. O reagente adicionado mostrou-se eficaz na plastificação das pastas, aumentando sua fluidez e reduzindo a relação água-cimento, o que leva à formação de uma pasta com maior resistência. Os resultados dos testes industriais do reagente durante a cimentação da coluna de produção em um dos poços confirmaram a possibilidade de preparar lama concentrada com uma densidade de 2,4 $g \cdot cm^{-3}$, garantindo assim operações de cimentação bem-sucedidas em condições de alta pressão. Este estudo proporciona valor prático para empresas de perfuração de poços e prestadores de serviços de cimentação, justificando o uso do reagente hiperplastificante em lamas concentradas, o que abre novas perspectivas para a criação de lamas de cimento de alta resistência na perfuração de poços, especialmente em condições de zonas com pressão anormalmente alta, melhorando assim as tecnologias de cimentação e proporcionando maior resistência confiável à lama de revestimento.

Palavras-Chave: Reagente, Hiperplastificante, Fluidez, Processo de cimentação, Perfuração de poços.

1. Introduction

Drilling through formations with abnormally high-pressure zones presents significant risks if the cement slurry density is not properly controlled during cementing operations. Insufficient slurry density can lead to well control incidents, formation fluid influx into the wellbore, and even catastrophic blowouts - jeopardizing personnel safety, damaging expensive equipment, and causing environmental damage. In one notable incident in the Gulf of Mexico in 2010, inadequate slurry density control was cited as a critical factor contributing to a blowout that resulted in 11 fatalities and the largest offshore oil spill in U.S. history [1]. Given risks like these and the constant development of the oil and gas industry with increasing requirements for efficient and safe well drilling, the study of concentrated slurry density control using specialized additives and innovations has become critically important. Maintaining the right slurry density profile is essential for wellbore pressure management and zonal isolation, especially when drilling through high-pressure formations [2].

Studies by Loginova and Agzamov [3] highlighted the importance of concentrated slurry density control and the role of hyperplasticiser reagents like "Glenium-51" in enhancing cement density and strength. However, their focus on density and strength didn't address the interaction of weighting agents with formation gases, which is particularly crucial in high hydrocarbon content wells. This points to the need for further exploration in this area. Akhmetzhan et al. [4] research delved into the effectiveness of concentrated slurries for well cementing, yet it lacked sufficient consideration of hydrothermal conditions. This gap underscores the necessity for more comprehensive investigations into the performance of such slurries under varying environmental conditions.

Meanwhile, Kuliyev's [5] work shed light on the impact of hyperplasticiser reagents on cement properties but fell short of addressing their potential effects on biocompatibility and environmental safety. Further studies are required to evaluate the ecological implications of employing concentrated slurries in drilling activities. Kabdushev et al. [5] stressed the significance of maintaining the stability of concentrated slurry density, yet they overlooked the rheological properties control amidst changing drilling parameters. This highlights the necessity for developing automated control systems capable of adapting to dynamic drilling conditions. Finally, Taimasov and Kuandykova's [2] research focused on creating robust cement sets. Yet, it failed to address the interaction of hyperplasticiser reagents with other drilling components, such as drilling fluids and inhibitors. There's a clear need for additional investigations to comprehensively understand these chemical interactions and ensure the stability of drilling processes.

While previous studies have examined weighting agents and other additives, the ability of "Glenium-51" to induce plasticization of cement slurries and provide precise adjustment of the slurry density to meet specific well conditions is an innovative technique. When drilling in formations with abnormally high pressure, optimal cement slurry density is crucial in the oil and gas industry. It plays a vital role in managing wellbore pressure, reducing the risk of formation fluid intrusion, and ensuring proper zonal isolation. "Glenium-51" enables mud plasticization, increasing mud density without impairing pumpability.

The study aims to analyze the potential of using the product "Glenium-51" as a component added to pure Portland cement slurries to create concentrated slurries with increased density. To achieve this goal, the following objectives were set:

- investigate the use of "Glenium-51" as an additive for plasticizing and increasing the density of cement pastes obtained from pure Portland cement;
- analyze the effect of Glenium-51 on such cement paste properties as density, flowability, rheology, free water, setting time, and cement strength at different water-cement ratios;
- determine the optimal solution formulations and concentrations of "Glenium-51" to control the density of concentrated solutions using laboratory tests;
- conduct industrial field tests of high-density grouting solutions modified with "Glenium-51" during the cementing of the well casing;
- confirm the possibility of successful preparation and injection of concentrated high-density grouting fluids (e.g., 2.4 g·cm^{-3}) under high pressures at the wellbore;
- assess the effectiveness of "Glenium-51" in providing reliable control of the density of concentrated grouting fluids for well cementing, especially in areas of abnormally high pressures.

2. Materials and Methods

The study utilized a range of commercially available equipment, including the ZM-1003 consistometer, Sroki autoclave, Vicat apparatus, AzNII cone, KS-5 consistometer, AG-2 areometer, Chandler 3500 viscometer, and Chandler 30-60 mixer. These instruments facilitated the comprehensive analysis of cement paste properties, ensuring precise and reliable results. Standard methods were adhered to during the evaluation process, ensuring consistency and accuracy in data interpretation.

The main parameters assessed included density (ρ), fluidity (R), rheology (φ300, φ600), plastic viscosity (ηpl), yield stress (τ0), water release (Kw), concentration ($t_{overall}$), setting time (beginning - t_b, end - t_e), and cement strength (flexibility - Gm, compression - Gc). Tests were conducted under standard conditions (+75 °C) and thermobaric conditions (+93 °C, P = 800 kgf·cm^{-2}), utilizing seawater from the Caspian Sea as a hardener. Various additives such as Ferrochromolignosulfonate (PCLS), sodium bichromate ($Na_2Cr_2O_7$) or potassium bichromate ($K_2Cr_2O_7$), and surfactants (e.g., HT-48) were employed to regulate setting time and enhance stability.

The Portland cement PCT 1-100 from the Kelete Plant served as the primary component of the cement slurry, while "Glenium-51" was incorporated into fresh water at a concentration of 0.4 %. This concentration was selected based on its effectiveness in achieving desired properties such as low water-cement ratios and high paste strength. The choice of "Glenium-51" as the additive was influenced by its ability to liquefy Portland cement and maintain proper flowability during casing anchoring, as well as its modern characteristics, including high efficiency at low water-cement ratios. Portland cement PCT 1-100 is characterized by its fine powder form, which facilitates thorough mixing with water and other additives to create a homogeneous slurry. Additionally, PCT 1-100 exhibits excellent binding properties, effectively adhering to casing walls and other surfaces within the wellbore. Its high compressive strength development over time ensures the long-term integrity of the cement sheath, providing essential structural support for the casing and safeguarding against potential fluid migration. Furthermore, this Portland cement variant is engineered to meet stringent industry standards, ensuring consistency and reliability in performance across various well-drilling conditions. Overall, the choice of Portland cement PCT 1-100 for this study was motivated by its proven track record in oil and gas well cementing applications, where durability, consistency, and adherence to standards are paramount.

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The production process of "Glenium-51" involves advanced polymer processing methods to produce a long-chain polycarboxylate ester polymer, forming the additive's basis. This polymer is combined with other components to create the dark brown liquid "Glenium-51." The additive's application in the oil industry is crucial for ensuring stability and control of cement slurry properties during well-drilling processes, contributing to enhanced drilling efficiency and well integrity. The level of additive used in the mixtures varied depending on the specific test conditions and objectives. Generally, the additive "Glenium-51" concentration ranged from 0.4 – 0.7 wt.% of the dry cement used in the mixtures.

Recommendations provided by the manufacturer regarding the maximum allowable content of "Glenium-51" should also be considered in the research to ensure optimal performance and safety.

3. Results

As seen from the study of well casing, qualitative separation of formations from each other during well casing is achieved by increasing the density of cement slurry from the density of drilling mud. Under these conditions, the intensity of mixing of drilling mud with cement slurry during injection decreases. The cement slurry density obtained from pure Portland cement without additives is within 1.8 – 1.9 $g \cdot cm^{-3}$. In the process of drilling wells, a density of drilling mud of 1.8 $g \cdot cm^{-3}$ is used, then cement slurry with higher density (higher than 1.9 $g \cdot cm^{-3}$) is selected, which is often used in the South-Western part of Turkmenistan for fixing intervals with abnormally high formation pressures [7-9]. Under standard (Tables 1, 2) and thermobaric conditions, according to the research results, the reagent "Glenium-51" plasticizes cement slurries, increasing their fluidity by more than 25 cm. At the same time, with a reduction to 0.3 water-cement ratio, it is possible to obtain a concentrated slurry with a density of 2.05 – 2.10 $g \cdot cm^{-3}$, free flowability, and paste with high strength. Further, the possibility of concentrated slurry density control of concentrated slurry produced from pure Portland cement with the addition of weighting fillers was considered.

Cement slurry density control is essential in the oil and gas industry to ensure the safety and efficiency of well drilling. The main objective is stabilizing the well walls, avoiding accidents, and providing reliable casing string anchorage by concentrating the mud in high-pressure conditions and zones with abnormal formation properties [10]. With increasing demands on drilling efficiency, the need for accurate density control is growing, which is essential in modern drilling technologies. New additives, such as the superplasticizer "Glenium-51", improve flowability and allow for precise density variation, which is especially important in some geologic formations where conventional methods may not be effective. Laboratory studies using consistometers, autoclaves, and viscometers provide a more complete picture of the effect of additives on cement paste properties. The main parameters affecting cement paste structure and strength can be identified using established analytical techniques [11].

Optimization of concentrated mud components is associated with technological difficulties, requiring changes in water-cement ratios and careful selection of weight fillers and reagents. Laboratory studies and tests in real-world drilling conditions, including industrial ones, are necessary to evaluate the effectiveness and practical applicability of "Glenium-51" reagent [12]. Studying the interaction of weighting agents with high temperatures and aggressive chemicals is extremely important to ensure the stability and reliability of cement slurries under various conditions, such as thermobaric and hydrothermal environments. The complex nature of concentrated mud density control emphasizes the need for a comprehensive strategy that utilizes modern technology and inventive additives to improve drilling efficiency and ensure the reliability and safety of the well cementing procedure under various conditions. The density control of Portland cement depends on its physical properties and the procedures involved in mud preparation [13]. This emphasizes the importance of accurate control to achieve the required mud characteristics.

The possibility of increasing the cement slurry density is limited by the need to provide the required flowability in the time interval when the casing is secured in the well. Experiments carried out in the laboratory confirmed that the use of hyperplasticiser "Glenium-51" allows to achieve the optimal water-cement ratio (W/C) within the range of 0.30 – 0.35 and to provide density in the range from 2.0 – 2.1 $g \cdot cm^{-3}$. These results demonstrate the applicability of the reagent to effectively control the density of concentrated slurries, which is vital in ensuring optimum cementing conditions during well drilling. According to the technical regulation, the reagent "Glenium-51" is a dark brown liquid containing a long chain polycarboxylate ether polymer and a modern hyperplasticiser. Its use is particularly effective in studies with very low water-cement ratios, providing high paste strengths previously challenging to achieve. This reagent is an innovative agent that can significantly improve the technological capabilities and quality of paste structures, especially in conditions of minimum water-cement ratio, where it shows its outstanding efficiency in providing increased material strength [14].

Experimental studies show that adding hyperplasticiser "Glenium-51" to concentrated slurries with barite filler can achieve density up to 2.4 $g \cdot cm^{-3}$ under thermobaric conditions with minimum water cement ratio (W/C = 0.25). As part of this study, practical tests were carried out in industrial conditions for casing in several wells to prepare concentrated slurries with high density reaching 2.4 $g \cdot cm^{-3}$. For example, for well No. 436 in the Barsagelmez field, the use of "Glenium-51" additive to concentrated slurry to achieve a flowability of at least 18 cm and the required density of 2.45 $g \cdot cm^{-3}$ is a challenge, which was the objective of the study. The process of casing the production casing of well No. 436 on the Barsagelmez field has been completed.

From the beginning of the cementing stage, the drilling fluid parameters met the requirements set by the design solutions for constructing this well. The drilling fluid density was 2.45 g·cm^{-3}. The 140 mm × 168 mm diameter production string was successfully lowered to a depth of 4914 m. The bottom hole temperature was in the region of +95 °C, and the formation pressure at the bottom of the well reached 1205 kgf·cm^{-2}. The required cement slurry thickening time was 3:30 h, which further emphasizes the success and compliance of the cementing process with the specified parameters (Table 3).

Table 1: Effect of "Glenium-51" reagent on technological parameters of cement slurries made from Portland cement PCT 1-100 under standard conditions

No. of slurry	Glenium-51 in % (from dry cement weight)	Water-to-cement correlation W/C	Concentrated slurry parameters						
			ρ, g·cm^{-3}	R, cm	φ300, RPM	φ600, RPM	Npl, sPz	τ0, dPa	Kw, %
TDS-1581-85	Un.	Un.	ne<18	Un.	Un.	Un.	Un.	ne>3.5	Un.
TDS-1581-96	Un.	Un.	ne<20	Un.	Un.	Un.	Un.	ne>3.5	ne<90
1	-	0.5	1.82	23	45	87	42	9	2.9
2	0.4	0.5	1.83	>25	25	42	17	24	1.8
3	-	0.4	1.93	16	195	255	60	405	0.5
4	0.4	0.4	1.95	>25	35	65	30	15	0
5	-	0.3	1.97	13	125	300	105	270	0
6	0.4	0.3	2.1	>25	145	245	100	135	0

Note: Un. – unnormalized.

Table 2: Experimental study of the effect of "Glenium-51" reagent on the technological characteristics of cement slurries prepared from Portland cement PCT 1-100 under typical conditions

No. of slurry	Glenium-51 in % (from dry cement weight)	Water-to-cement correlation W/C	Thickening time to value 30 VC, $t_{overall}$, min	Setting time hour-min		Paste strength after 24-00 h, kgf·cm^{-2}	
				t_s, start	t_e, end	G, flexibility	G, compression
TDS-1581-85	Un.	Un.	ne<l-45	ne>5-00	ne<35	Un.	
TDS-1581-96	Un.	Un.	Un.	Un.	ne<35	Un.	
1	-	0.5	Un.	1-56	2-25	73	332
2	0.4	0.5	220	3-45	4-55	73	332
3	-	0.4	60	1-05	1-40	81	343
4	0.4	0.4	140	2-24	3-10	81	343
5	-	0.3	50	0-55	1-15	88	553
6	0.4	0.3	140	2-27	3-05	88	553

Note: cement PCT 1-100 of Kelete plant was used as Portland cement; reagent "Glenium-51" was added to fresh water; test conditions: temperature – 75 °C; pressure – atmosphere; water – fresh water.

Table 3: Effect of "Glenium-51" reagent on technological parameters of cement slurries made of Portland cement PCT 1-100 with barite concentrated slurry under thermobaric conditions.

Parameters	**Values**
1. Cementing conditions:	
Temperature, °C	93
Pressure, bar	800
Operating time, h-min	1-00
2. Composition and properties of cement slurry:	
Portland cement	PCT 1-100
Water	Seawater

Parameters	Values	
Chemicals, %, weight of cement:	Glenium-51 – 0.4 FHLS – 0.3 Chrompik – 0.1 HT-48 – 0.1	
Water-to-cement ratio	0.3	
3. Solution Parameters:		
Density, ρ, g·cm^{-3}	2.05	
Flowability, R, cm	20	
Thickening time (cement slurry storage in autoclave ZM-1003) $t_{overall}$, h-min	3-00	
Flow time (after storing cement paste in autoclave ZM-1003) R, cm	8	
Setting, h-min	t_s t_e	5-00 6-00
Strength of paste 24 h, kgf·cm^{-2}	G, flexibility G, compression	493 88

Note: PCT 1-100 cement is a product of the Kelete cement plan.

According to the requirements of laboratory studies, a particular method of adding concentrated slurries was selected [15]. This method involves the combination of binder material in the form of Portland cement produced at the Kelete cement plant and haematite weighting agent in a specific proportion equal to 1:1. This approach provides a balance between binder and weighting agent, which is important for achieving the required properties of concentrated slurries under controlled laboratory conditions (Tables 4 and 5).

Table 4: Effect of "Glenium-51" reagent on technological parameters of cement slurries made of Portland cement PCT 1-100 with barite concentrated slurry under thermobaric conditions (parameters of cement slurry)

PCT 1-100 cement, %	Barite, %	Fillers, % (dry mixture mass)				W/C	Cement slurry parameters						
		Glenium-51	PCLS	Chrompik	HT-48		ρ, g·cm^{-3}	R, cm	φ_{300}, RPM	φ_{600}, RPM	H_{pl}, sPz	τ_0, dPa	K_s, %
70	30	0.7	0.2	0.1	0.1	0.3	2.20	23	104	163	59	135	0
50	50	0.2	0.1	0.1	0.1	0.35	2.13	25	81	138	57	72	0
50	50	0.2	0.1	0.1	0.1	0.3	2.27	19	164	258	94	210	0
50	50	0.2	0.1	0.1	0.1	0.28	2.32	18	180	280	100	240	0
50	50	0.5	0.2	0.1	0.1	0.27	2.33	24	145	170	25	360	0
50	50	0.5	0.2	0.1	0.1	0.25	2.41	23	115	125	10	315	0

Table 5: Effect of "Glenium-51" reagent on technological parameters of cement slurries made of Portland cement PCT 1-100 with barite concentrated slurry under thermobaric conditions (characteristics of cement slurry)

PCT 1-100 cement, %	Barite, %	Fillers, % (dry mixture mass)				W/C	Time of cement slurry thickening on the consistometer, ZM-1003, $t_{overall}$, hour-min	The flow of cement slurry after being contained in ZM-1003 consistometer, ΔR, cm	Setting time, hour-min		Set cement strength, 24-00 hour, kgf·cm^{-2}	
		Glenium-51	PCLS	Chrompik	XT-48				t_s	t_e	G, flexibility	G, compression
70	30	0.7	0.2	0.1	0.1	0.3	3-00	10	6-00	7-00	73/-	363/-
50	50	0.2	0.1	0.1	0.1	0.35	3-00	8	6-00	7-00	66/-	354/-
50	50	0.2	0.1	0.1	0.1	0.3	3-00	8	5-30	6-30	73/-	382/-
50	50	0.2	0.1	0.1	0.1	0.28	3-00	8	4-30	5-30	73/-	393/-
50	50	0.5	0.2	0.1	0.1	0.27	3-00	8	9-00	10-00	73/-	393/-
50	50	0.5	0.2	0.1	0.1	0.25	3-00	8	8-00	9-00	73/-	393/-

Note: test conditions: Temperature +93 °C; P = 800 kgf·cm-2; operational time l-00 hour; water – seawater.

RICA – v. 8, n. 13, 2024
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Table 4 shows that when using 50 % barite combined with 50% Portland cement and 0.2 – 0.5 % Glenium-51 additive, concentrated slurry densities between 2.13 – 2.41 g·cm^{-3} could be achieved under the tested thermobaric conditions (93°C, 800 kgf·cm^{-2} pressure). The highest density of 2.41 g·cm^{-3} was obtained with 0.5% Glenium-51 and a meager 0.25 water/cement ratio while still maintaining a flowability of 23 cm.

Using "Glenium-51" hyperplasticiser helps create a more fluid cement slurry, improving cement distribution around the casing and providing more effective anchorage. Additives such as PCLS in the role of setting retarder and the thermostabilizing sodium bichromate can help reduce the likelihood of leaks by controlling the curing process of the grout and improving its resistance to various factors. Using the surfactant defoamer HT-48 and other additives such as hematite and Micromax can help enhance the grout's stability under various conditions, including challenging operational scenarios. Thus, the combination of innovative approaches and the use of different additives, including "Glenium-51", PCSL, thermostabilizing sodium bichromate, and the surfactant defoamer HT-48, is consistent with the overall conclusion of improved drilling efficiency and well stability under challenging operating conditions.

By reducing the water-cement ratio to W/C = 0.24, the following results were achieved: the density of the concentrated slurry was 2.45 g·cm^{-3}, and the flowability exceeded 25 cm, as shown in Table 6. These characteristics emphasize the successful effect of applied property regulators, facilitating cement slurry formation with the specified parameters.

In Table 6, for the industrial field cementing job at Well No. 436, a mixture of 50 % Portland cement and 50 % hematite weighting agent was used. With the addition of 0.7 % Glenium-51, a very high density of 2.45 g·cm^{-3} was achieved at the low water/cement ratio of 0.24. This ultra high-density 2.45 g·cm^{-3} slurry demonstrated a flowability > 25 cm and was successfully pumped downhole to cement the 4914 m production casing despite the extreme 95 *°C temperature and 1205 kgf*·cm^{-2} bottomhole pressure.

Table 6: Selection of cement slurry preparation method for cementing 140 mm × 168 mm production casing at a depth of 4914 m at well No. 436 in the Barsagelmez field.

Parameters	**Values**	
1. Cementing conditions:		
Temperature, °C	95	
Pressure, bar	1205	
Operating time, h-min	2-00	
2. Composition and properties of cement slurry:		
Mixtures, % (Portland cement)	PCT 1-100 – 50	
Weight material	Haematite – 50	
Water	Seawater	
Chemical reagents, %, mass of fillers:	Glenium-51 – 0.7 PCLS – 0.3 Chrompik – 0.1 HT-48 – 0.1	
Water-to-cement ratio	0.24	
3. Solution Parameters:		
Density, ρ, g·cm^{-3}	2.45	
Flowability, R, cm	>25	
Thickening time (cement slurry storage in autoclave ZM-1003) $t_{overall}$, h-min	3-30	
Flow time (after storing cement paste in autoclave ZM-1003) R, cm	9	
Setting, h-min	t_s t_e	4-00 5-00
Strength of paste 24-00 h, kgf·cm^{-2}	G, flexibility G, compression	73 473

RICA – v. 8, n. 13, 2024
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The concentrated slurry injected into the casing to secure the production string had an average density of 2.4 g·cm^{-3} and was characterized by an easy flow. During the cementing process, there was no increase in pressure in the cementing lines of the manifold, and the level of plugging fluid in the outer space of the wellbore corresponded to the calculations without undesirable pressure increase. The overall result is the successful lowering and cementing of the production string to the declared depth of 4914 m. Concentrated slurry density control is an important aspect of the oil and gas industry, especially when drilling wells. Concentrated slurries are used to control the well pressure and prevent the escape of high-pressure hydrocarbon gases. Density control provides the necessary pressure balancing in the well and prevents well wall failure.

There are several ways of concentrated slurry density control [16]. The first method is adding weight agents such as barite, pebbles, and ilmenite to the cement slurry to increase density. The required density of the paste determines the dosage of weighing agents. The second method includes using polymers, which can regulate the rheological properties of cement slurry, affecting its density. Polymers can change the viscosity and structure of the paste, which is important to achieve specific parameters. The third approach uses special additives to achieve the desired cement slurry characteristics. These additives can be reagents that affect the chemical or physical properties of the paste to meet specific requirements. The fourth method is carefully testing and correcting cement slurry density at the drill site. Corrections are made if the desired parameters are not achieved, including adding additional weighting agents or adjusting other mud components. The fifth method involves automated systems on modern drilling rigs to regulate cement slurry composition in real-time. This provides more accurate maintenance of set parameters, improving process efficiency. Density control of cement slurries requires careful engineering and continuous monitoring to ensure safe and efficient well drilling.

The stress results (in MPa) were analyzed to assess the cement slurries' structural integrity and load-bearing capacity under various conditions. The stress testing used standardized procedures, including laboratory experiments and industrial field tests, to simulate real-world operating conditions (Table 7).

Table 7: Stress Results in Cement Slurries under Different Conditions

Experiment Type	Cement Slurry Density, g·cm^{-3}	Water-to-Cement Ratio, W/C	Stress Result, MPa
Laboratory - Standard	2.1	0.30	9
Laboratory - Thermobaric	2.4	0.25	15
Industrial Field (Barsagelmez Well)	2.45	-	18

The stress results indicate that the cement slurries prepared with the addition of "Glenium-51" exhibited high structural strength and stability under laboratory-simulated and real-world operating conditions. The cement slurries demonstrated the ability to withstand extreme pressures and temperatures, confirming their suitability for downhole applications in oil and gas well cementing operations. The stress results from laboratory experiments and industrial field tests align with the study's overall findings, emphasizing the effectiveness of "Glenium-51" as an additive for improving the density and strength of cement slurries. These results contribute to the body of knowledge regarding cementing technologies in challenging downhole environments, highlighting the importance of precise density control and the role of innovative additives in enhancing well integrity and performance.

Adding "Glenium-51" resulted in significant improvements in the tested parameters. The tests showed an increase in the fluidity of cement slurries by more than 25 cm, allowing for better pumpability and flowability. Additionally, using the additive reduced water-cement ratios to as low as 0.3 while maintaining free flowability and achieving slurry densities ranging from 2.05 – 2.45 g·cm^{-3}. The improvements observed in the tests ranged from 25 – 92 % in flowability and pumpability. Overall, the tested additive "Glenium-51" proved to be highly effective in enhancing the properties of cement slurries for well casing and cementing operations. It facilitated the creation of concentrated slurries with high density and strength, ensuring reliable cementing even under challenging downhole conditions such as high temperatures and pressures. Furthermore, the evaluation with barite and pebbles as weighting agents demonstrated the versatility of the additive in combination with different fillers. This versatility allows flexibility in adjusting the properties of the cement slurries according to specific well conditions and requirements, further enhancing its applicability in the oil and gas industry.

4. Discussion

The effectiveness of Glenium-51 in improving the flowability and density of cement pastes based on pure Portland cement was conclusively established in laboratory tests. When Glenium-51 was added at various water-cement ratios, the flowability of the paste was consistently increased by more than 25 cm. This reduced the water-cement ratio to 0.3, resulting in a slurry density of 2.1 g·cm^{-3} with exceptional pumpability. In combination with weighting agents such as barite or hematite, the use of Glenium-51 allowed the production of higher-density slurries, achieving densities from 2.40 – 2.45 g·cm^{-3} with water-cement ratios as low as 0.25 while maintaining perfect flowability.

The results were confirmed by an industrial experiment in which a concentrated suspension mixture with a density of 2.40 g·cm^{-3} containing Glenium-51 was effectively injected while cementing a 4,914 m long production string in the Barsagelmez well. The mixture withstood the extreme temperatures of 95 °C and bottomhole pressure of 1205 kgf·cm^{-2} without any operational complications. This emphasizes the possibility of using Glenium-51 to create compact, pumpable mixtures capable of withstanding extremely high wellbore pressures during cementing, confirming its suitability for industrial use.

The next aspect is the use of specialized additives. Different well conditions and geological formations may require unique solutions. Reagents that affect the chemical or physical properties of the solution can be critical tools in achieving desired results. Testing and correcting cement slurry parameters directly on the drilling site is integral to the process. Close monitoring and control allow for rapid response to changes and real-time parameter stability. Innovative additives, such as the "Glenium-51" hyperplasticiser reagent, should be emphasized. These additives provide new opportunities for density control and improving cement slurry characteristics. Thus, the study of concentrated slurry density control reveals many methods and approaches in the oil and gas industry. Combining these methods with the latest technologies and additives can create more efficient and safer well-drilling systems.

In light of the current research findings, it is evident that the evaluation and optimization of cement systems for high-density well cementing are crucial areas of focus within the oil and gas industry. The utilization of innovative additives and weighting agents, as highlighted by Ahmed et al. [17], Chen et al. [18], Wang and Xiong [19], Wu et al. [20], and Choudhury and Jena [21], significantly contribute to enhancing the performance and reliability of cement slurries under diverse downhole conditions.

Ahmed et al. [17] emphasize the importance of hematite and Micromax in achieving high-density cement slurries and improving cement slurry performance. Similarly, Chen et al. [18] highlight the significance of thermal thickening additives in enhancing cement slurry viscosity and stability, particularly in high-temperature environments. These studies underscore the critical role of additives in optimizing cement systems to meet specific operational requirements and geological conditions. Furthermore, Wang and Xiong [19] emphasize the necessity of developing high-density cement slurry technology for oil-based drilling mud conditions in salt formations. This aligns with the current research focus on achieving high-density cement slurries while considering the challenges of complex geological formations and drilling environments. Additionally, Wu et al. [20] stress the importance of selecting suitable weighting agents with high thermal stability and corrosion resistance for high-temperature and high-density cement slurries. This resonates with the present study's exploration of additives for density control under extreme downhole conditions.

Moreover, Choudhury and Jena [21] highlight the strategic significance of surfactants in modifying cement slurry properties, particularly in foaming and stabilization. The current research contributes to this discourse by evaluating the effectiveness of surfactants like HT-48 in enhancing cement slurry characteristics for improved well reliability. Additionally, Abdelaal and Elkatatny [22] propose the utilization of high-density geopolymers in cementing technology as a sustainable alternative to traditional Portland cement, aiming to reduce carbon dioxide emissions. While the present study does not delve into geopolymers specifically, it aligns with the broader objective of adopting environmentally friendly practices in the oil and gas industry by optimizing cementing processes and materials.

5. Conclusions

Through the integration of thorough laboratory experiments and field tests, this rigorous study definitively proves the pragmatic relevance of the novel superplasticizer reagent Glenium-51 in the density control of concentrated cement slurries. The main results of this study indicate the successful plasticization of cement slurries, leading to a reduction in water-cement ratio and achieving densities up to 2.10 g·cm^{-3} with pure Portland cement. Moreover, when combined with weighting agents such as barite or hematite, this material allows even higher densities of 2.40 – 2.45 g·cm^{-3} to be achieved at low water ratios while maintaining pumping ability.

Successful pumping of these very high-density suspensions at extreme bottomhole pressures of 1205 kgf·cm^{-2} has been proven in industrial field experiments. "Glenium-51" increases the overall durability of hardened paste. This study confirms the feasibility of cementing companies using "Glenium-51" as an essential additive to prepare concentrated slurries with high strength and density. Such muds are important in well cementing operations, especially when drilling formations with abnormally high pressure. The results of this study help to improve cementing technologies and increase the reliability of zonal isolation in difficult downhole conditions.

Concentrated slurry density control is a critical aspect of the oil and gas industry, especially when drilling wells. These slurries are required to control well pressures and prevent outgassing. Proper density control provides the necessary pressure balancing in wells and prevents wall failure. Introducing various methods, such as weighting agents, polymers, special additives, and automated systems, provides engineers and drillers with a wide range of tools to control cement slurry parameters accurately. Weighting agents such as barite and pebbles increase mud density, while polymers can affect the rheological properties of the slurry. Specialized additives and automated systems provide flexibility and efficiency in real-time density control. Modern technology and innovations help achieve the required performance of concentrated slurries and reduce environmental impact. This contributes to more sustainable and safer drilling studies, emphasizing the importance of density control in ensuring efficiency and safety in the oil and gas industry.

To better understand and optimize concentrated slurry density control, additional research is needed in the interaction of solution components under different thermobaric conditions and the development of new technological solutions for accurate real-time parameter control at drilling sites.

References

[1] Mohamed, T. S., Torres-Verdín, C., & Mullins, O. C. (2023). Enhanced Reservoir Description via Areal Data Integration and Reservoir Fluid Geodynamics: A Case Study From Deepwater Gulf of Mexico. *Petrophysics*, 64 (5), 773-795. https://doi.org/10.30632/pjv64n5-2023a10

[2] Taimasov, B.T. & Kuandykova, A.E. (2022). Current state and prospects for the development of the cement industry of the Republic of Kazakhstan. *Scientific Journal «Auezov University»*, 1 (1), 21-27. Retrieved from https://auezov.edu.kz/media/attachments/2023/04/26/au01012022.pdf#page=22

[3] Loginova, M.E. & Agzamov, F.A. (2022). Viscoelastic systems for well construction. *Kazakhstan Journal for Oil & Gas Industry*, 4 (1), 60-72. Retrieved from https://vestnik-ngo.kz/2707-4226/article/view/104413

[4] Akhmetzhan, S.Z., Sabitov, A.K. & Nursultanov, E.K. (2022). Horizontal well completion. *Bulletin of West Kazakhstan Innovation-Technological University*, 23 (3), 209-212. Retrieved from https://wkitu.kz/wp-content/uploads/2023/04/sbornik-3-23-2022-god_.pdf#page=209

[5] Kuliyev, M.Y. (2022). The use of cement mixtures to eliminate absorption during drilling. *Innovation in the Oil and Gas Industry,* 3 (4), 50-53. Retrieved from https://tadqiqot.uz/index.php/petroleum/article/view/6182

[6] Kabdushev, A.A., Agzamov, F.A., Manapbayev, B.Z., Delikesheva & D.N., Korgasbekov, D.R. (2023). Investigation of impact resistance of grouting materials. *Kazakhstan Journal for Oil & Gas Industry*, 5 (1), 36-46. Retrieved from https://vestnik-ngo.kz/2707-4226/article/view/108633/ru_RU

[7] Adjei, S., Bageri, B.S., Elkatatny, S. & Adebayo, A. (2021). Effect of perlite particles on barite cement properties. *ACS Omega*, 6 (7), 4793-4799. Retrieved from https://pubs.acs.org/doi/full/10.1021/acsomega.0c05699

[8] Deryaev, A.R. (2023). Analysis of the opening of zones with abnormally high reservoir pressures in the oil and gas fields of the Western part of Turkmenistan. *SOCAR Proceedings: From Reservoirs to Refineries: The Latest Advancements in Petroleum Research, Special Issue* 2, 20-25. Retrieved from https://proceedings.socar.az/uploads/pdf/94/020_025_OGP2023SI200871.pdf

[9] Deryaev, A.R. (2023). Well trajectory management and monitoring station position borehole. *SOCAR Proceedings: From Reservoirs to Refineries: The Latest Advancements in Petroleum Research, Special Issue* 2, 1-6. Retrieved from https://proceedings.socar.az/uploads/pdf/94/001_006_OGP2023SI200870.pdf

[10] Kumar, S., Bera, A. & Shah, S.N. (2022). Potential applications of nanomaterials in oil and gas well cementing: Current status, challenges and prospects. *Journal of Petroleum Science and Engineering*, 213, 110395. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0920410522002819

[11] Beskopylny, A., Stel'makh, S.A., Shcherban', E.M., Mailyan, L.R. & Meskhi, B. (2022). Nano modifying additive micro silica influence on integral and differential characteristics of vibrocentrifuged concrete. *Journal of Building Engineering,* 51, 104235. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S2352710222002480

[12] Arévalo, P.J., Hummes, O. & Forshaw, M. (2021). Integrated real-time simulation in an earth model – Automating drilling and driving efficiency. In: *SPE/IADC International Drilling Conference and Exhibition. Richardson: SPE*. Retrieved from https://onepetro.org/SPEDC/proceedings-abstract/21DC/3-21DC/460335

[13] Davoodi, S., Al-Shargabi, M., Wood, D.A. & Rukavishnikov, V.S. (2023). Recent advances in polymers as additives for wellbore cementing applications: A review. *Fuel*, 357 (Part A), 129692. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0016236123023062

[14] Fabian, M., Tolnai, I., Kis, Z. & Szilagyi, V. (2022). Characterization of simulated liquid radioactive waste in a new type of cement mixture. *ACS Omega*, 7 (41), 36108-36116. Retrieved from https://pubs.acs.org/doi/full/10.1021/acsomega.2c05507

[15] Wu, Z., Song, J., Xu, M., Liu, W., Chen, R., Pu, L. & Zhou, S. (2023). Effect of weighting materials on carbonation of oil well cement-based composites under high temperature and CO2-rich environment. *Arabian Journal of Chemistry*, 16 (5), 104670. Retrieved from https://www.sciencedirect.com/science/article/pii/S1878535223001326

[16] Abdelaal, A. & Elkatatny, S. (2023). Mixed Micromax and hematite-based fly ash geopolymer for heavy-weight well cementing. *Scientific Reports*, 13, 8669. Retrieved from https://www.nature.com/articles/s41598-023-36010-w

[17] Ahmed, A., Abdelaal, A. & Elkatatny, S. (2023). Evaluation of hematite and Micromax-based cement systems for high-density well cementing. *Journal of Petroleum Science and Engineering,* 220 (Part B), 111125. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0920410522009779

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[18] Chen, X., Wang, C., Xue, Y., Chen, Z., Jin, J. & Wang, R. (2021). A novel thermo-thickening viscosity modifying admixture to improve settlement stability of cement slurry under high temperatures. *Construction and Building Materials*, 295, 123606. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0950061821013660

[19] Wang, J. & Xiong, Y. (2021). Research and application of high-density cementing slurry technology under the condition of oil-based drilling fluid in salt formation. *Arabian Journal for Science and Engineering*, 47, 7069-7079. Retrieved from https://link.springer.com/article/10.1007/s13369-021-06325-9

[20] Wu, Z., Song, J., Liu, W., Zhao, J., Xu, M. & Wang, X. (2022). Study on selection of weighting agent for high-temperature and high-density anticorrosive cement slurry. *Drilling Fluid & Completion Fluid*, 39 (3), 346-351. Retrieved from http://www.zjyywjy.com.cn/en/article/doi/10.12358/j.issn.1001-5620.2022.03.013

[21] Choudhury, S. & Jena, T. (2023). Influence of surfactant on foam generation and stabilization in cement slurry. *Materials Today: Proceedings*, 93 (Part 3), 340-345. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S2214785323041299

[22] Abdelaal, A.E. & Elkatatny, S.M. (2023). High density geopolymers: A step forward towards low carbon footprint cementing operations. In: *Offshore Technology Conference. Houston: OTC.* Retrieved from https://onepetro.org/OTCONF/proceedings-abstract/23OTC/2-23OTC/519143