Research Article

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Performance evaluation of a high-performance offshore cementing wastes accelerating agent

https://doi.org/10.1515/phys-2022-0020
received December 11, 2021; accepted March 02, 2022

Abstract: This article reports a quick-setting agent named AS-G1. In the current offshore oil exploitation, there are usually wastes mixed with the drilling fluid, completion fluid, cement slurry, *etc.* To protect the marine environment, offshore construction workers need to weakly solidify these wastes so that they can be transported to land for disposal. The accelerating agent can reduce the fluidity of offshore cementing wastes and achieve the effect of solidifying wastes. Compare the time for the three cement slurries to lose fluidity with the addition of accelerating agents. Evaluate the setting time of cement slurry under the action of the accelerating agent after adding two drilling fluids. The solidification effect of this kind of accelerating agent on cementing waste is verified. It can be applied to waste treatment in oil fields.

Keywords: waste disposal, colloid, liquidity, grout, accelerating agent

1 Introduction

In the 21st century, environmental protection is an increasingly important issue [1,2]. Recently, to protect the environment, a number of laws and regulations have been enacted [3–5], and offshore oilfield operations require full waste recovery [6]. Among them, the Bohai Oilfield and Western South China Sea oilfields have the highest environmental protection production requirements [7]. Wastes such as drilling fluid and cement slurry generated during mining must be transported back to the land for disposal [8]. In 2020, there will be 511 wells drilled in Bohai Oilfield each year. A single well will produce about 600 m^3 of completion/workover fluid and cementing fluid waste, and a total of about 300,000 m^3 of waste fluid will be produced. China National Offshore Oil Corporation has packaged the full recovery of drilling/completion/workover/cementing fluid waste into the service contract [9]. However, there is no mature process plan for how to transport the waste with a lot of water content back to the mainland [10]. The shortcomings of cementing fluid waste treatment technology will seriously affect the subsequent business development and even lead to the risk of contract suspension [11–13]. Only after completing the relevant technical research, we can continue to extract oil at sea [14]. With the increasingly severe environmental protection situation, to implement a zero-emission policy in marine operations, it is urgently necessary to study technologies suitable for offshore cementing fluid waste treatment [15–17].

In the 1960s, with more and more large-volume and super-volume buildings, scholars began to use slow-setting water-reducing agents in concrete projects [18,19]. After the 1960s, some organic or inorganic retarders, such as zinc salts, hemicellulose, and water reducers, have been widely used and have achieved good results. Among them, calcium lignosulfonate and molasses water reducers are the most commonly used. At the same time, research has been conducted on the inadaptability of wood calcium and molasses water-reducing agent to some cement varieties, and the retarding mechanism has been discussed. Relatively speaking, the research on retarders is relatively monotonous and slow. It can be roughly divided into inorganic retarders and organic retarders [20–25].

Currently, the overall treatment of cementing waste in offshore oilfields cannot meet the requirements of offshore oilfields, does not meet the requirements for environmental protection at this stage, and does not meet the requirements of relevant national laws and regulations. Therefore, there is an urgent need for simple operation,

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small footprint, and environmentally friendly treatment agents. Therefore, this article reports a quick-setting agent named AL-G1 and evaluates its performance. The accelerating agent can reduce the fluidity of offshore cementing wastes and achieve the effect of solidifying wastes. When the waste with more water content loses its mobility, it can be more conveniently transported to the land for subsequent treatment. The time for the three cement slurries to lose fluidity with the addition of accelerating agents is compared. Evaluate the setting time of cement slurry under the action of the accelerating agent after adding two drilling fluids. The solidification effect of this kind of accelerating agent on cementing waste is verified. It can be applied to waste treatment in oil fields [26].

2 Method

We aim to solidify the waste with high water content at the sea, so that it can be transported to the land. If the intensity of these wastes is too high, they are difficult to handle on the ocean. Therefore, we synthesized an accelerating agent named AL-G1 that can weakly solidify the waste. The vision of this accelerator for future applications is to turn waste fluidity into 0. Therefore, our experimental steps are as follows.

We purchased a metal cylinder with an inner diameter of 30 mm and a height of 50 mm and a flat glass with an area of 300 mm × 300 mm. This metal cylinder is called the mold. We placed the object to be tested in a metal mold, which is placed horizontally at the center of the glass plate. After placing for 1 s, 1 h, 2 h, 3 h, and 4 h, the metal mold is lifted vertically upward. The fluidity and free water after 10 s are recorded.

3 The weak curing performance before and after three kinds of pure cement slurry accelerating agents

3.1 Three basic formulas of pure cement slurries

The three pure cement slurries are surface cementing early-strength cement slurry C1, surface cementing soil moving (bentonite) cement slurry C2, and PC-LET 6 K low-density cement slurry C3, and their basic formulations are presented in Table 1. The density of cement slurry C1 is 1.58 g/cm^3, and the density of C2 and C3 is 1.50 g/cm^3.

3.2 Evaluation of weak curing performance of three kinds of pure cement slurries

300 mL of the prepared pure cement slurry is taken, in which the density of surface cementing early. y-Strength cement slurry C1 is 1.54 g/cm^3, the density of surface cementing cement slurry C2 is 1.49 g/cm^3, and the density of PC-LET 6 K low-density cement slurry C3 and C2 is 1.48 g/cm^3. The weight reduction material in PC-LET 6 K low-density cement slurry C3 is 42.5 g/100 g cement, and the weak curing performance and free water of the three pure cement slurries are evaluated.

As shown in Figures 1–3, surface cementing early-strength cement slurry C1 can lose its fluidity within 4 h, but the free water is relatively large. The surface cementing bentonite cement slurry C2 still has a certain fluidity and a certain amount of free water after 4 h. PC-LET 6 K low-density cement slurry C3 can lose its fluidity in 4 h without free water.

Table 1: Basic formula of three kinds of pure cement slurries

Type of grout	Drug name	Dosage/g	Wt/%
Surface cementing early strength cement slurry C1	Water	86	—
	PC-A90L	2.4	2.4
	PC-X60L	1	1
	PC-A90S	3.6	3.6
	Cement	100	—
Surface cementing bentonite cement slurry C2	Water	106.7	—
	PC-H21L	1	1
	PC-X60L	1	1
	PC-P50	4.5	4.5
	Cement	10.0	—
PC-LET 6 K low-density cement slurry C3	Water	69.1	—
	PC-G81L	7.9	7.9
	PC-H21L	0.7	0.7
	PC-F41L	0.35	0.35
	PC-X60L	0.7	0.7
	PC-GS12S	2.1	2.1
	Cement	100	—

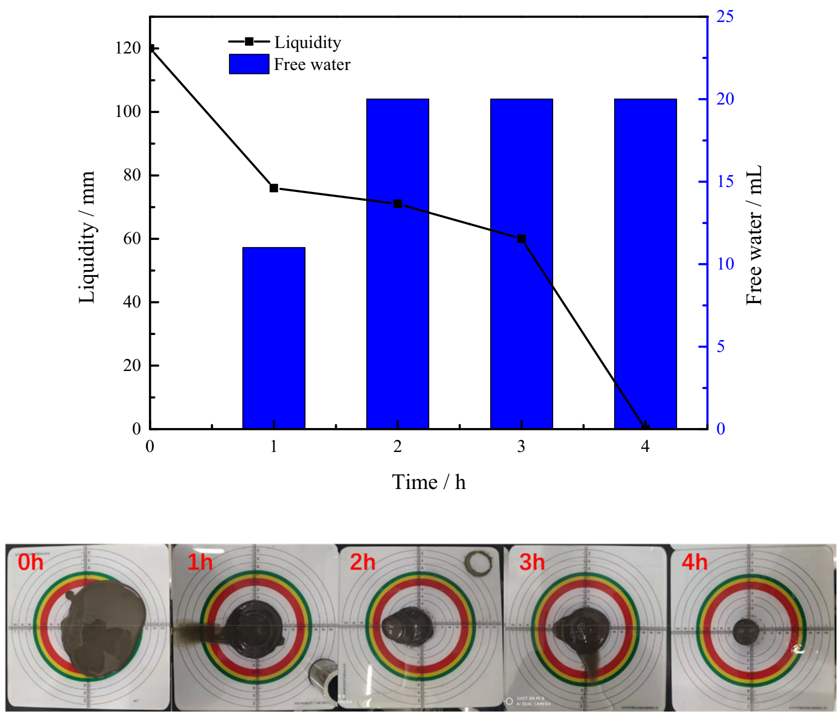

Figure 1: The weak curing performance of surface cementing early-strength cement slurry C1.

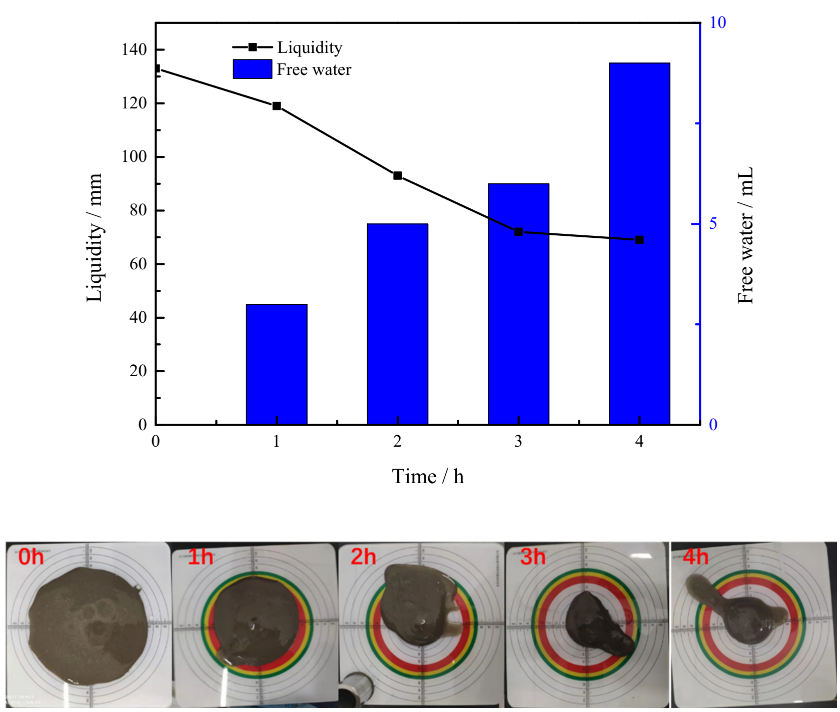

Figure 2: The weak curing performance of surface cementing Bentonite cement slurry C2.

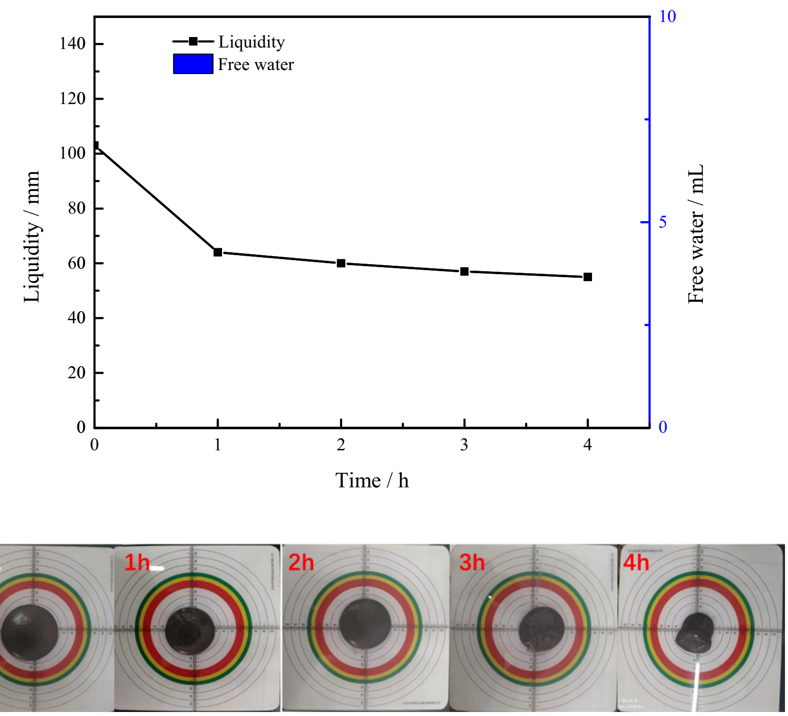

Figure 3: The weak curing performance of PC-LET 6 K low-density cement slurry C3.

3.3 Evaluation of weak curing performance of three kinds of pure cement slurries + accelerating agent.

The three pure cement slurries after adding 1% accelerating agent are evaluated. As shown in Figures 4–6, after surface cementing early-strength cement slurry C1 + 1% accelerating agent, it loses its fluidity within 2 h and the free water is less than 3%. After surface cementing early-strength (cementing Bentonite) cement slurry C2 + 1% accelerating agent, it loses its fluidity within 1 h, and the free water is less than 3%.

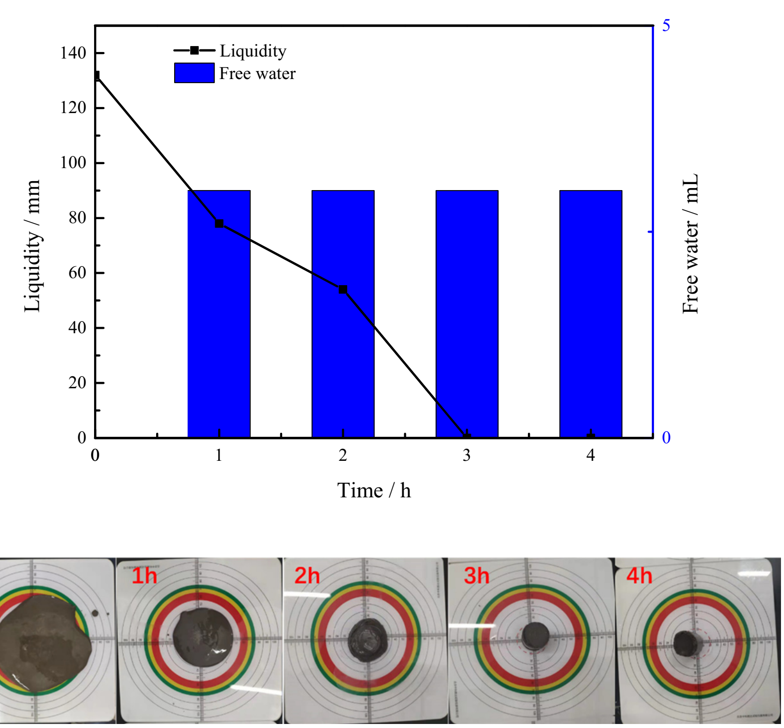

Figure 4: The weak curing performance of surface cementing early strength cement slurry C1 + 1% accelerating agent.

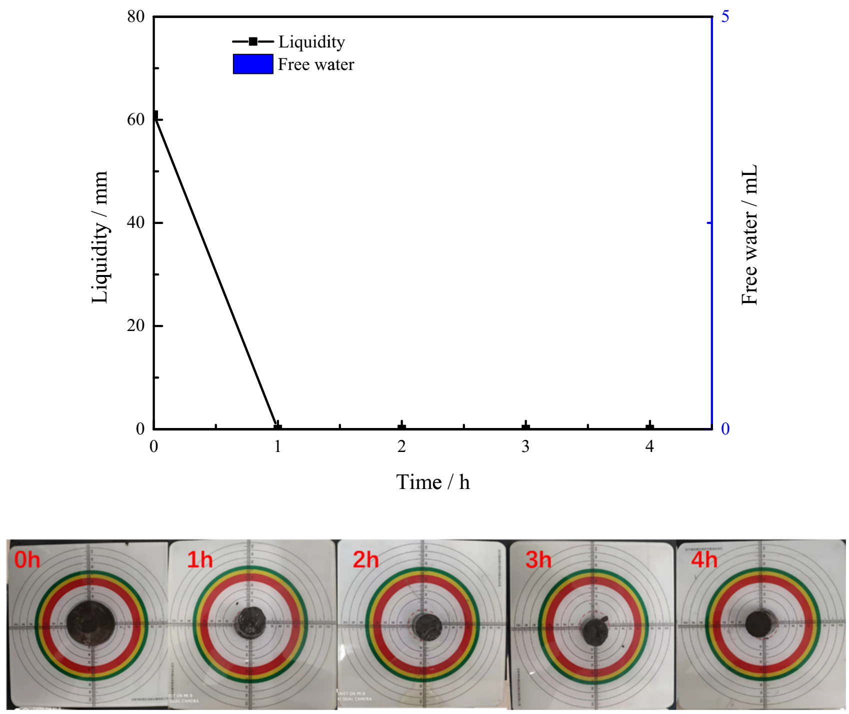

Figure 5: The weak curing performance of surface cementing early-strength (cementing bentonite) cement slurry C2 + 3% accelerating agent.

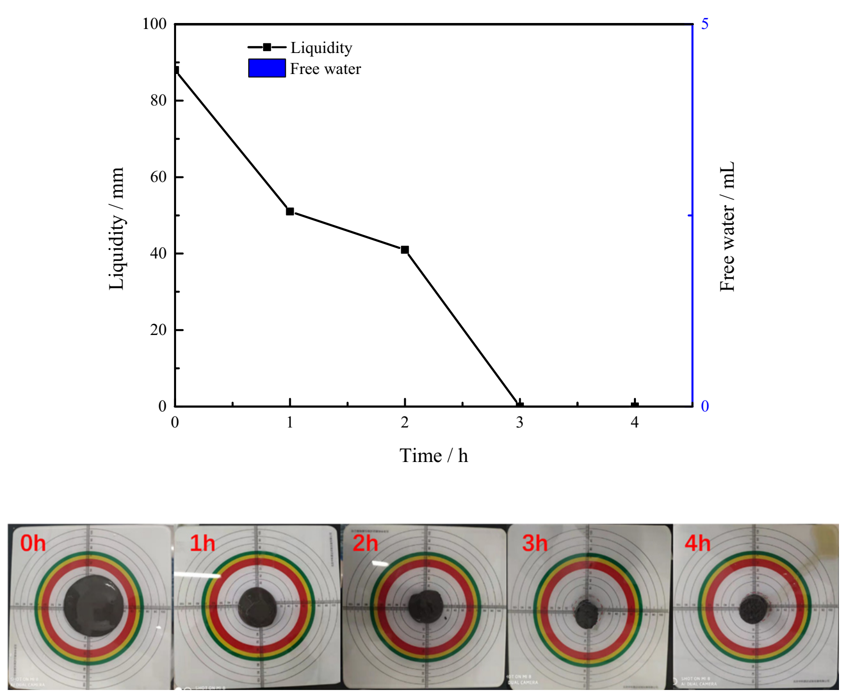

Figure 6: The weak curing performance of surface cementing early strength (PC-LET 6 K low-density) cement slurry C3 + 1% accelerating agent.

After surface cementing early-strength (PC-LET 6 K low-density) cement slurry C3 + 1% accelerating agent, it loses its fluidity within 4 h, and the free water is less than 3%.

4 Evaluation of weak solidification performance of PEM drilling fluid to cementing fluid waste

4.1 Preparation of cementing fluid waste solution

Preparation of simulated cementing fluid waste solution: the ratio of isolation fluid + flushing fluid mixture is fixed, three types of cement slurry is changed, the ratio of PEM drilling fluid is changed, and three different cementing fluid waste solutions are prepared, see Table 2.

Table 2: Preparation formula of simulated cementing fluid waste solution

Formula system	The added volume ratio of different cementing fluid wastes			
	Isolation fluid (A) + flushing fluid (B)/%	Type of grout	Grout/%	PEM drilling fluid (D2)/%
21-1	25	C1	50	25
21-4	14.3		28.6	57.1
22-1	25	C2	50	25
22-4	14.3		28.6	57.1
23-1	25	C3	50	25
23-4	14.3		28.6	57.1

4.2 The effect of PEM drilling fluid addition on the weak curing performance of surface cementing early-strength cement slurry C1

Choose the surface cementing early-strength mixing system 21-1 (1:2:1) and system 21-4 (1:2:4) with large differences. Aluminum sulfate (AS-G1) is selected as the accelerating agent, and the dosage is 5%, and its weak curing performance and free water are evaluated, see Figures 7 and 8. After adding 5% quick-setting agent to the system 21-1, its fluidity will be lost within 1 h, and the free water will be less than 3%. After the system 21-4 + 5% quick-setting agent, the fluidity will be lost within 2 h, and the free water will be less than 3%.

4.3 Influence of PEM drilling fluid addition on C2 weak solidification performance of surface cementing mud

The surface cementing bentonite slurry system 22-1 (1:2:1) and system 22-4 (1:2:4) with large differences are chosen.

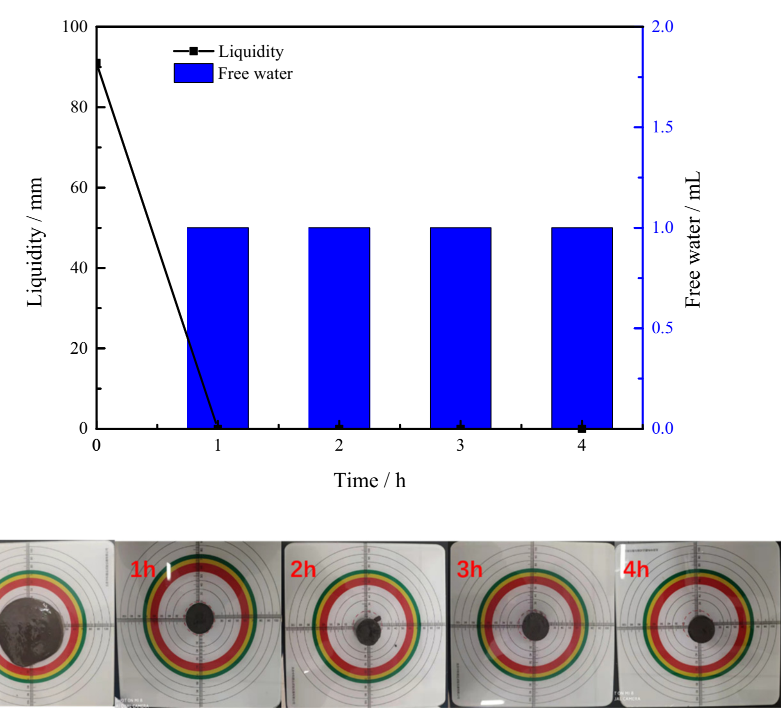

Figure 7: The weak curing performance of system 21-1 mixed slurry.

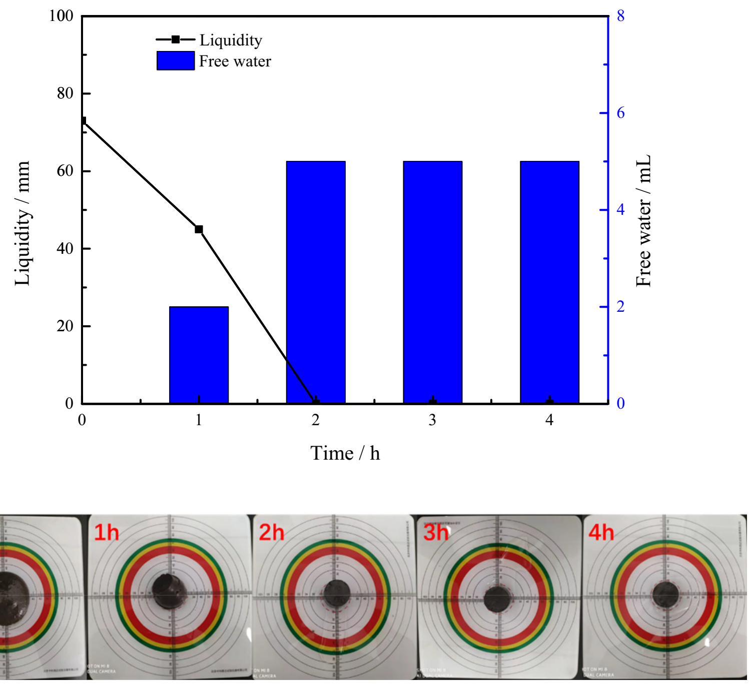

Figure 8: The weak curing performance of system 21-4 mixed slurry.

Aluminum sulfate (AS-G1) is selected as the accelerating agent, 3% of aluminum sulfate is used, and its weak curing performance and amount of free water are evaluated. As shown in Figures 9 and 10, after the addition of the accelerating agent, the system 22-1 gelled quickly and the slurry lost fluidity. Surprisingly, the system 22-4 did not gel.

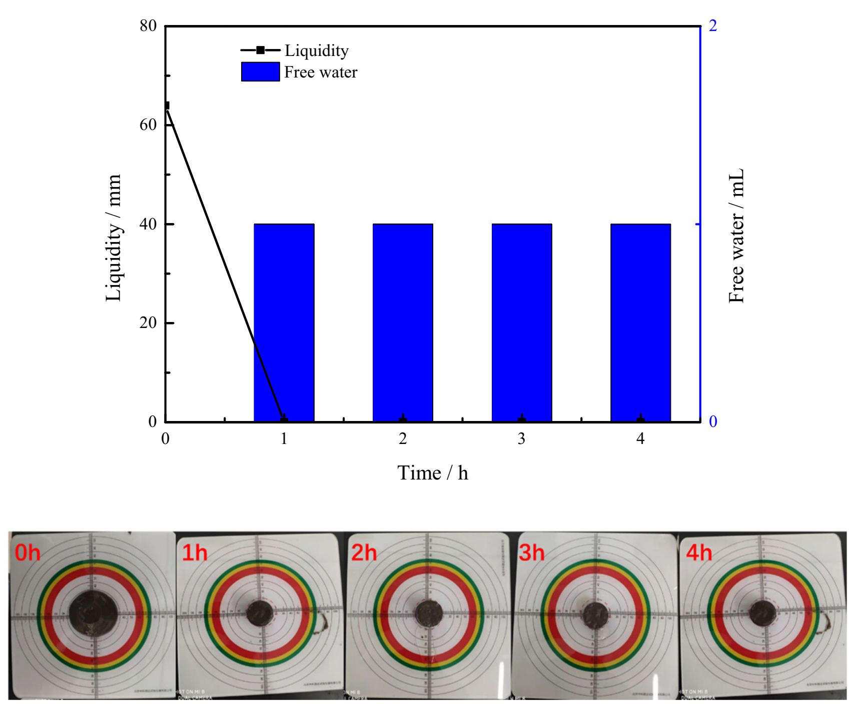

Figure 9: The weak curing performance of system 22-1.

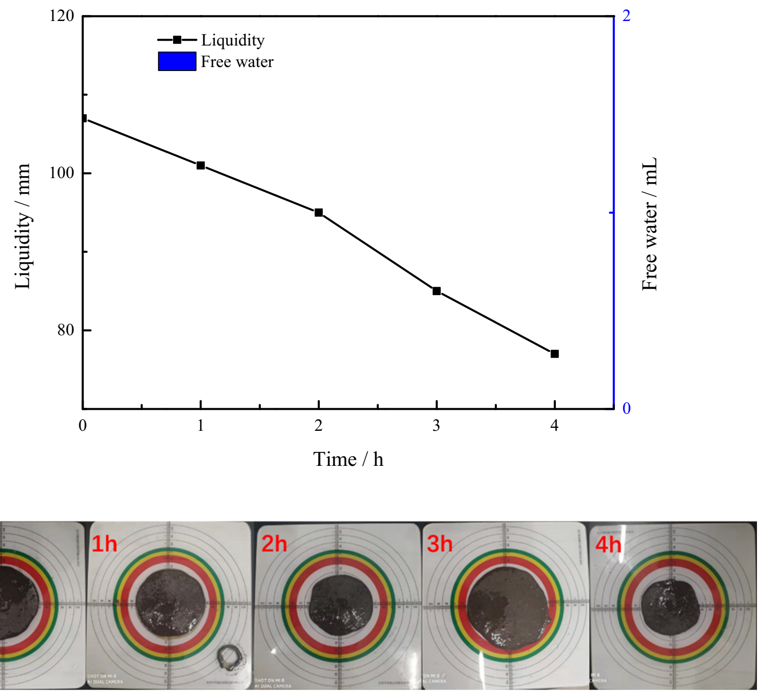

Figure 10: The weak curing performance of system 22-4 mixed slurry.

4.4 Influence of PEM drilling fluid addition on C3 weak solidification performance of low-density cement slurry

The PC-LET 6 K low-density cement slurry system 23-1 (1:2:1) and system 23-4 (1:2:4) with large differences are chosen. Aluminum sulfate (AS-G1) is selected as the accelerating agent and added to the system 23-1 The amount is 4%, and the additional amount of the system 23-4 is 3%. The weak curing performance and free water are evaluated. Figure 11 shows that the system 23-1 started to solidify after 2 h, and there was not much free water. In Figure 12, the system 23-4 solidified within 1 h, but the free water continued to increase.

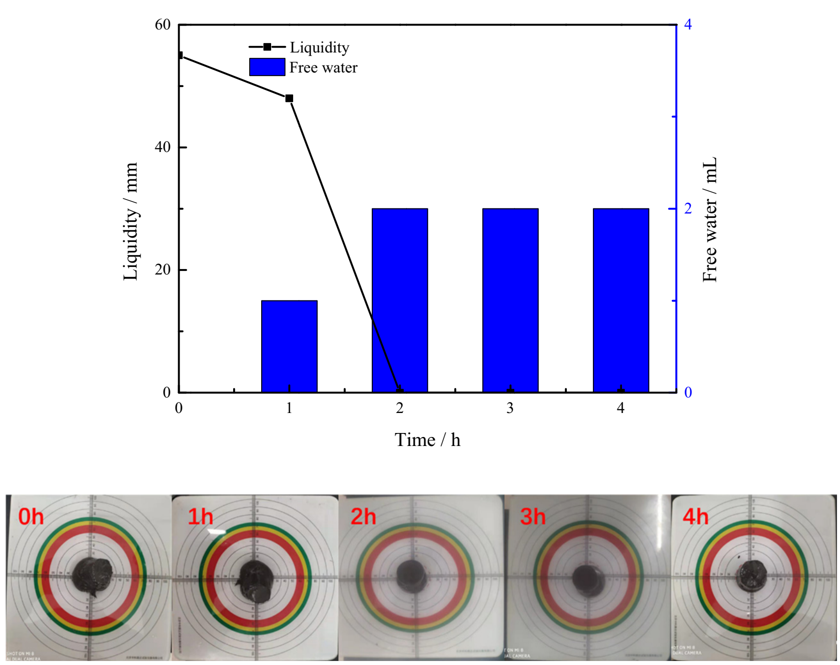

Figure 11: The weak curing performance of cement slurry C3 and system 23-1.

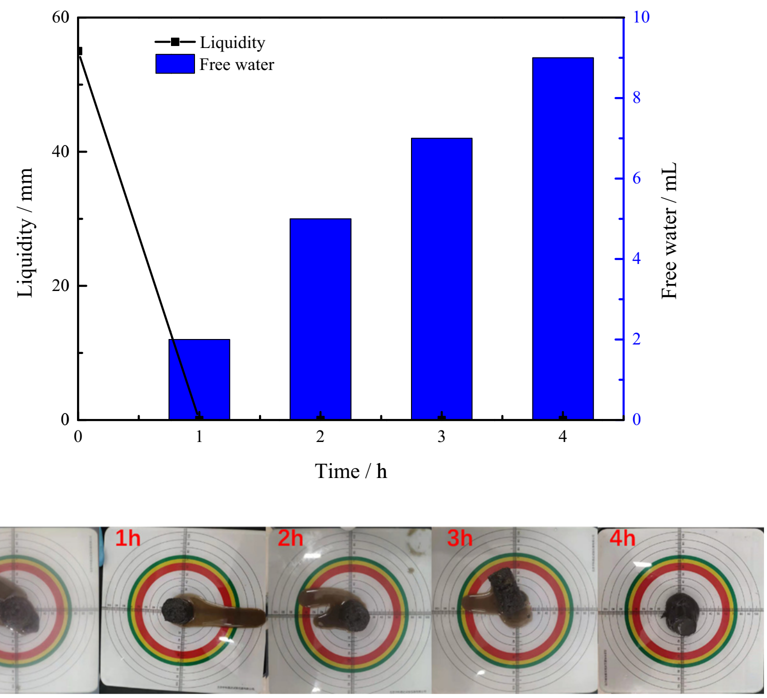

Figure 12: The weak curing performance of cement slurry C3, system 23-4 mixed slurry.

5 Evaluation of the weak solidification performance of PEC drilling fluid for cementing fluid waste

5.1 Preparation of cementing fluid waste solution

The preparation of simulated cementing fluid waste solution: the ratio of isolating fluid + flushing fluid mixture is fixed, the three types of cement slurry are changed, the ratio of PEC drilling fluid is changed, and three different cementing fluid waste solutions are prepared (Table 3).

Table 3: Preparation formula of simulated cementing fluid waste solution

Formula system	The added volume ratio of different cementing fluid wastes			
	Isolation fluid (A) + flushing fluid (B)/%	Type of grout	Grout/%	PEC drilling fluid D3
31-1	25	C1	50	25
31-4	14.3		28.6	57.1
32-1	25	C2	50	25
32-4	14.3		28.6	57.1
33-1	25	C3	50	25
33-4	14.3		28.6	57.1

5.2 The effect of PEC drilling fluid addition on the weak curing performance of surface cementing early-strength cement slurry C1

The surface cementing early-strength mixing system 31-1 (1:2:1) and system 31-4 (1:2:4) with large differences are chosen, aluminum sulfate (AS-G1) is selected as the accelerating agent, system 31-1 (1:2:1) dosage is 5%, system 31-4 (1:2:4) dosage is 4%, its weak curing performance and free water are evaluated. As shown in Figures 13 and 14, both system 31-1 and system 31-4 lose their fluidity in 1 h, and there is no free water overflow.

5.3 The effect of PEC drilling fluid addition on the C2 weak curing performance of surface cementing early-strength cement slurry

The surface cementing early-strength mixing system 32-1 (1:2:1) and system 32-4 (1:2:4) with large differences are

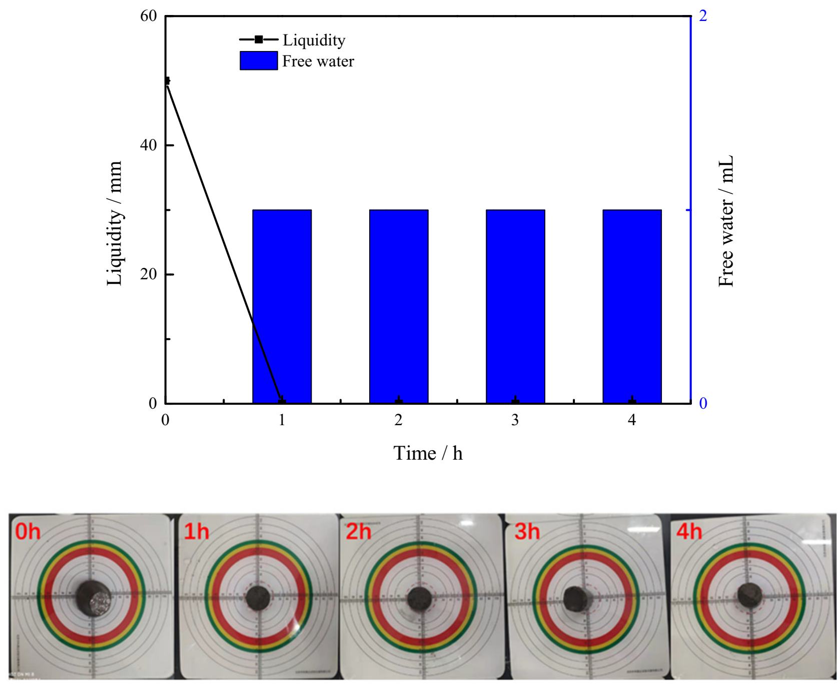

Figure 13: The weak curing performance of system 31-1 mixed slurry.

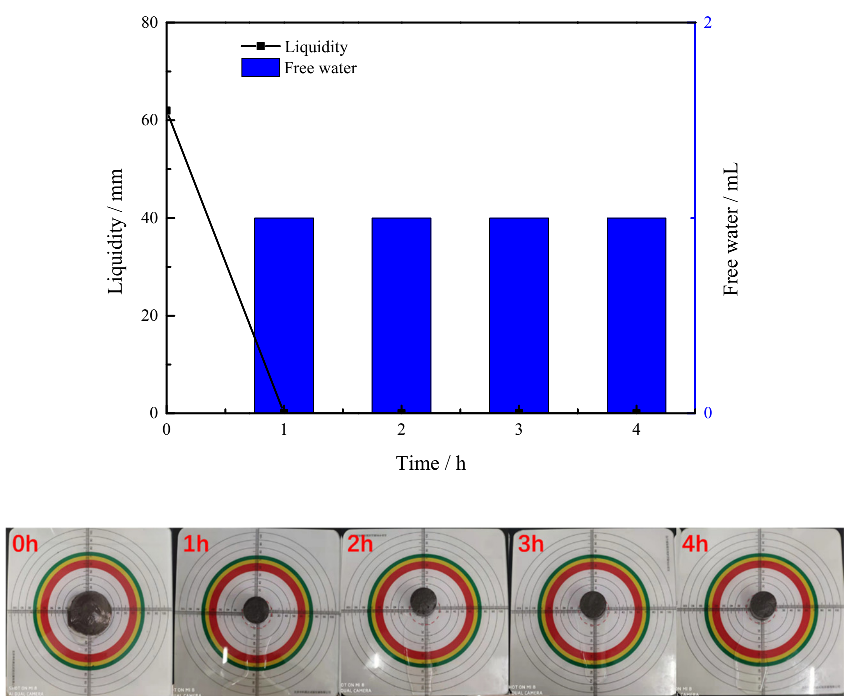

Figure 14: The weak curing performance of system 31-4 mixed slurry.

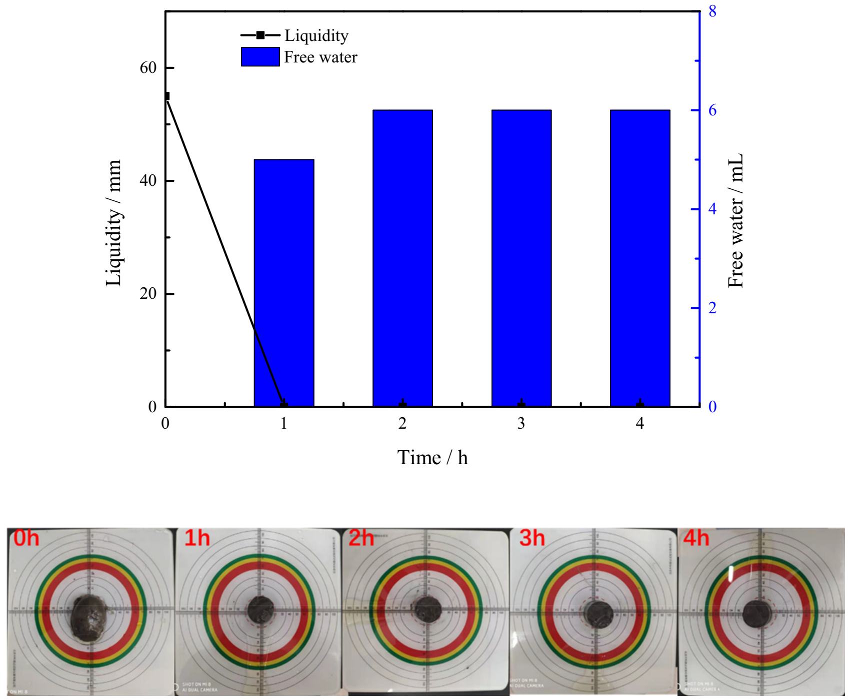

Figure 15: The weak curing performance of system 32-1.

chosen, AL-G1 is selected as the accelerating agent, system 32-1 (1:2:1) dosage is 3%, system 32-4 (1:2:4) dosage is 4%, and its weak curing performance and free water are evaluated. Figure 15 shows that the system 32-1 loses its fluidity within 1 h, and the free water remains unchanged at 6 mL. Figure 16 shows that the curing effect of system 32-4 is very bad, and it fails to cure within 4 h.

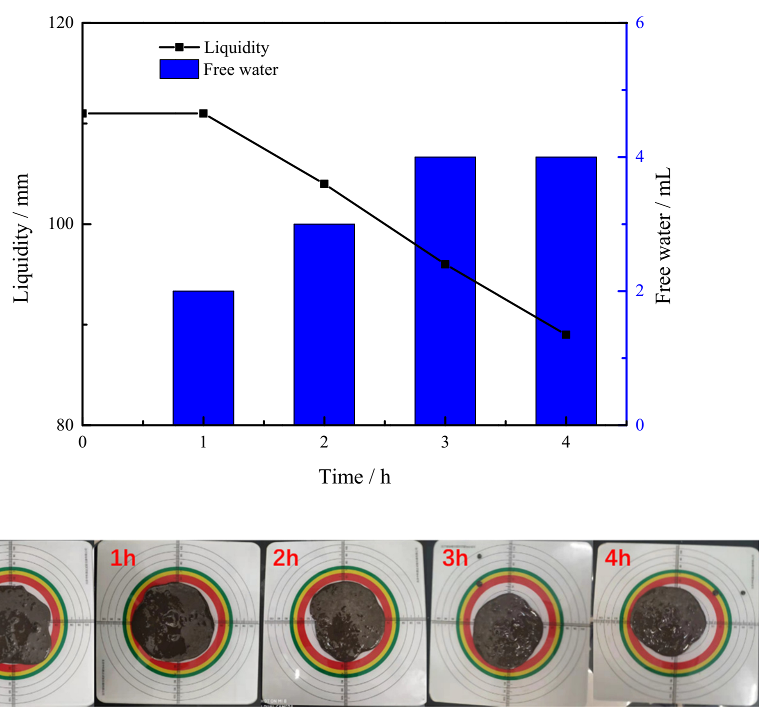

Figure 16: The weak curing performance of system 32-4 mixed slurry.

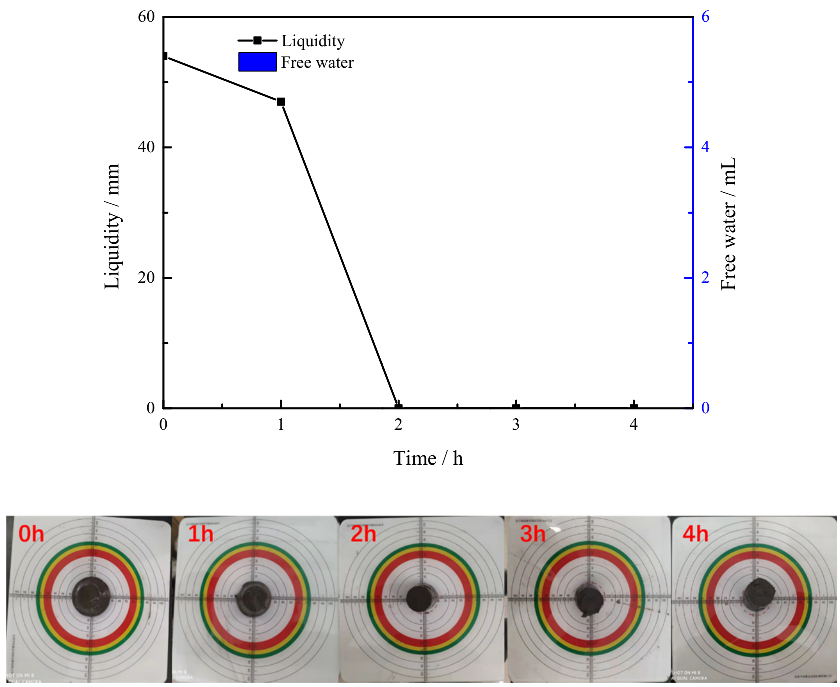

Figure 17: The weak curing performance of system 33-1.

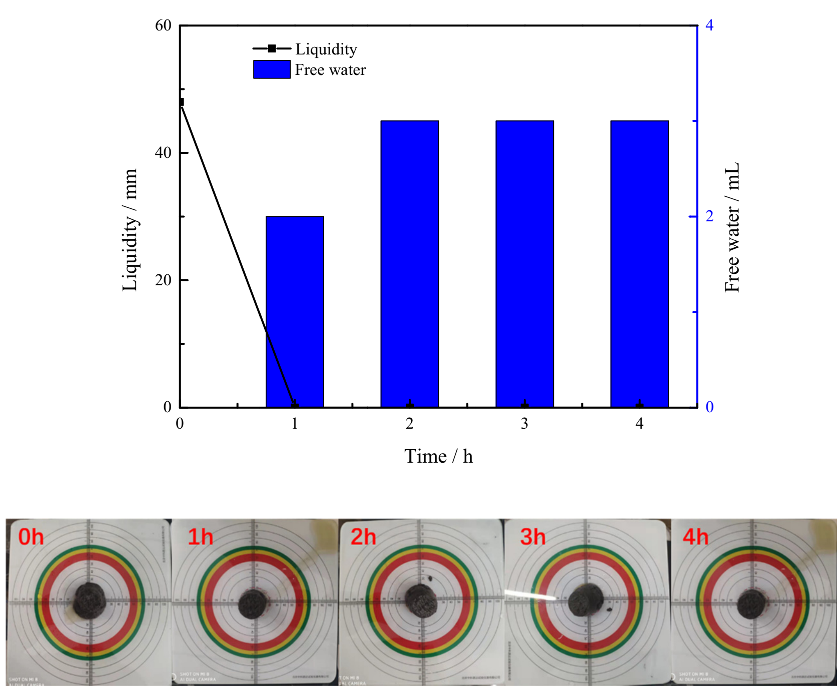

Figure 18: The weak curing performance of system 33-4 mixed slurry.

5.4 The effect of PEC drilling fluid addition on the C3 weak curing performance of surface cementing early-strength cement slurry

The surface cementing early-strength mixing system 33-1 (1:2:1) and system 33-4 (1:2:4) with large differences are chosen. Aluminum sulfate (AS-G1) is selected as the accelerating agent, system 33-1 (1:2:1) dosage is 3%, system 33-4 (1:2:4) dosage is 4%, and its weak curing performance and free water are evaluated. In Figure 17, we have an exciting result: system 33-1 has no free water, and it can be cured within 2 h. In Figure 18, the result of system 34-4 is still very good, and although there is a small amount of flowing water, it still loses fluidity within 2 h.

6 Conclusion

Accelerating agent AS-G1 has the best effect on cement slurry C2. 1 h after the cement slurry was added with 1% accelerating agent, the cement slurry lost its fluidity, and there was no free water in the cement slurry C2. Accelerating agents also have good effects on cement slurries C1 and C3 and can make the cement slurry lose fluidity after 3 h. After adding PEM and PEC drilling fluids, the setting effect of accelerating agents on cement slurry C1 and C3 is still very good. However, the effect on C2 is extremely poor, and the curing effect is not achieved. In general, the coagulant AS-G1 is effectively used in the waste solidification treatment in offshore oil extraction. Waste treated with AS-G1 is transported to the land by ship for subsequent processing. This report provides new solutions for the solidification of cementing waste in the future.

Funding information: The project was supported by Heilongjiang Province Natural Science Foundation of “Study on flocculation of oilfield wastewater with magnetic nano-materials Fe3O4@SiO2-NH2”. Fund No.: LH2020E014.

Author contributions: All authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Conflict of interest: The authors state no conflict of interest.

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